TURKISH JOURNAL OF AGRICULTURAL ENGINEERING RESEARCH

TURKAGER

Turkish Journal of Agricultural Engineering Research (TURKAGER)

Volume 2, Issue 1,

Year 2021

Indexing

Turkish Journal of Agricultural Engineering Research (TURKAGER)

Review Article

Effect of Profile Size and Material Properties on the Strength of the Single Axle Trailer Platform Design

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ABSTRACT

In this study, a trailer platform measuring 150×110 cm with a capacity of 700 kg was designed and the most suitable profile section dimensions and material were determined for low-cost production. 40×40×3 and 50×50×4 mm box profiles were used in the modelling. S355 (St52) steel in small section profile and S235 (St37) steel in large section profile was selected as Platform material. The analysis was conducted according to the finite element method and as a result of the static load analysis, stress value, displacement amount and safety coefficient data were reached in critical regions. According to research results, it was determined that the trailer with Profile section dimensions of 50×50×4 mm and made of S235 steel was more economical than the other. A leaf spring was used for the trailer's suspension arrangement and modelled on its commercially available counterparts in accordance with maximum load. As a result of load analysis, the greatest stress arising in the leaf spring was formed in the spring connections. In the study, the selection of axle, wheel hub, wheel, lever jack and coupling were made and the mass of each component was determined. Sheet metal, cabinet back cover, fasteners, etc. the total mass of the trailer, excluding components, was estimated at about 172 kg. In production, the market price of each part that makes up the trailer components, excluding resources, labour, taxes and transportation expenses, was investigated and the total cost of a single-axle trailer with a capacity of 700 kg was subtracted.

Tek Dingilli Römork Platformu Tasarımında Profil Ölçüsü ve Malzeme Özelliklerinin Dayanıma Etkisi

ÖZET

Bu çalışmada 150×110 cm ölçülerinde 700 kg kapasiteli bir römork platformunun tasarımı yapılmış ve düşük maliyetli üretim için en uygun profil kesit ölçüleri ve malzemesi belirlenmiştir. Modellemede kare kesitli 40×40×3 ve 50×50×4 mm ölçülerinde kutu profiller kullanılmıştır. Platform malzemesi olarak küçük kesitli profilde S355 (St52) çeliği ve büyük kesitli profilde S235 (St37) çeliği seçilmiştir. Analizler sonlu elemanlar metoduna göre yapılmış ve statik yük analizi sonucunda kritik bölgelerde gerilme değeri, deplasman miktarı ve emniyet katsayısı verilerine ulaşılmıştır. Araştırma bulgularına göre profil kesit ölçüleri 50×50×4 mm olan ve S235 çeliğinden imal edilen römorkun diğerine göre daha ekonomik olduğu belirlenmiştir. Römorkun süspansiyon düzeninde yaprak yay kullanılmış ve maksimum yüke uygun olarak piyasada bulunan muadillerine göre modellenmiştir. Yük analizi sonucunda yaprak yayda ortaya çıkan en büyük gerilme yay bağlantılarında oluşmuştur. Çalışmada dingil, porya, jant, teker, kriko ve kaplin seçimi yapılmış ve her bir bileşenin ağırlığı belirlenmiştir. Sac levha, kabin arka kapağı, bağlantı elemanları vb. bileşenler hariç römorkun toplam ağırlığı yaklaşık 172 kg olarak hesaplanmıştır. Üretimde kaynak, işçilik, vergi ve nakliye giderleri hariç olmak üzere römork bileşenlerini oluşturan her bir parçanın piyasa fiyatı araştırılarak 700 kg kapasiteli tek dingilli römorkun toplam maliyeti çıkarılmıştır.

Kısaltmalar

F_T	Römorkun çeki demirine bağlandığı noktadaki kuvvet değeri (N)	F_A'	Yaprak yaya gelen toplam kuvvet (N)
F_A	Römork lastiklerinin yere temas noktasındaki kuvvet değeri (N)	σ_e	Yaprak yayda oluşan eğme zorlama gerilmesi (MPa)
W_F	Römorkun platform ağırlığı (N)	σ_g	Yaprak yayı zorlayan değişken gerilme genliği (MPa)
W_D	Römorkun taşıyabileceği maksimum yük (N)	σ_{ort}	Yaprak yayda ortalama eğilme gerilme (MPa)
L_3	Römorkun ağırlık merkezinin uzaklığı (m)	R_{fet}	Tam değişken eğilme gerilme dayanımı (MPa)
L_4	Römorkun yük merkezinin uzaklığı (m)	R_{fet}'	Tam değişken eğilme yorulma dayanımı (MPa)
L_5	Römorkun aks uzaklığı (m)	K_b	Malzemenin boyut faktörü
L_1	Römorkun bağlantı kolu uzunluğu (m)	K_y	Malzemenin yüzey faktörü
L_2	Römorkun yükleme bölgesinin uzunluğu (m)	K_s	Sağlamlaştırma faktörü
2L	Yaprak yayın toplam uzunluğu (mm)	K_f	Yorulma dayanımı düşüş faktörü
F	Yaprak yayda bağlantı gözüne gelen kuvvet (N)	S	Emniyet katsayısı
n'	Ana yay sayısı	R_{feg}	Genel değişken gerilme genliği (MPa)
n	Yaprak yay sayısı	δ	Yaprak yayda meydana gelen çökme miktarı (mm)
C_o	Yay katsayısı	$\varnothing A$	Jant göbek çapı (mm)
b	Yaprak yayın lama genişliği (mm)	$\varnothing B$	Bijon ekseni çapı (mm)
h	Yaprak yayın lama kalınlığı (mm)	H	Yay bağlantı uzaklığı (mm)
E	Elastisite modülü (MPa)	M	Metrik bijon ölçüsü
R_e	Akma dayanımı (MPa)	C	Aks mili kesit ölçüsü (mm)
R_m	Kopma dayanımı (MPa)	D	Dingil jant açıklığı (mm)

GİRİŞ

Traktörlerde yaygın olarak kullanılan en genel yük taşıma aracı römorklardır. Bağlantı şekli ve bağlantı noktası yönüyle farklı konstrüksiyonlara sahip römorkların geçmişten bugüne kadar ağır yüklerin ve özellikle tarım ürünlerinin taşınmasında yaygın olarak kullanıldığı bilinmektedir. Bu römorklar arazi araçları, kamyon, tır ve standart tarım traktörü gibi ağır yük taşıyan araçlara bağlandığı gibi küçük kapasiteli üretilerek otomobil, motosiklet ve mini bahçe traktörü gibi hafif araçlarda da yaygın olarak kullanılmaktadır. Kara taşıtlarına taşıma ekipmanı olarak üretilen römork platformları gereksinimlere göre farklı tip ve kapasitelerde imal edilmektedir. Römork platformu üzerine karavanlar, yarı açık ya da kapalı karoser yapılar, asansörler ve araç, motosiklet ve tekne taşımacılığı için ilave çeki düzenekleri yerleştirilmektedir. Yükün cinsi ve miktarına bağlı olarak farklı tip, kapasite ve ölçülerde römork platformu tasarımları yapılabilmektedir. Bu tasarımlar römorkun kullanım alanına özgü gereksinimlerini karşılamaktadır.

İmalattan önce oluşturulan modeller üzerinde simülasyon çalışmaları yapılarak makine parçaları için seçilen malzemelerin uygunluğu, kuvvetlerin etkisinde kalan parçaların mekaniksel davranışları, oluşturulan yapı için ağırlık tahminleri ve bunların maliyet analizleri yapılabilmektedir. Bu amaçla kullanılan sonlu elemanlar yönteminde büyük bir sistem çok sayıda küçük elemana bölünerek kuvvet etkisinde kalan her bir eleman için gerilme ve deplasman analizleri yapılabilmektedir (Erkoç *ve ark., 2006*; Şahin *ve ark.*, 2018b). Uygulanan kuvvetin büyüklüğüne bağlı olarak sonlu elemanlar yöntemiyle yapının kritik bölgeleri iyileştirilerek taşıyabileceği maksimum yük tahminlenebilmektedir. Belirli bir emniyet katsayısıyla model üzerinde yapılan analizlerin neticesinde tasarım optimizasyonu gerçekleştirilmekte ve zamandan tasarruf edilirken imalat kayıpları azaltılarak üretimdeki maliyet düşürülmektedir (Şahin *ve ark.*, 2018a).

Tarım makinelerinin büyük bir kısmı dinamik yüklerin etkisi altında değişken zorlanmalara maruz kaldığından işleyici organların farklı yük koşullarında mukavemet yönünden incelenmesi, doğru malzeme seçimi ve konstrüksiyon açısından büyük önem taşımaktadır. Bu kapsamda çeşitli toprak işleme makineleri (Zeytinoğlu, 2002; Akinci *ve ark.*, 2005; Mandal *ve ark.*, 2005; Gürsel ve Köftecioğlu, 2006; *Gök ve ark.*, 2012; Çelik *ve ark.*, 2007; Polat *ve ark.*, 2012; Makange *ve ark.*, 2015; *Topakci ve ark.*, 2008; Şahin ve ark., 2018a, 2018b; Topakci ve ark., 2010); hasat makineleri (Bahadır *ve ark.*, 2009) ve tarım arabaları (Zeytinoğlu, 2006) için mukavemet analizleri yapılmış ve yük etkisi altında gerilme ve deplasman davranışları incelenmiştir. Dünya genelinde römork imalat sektörü geniş bir yelpazede çok amaçlı olarak yürütülmekte ve bu alanda da çeşitli çalışmalar yapılmaktadır. Posiadala ve Ladra (2018), tarafından yürütülen araştırmada kullanım amacı geniş olan bir araç römorku modellenmiş ve mukavemet analizleri yapılmıştır. Model üzerinde farklı malzemeler kullanılarak uygunluğu test edilmiştir. Zentinoğlu (2006), tarım arabalarında değişken yüklere maruz kalan çeki halkasının kalınlık ölçüsünü düşürmek için St37 (S235) yapı çeliğinin uygun olduğunu belirtmiştir. Aksoy (2014), bir ticari yarı römork akaryakıt tanker şasisinin yorulma karakteristiklerini incelemiştir. Araştırmada yoldan dolayı dinamik yüklenmeler nedeniyle oluşan titreşimlerin yorulmaya olan etkileri araştırılmıştır. Çalışmada doğal frekans analizleri ve statik analiz senaryoları oluşturulmuş ve model üzerindeki kritik bölgeler tespit edilmiştir. Karaçay ve Aktürk (2002)'nin çalışmalarında araçların seyir karakteristiklerinin modellenmesinde kullanılan yarım

araç modeli esas alınarak değişen römork ağırlığı ve emniyetli taşıma kapasitesi arasındaki ilişki gerçek yol karakteristiği koşullarında araştırılmıştır. Patel ve ark. (2014), tarafından yapılan çalışmada hacmi 3 m³ olan bir traktör römorku modellenmiş ve değişen kesit ve malzemeler için statik analiz yapılmıştır. Tolun (2014) yarı römork şasilerinde kullanılan kaynak işlemi ve uygulamalarının zamanla römork şasilerinde meydana getirdiği bazı problemleri ele almıştır. Araştırmasında römork şasilerinde uygun kaynak türünün belirlenmesi ve dinamik yükler altında kaynağın tepkileri belirlenmiştir. Güven (2011), araştırmasında römorklarda yaygın olarak kullanılan yaprak yaylı süspansiyonların yapısı, araçlara montajı ve yaprak yay çelikleri ayrıntılı olarak incelenmiştir. Yaprak yaylar geometri, yay katsayısı, yük, gerilme ve sürüş kalitesi açısından incelenmiş ve bilgisayar ortamında analizleri gerçekleştirilerek bir araç için optimum yaprak yay tasarımı yapılmıştır.

Çekilir tip bir römorkun ana şasi platformu, hareketli aksamın en önemli bileşeni olup yapının omurgasını oluşturmaktadır. Römork platformunun ana bileşenleri olan dingil (aks), teker, porya, süspansiyon ve kabinin platformun konstrüksiyonuna ve taşıma yüküne uygun olarak seçilmesi gerekmektedir. Buna ek olarak kullanılan kriko ve kaplin bağlantısı taşıma römorkunun yardımcı bileşenlerini oluşturmaktadır. Bu kapsamda imalatı yapılan römork platformlarında hem ölçü hem de malzeme bakımından standart profiller kullanıldığından gerekli mukavemet sınırlarını karşılayan düşük maliyetli üretimlere rastlanmamıştır. Bu gerekçeyle yürütülen çalışmada amaç;

i)   Düşük maliyetli üretim için küçük kapasiteli çekilir tip bir römork platformunda kesit ölçüleri ve mukavemet sınıfı farklı profil çeliklerinin uygunluğunu araştırmak;

ii)   Sonlu elemanlar yöntemiyle römork platformunun statik koşullarda kritik gerilme ve deplasman değerlerini belirlemek, bunların yerini saptamak ve güvenirliliğini ortaya koymak,

iii) Römork platformu için en uygun yaprak yay, aks, porya, jant, lastik teker, kaplin ve krikoyu belirlemek,

iv)   Üretim maliyetini ortaya çıkarmaktır.

MATERYAL ve YÖNTEM

Platformun Ölçüsü ve Profil Malzemesi

Römork platformu tasarımında ölçüleri 40×40×3 mm ve 50×50×4 mm olan profiller kullanılmıştır. Platform malzemesi olarak küçük kesitli profilde S355 (St52) çeliği ve büyük kesitli profilde S235 (St37) çeliği seçilmiştir. Platform tasarımının genel ölçüleri mevcut üretimi yapılan römorkların genel ölçüleri referans alınarak belirlenmiştir. Çalışmada maksimum 700 kg kapasiteli bir römork platformunun imalatı hedeflenmiştir. Genel ölçüleri 110×150 cm olan römork platformunun ölçüleri Şekil 1'de gösterilmiştir.
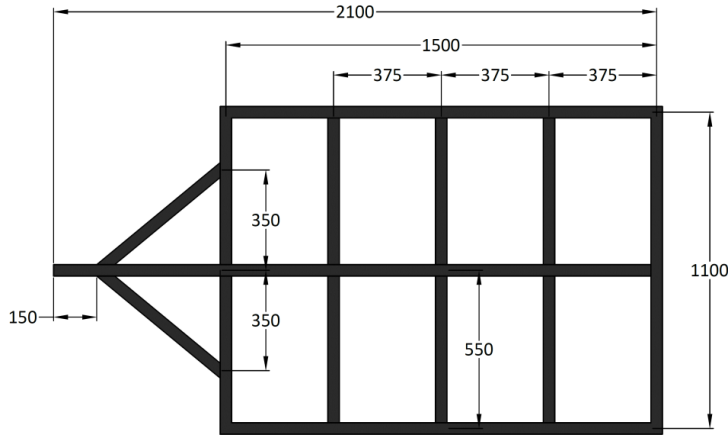
Şekil 1. Römork platformunun ölçüleri.
Figure 1. Trailer platform dimensions.

Platformun Kabin Profilleri

Römork platformun kabini için standart olarak 30×30×2.5 mm ölçülerinde S235 kalite kutu profil seçilmiştir (Şekil 2). Yüksekliği 50 cm olarak tasarlanmış ve platformun ön ve yan kenarlarına yerleştirilmiştir. Bu amaçla ön ve yan kenarlar için tasarlanan kabin için toplam 11 metre uzunluğunda profil kullanılmış olup platform üzerinde yaklaşık 20 kg yük oluşturmuştur.
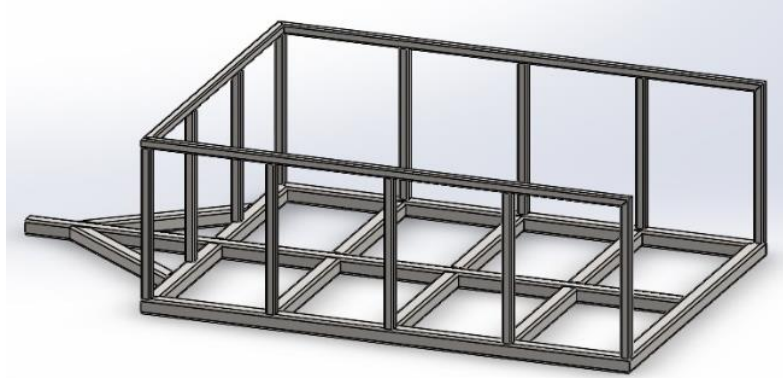
Şekil 2. Platformun kabin profilleri.
Figure 2. Platform cabin profiles.

Yükleme ve Sınır Koşulları

Platform, çeki demiri bağlantı noktası ve aks hizasında iki eklem bölgesi olmak üzere toplam üç noktadan sabit geometriye sahiptir. Römork platformuna toplam 7000 N'luk yük uygulanmıştır.

Tatbik edilen toplam yükün 5000 N'luk kısmı platformun yükleme bölgesine yayılı olarak uygulanmıştır. Römork seyir halindeyken uygun olmayan yol koşullarında (engebe, patika yol vb.) sağa-sola salınım yapabilmektedir. Bu nedenle platform kabininin çevresine uygulanan bu yayılı yük değeri, statik dengede oluşacak bozulmalardan dolayı kabin çevresine etkiyen maksimum yük değeri olarak kabul edilmiştir.

Araç seyir halindeyken ani fren sonucu, toplam yükün 1/3'lik kısmının orta profile etki edebileceği öngörülmüştür. Bu durumda platformun ortasında bulunan ve römork ile araç arasında bağlantı sağlayan profile parabolik dağılmış halde geri kalan 2000 N'luk yük yayılı olarak uygulanmıştır. Römorkun kendi ağırlığından kaynaklanan

yerçekimi kuvveti ayrıca tanımlanmıştır. Ölçüleri ve mukavemet sınırları birbirlerinden farklı çelik malzemeler tanımlanarak tasarlanan römork platformları belirlenen statik yük koşulları altında SolidWorks yazılımı kullanılarak analiz edilmiştir. Analiz sonucunda modele ait gerilme, deplasman ve emniyet katsayısı değerleri elde edilmiş ve ağırlıkları tahmin edilerek karşılaştırılmıştır. Ayrıca piyasa araştırması yapılarak römork platformunun malzeme maliyeti ortaya çıkarılmıştır.

Dingilin Yeri ve Yük Dağılımı

Tek dingilli römorklarda üç temas noktası bulunmaktadır. Bunlardan biri römorkun çeki demiri bağlantı noktası, diğeri ise dingile (aks mili) bağlı olan tekerleklerdir. Bu gibi yük taşımada kullanılan araçlarda dingilin yeri, römorkun temas noktalarına gelen kuvvetin büyüklüğünü değiştirdiğinden büyük önem arz etmektedir. Bir römork platformuna etkiyen kuvvetler Şekil 3'te gösterilmiştir.
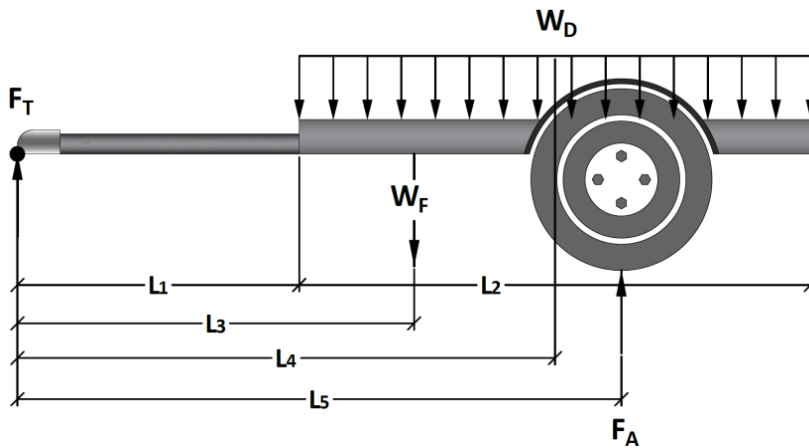
Şekil 3. Römork platformuna etki eden yükler.
Figure 3. Loads affecting the trailer platform.

Römorka etki denge kuvvetleri Eşitlik (1)'de verilmiştir.

$$F_T + F_A = W_F + W_D \tag{1}$$

Katı modeli oluşturulan römork platformu üzerinden W_F ve W_D yükleri belirlenmiştir. Bu yükler aynı zamanda römorkun ve yüklenen ağırlığın temas noktalarına etkiyen F_T ve F_A kuvvetlerinin toplamını vermektedir. Hesaplamalarda römorka etki eden toplam kuvvetin %20'sinin çeki noktasına etki ettiği kabul edilerek F_T kuvveti hesaplanmıştır. Buna bağlı olarak lastiklerin yere temas noktasındaki F_A kuvveti belirlenmiştir. Bu kuvvet değerleri esas alınarak römorkun çeki bağlantı noktasına göre moment alınmış ve Eşitlik (2) elde edilmiştir.

$$F_A \cdot L_5 = W_F \cdot L_3 + W_D \cdot L_4 \tag{2}$$

L_3 ve L_4 uzunlukları katı model üzerinden ölçülmüştür. Buna göre L_5 mesafesini hesaplamak için moment eşitliğinden yararlanılmış ve römorkun çeki demirine bağlandığı noktadan itibaren dingilin (aks) yeri belirlenmiştir.

Yaprak Yay Seçimi

Diğer yay tipleriyle karşılaştırıldığında satın alma maliyetinin düşük olması, ağır yük altında çalışabilmeleri ve ağır işlerde yaygın olarak tercih edilmelerinden dolayı römorkun hareketli aksamında konvansiyonel tip yaprak yay kullanılmıştır.

Mevcut üretimler arasından seçilen yaprak yayın teknik özellikleri Çizelge 1'de verilmiştir. Yay malzemesi olarak 51CrV4 yay çeliği seçilmiştir. Yaprak yay profilinin kesit geometrisi dikdörtgen olup 50×7 mm ölçülerinde lamadan üretilmiştir. Mevcut üretimler arasında uzunluğu ($2L$) 700 mm olan bir yaprak yay seçilmiştir. Ana yay sayısı (n) 1 adet olup üzerinde toplam 5 adet yaprak yay (n) bulunmaktadır. Yük etkisi altında yaprak yayda oluşan deplasman miktarı yay katsayısına bağlı olarak değişmektedir. Bu nedenle yaprak yay katsayısı (C_o) Eşitlik (3) kullanılarak hesaplanmıştır (Can, 2020).

$$C_o = 3/(2 + n'/n) \tag{3}$$

Çizelge 1. Yaprak yayın teknik özellikleri.
Table 1. Specifications of leaf spring.

Teknik özellikler	Değer
Yaprak yay lama sayısı (n)	5
Ana yay sayısı (n)	1
Yay uzunluğu ($2L$), mm	700
Lama genişliği (b), mm	50
Lama kalınlığı (h), mm	7
Yay malzemesi	51CrV4
Elastisite modülü (E), MPa	210000
Akma dayanımı (R_e), MPa	1200
Kopma dayanımı (R_m), MPa	1350

Römork platformu için kullanılacak yaprak yay ve bağlantı elemanlarının montaj çizimi için ölçüler, piyasada bulunan yaprak yay üreticilerinin tasarladıkları yay modellerinden alınmıştır. Yaprak yayın bazı ölçüleri ve montaj modeli Şekil 4'te gösterilmiştir.
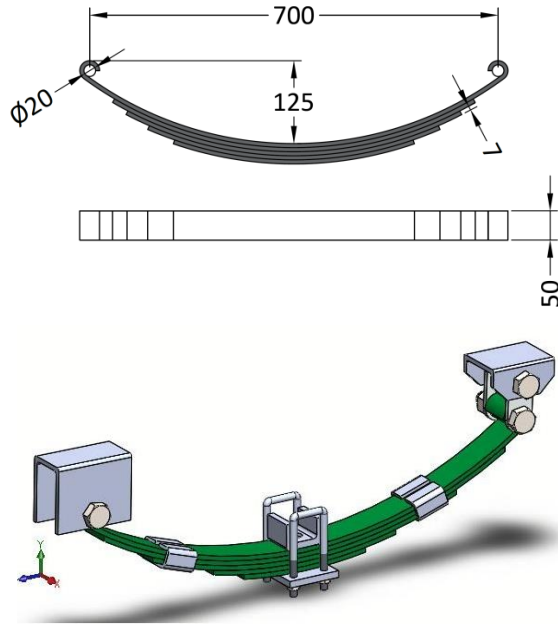
Şekil 4. Yaprak yayın montaj çizimi ve bazı ölçüleri.
Figure 4. *Assembly drawing of leaf spring and some dimensions.*

Yaprak yay ile ilgili tüm hesaplamalarda Can (2020), tarafından bildirilen hesap ilkeleri, çizelge ve grafikler kullanılmıştır. Buna göre yük etkisi altında yayda oluşan eğme zorlama gerilmesi (σ_e) Eşitlik (4) kullanılarak belirlenmiştir.

$$\sigma_e = F \cdot L \cdot 6/(n \cdot b \cdot h^2) \tag{4}$$

Taşıt platformu hareket halinde iken statik çökme miktarı kadar ilave bir çökme daha oluşmaktadır. Bu durum yay üzerinde statik gerilme kadar değişken gerilme genliğinin oluşmasına neden olduğundan eğilme gerilmesinin artmasına neden olmaktadır. Yayı zorlayan değişken gerilme genliği $\left(\sigma_g\right)$ Eşitlik (5) kullanılarak hesaplanmıştır.

$$\sigma_g = \sigma_e/2 \tag{5}$$

Ortalama eğilme gerilme değeri (σ_{ort}) olarak Eşitlik (6) kullanılarak bulunmuştur.

$$\sigma_{ort} = \sigma_e + (\sigma_e/2) \tag{6}$$

Yaprak yaylar hareketsiz halde statik zorlama etkisi altında iken hareket halinde tam değişken zorlama etkisi altında eğilmeye maruz kalmaktadır. Eğilme durumunda tam değişken eğilme gerilme dayanımı (R_{fet}) Eşitlik (7) kullanılarak belirlenmiştir.

$$R_{fet} = 0.44 \cdot R_m \tag{7}$$

Yaprak yayın tam değişken eğilme yorulma dayanımı (R'_{fet}), malzemenin boyut faktörüne (K_b), yüzey faktörüne (K_y), sağlamlaştırma faktörüne (K_s) ve yorulma dayanımı düşüş faktörüne (K_f) bağlı olarak Eşitlik (8)'den hesaplanmıştır.

$$R'_{fet} = K_b \cdot K_y \cdot K_s \cdot R_{fet}/K_f \qquad (8)$$

Yaprak yayın eğilme etkisi altında genel değişken gerilme genliği (R_{feg}) Eşitlik (9) ve emniyet katsayısı (S) Eşitlik (10) kullanılarak bulunmuştur.

$$R_{feg} = R'_{fet} \cdot [1 - (\sigma_{ort}/R_m)^2] \qquad (9)$$

$$S = R_{feg}/\sigma_g \qquad (10)$$

Yaprak yayda meydana gelen çökme miktarı (δ) Eşitlik (11) kullanılarak hesaplanmıştır.

$$\delta = 4 \cdot F \cdot L^3 \cdot C_o/E \cdot n \cdot b \cdot h^3 \qquad (11)$$

Yaprak Yay için Yük Analizi

Katı modeli oluşturulan yaprak yay için malzeme tanımlaması yapılmıştır. Analiz için yaprak yayın her iki bağlantı (göz) kısmı sabitlenmiş geometri olarak belirlenmiştir. Uygulanan kuvvet, yaprak yay merkez civatası doğrultusunda olup üst yatay düzleme dik konumdadır. Kuvvet değeri olarak F_A değerinin yarısı (3100 N) alınmıştır. Model üzerinde mesh oluşturmak için eğrilik tabanlı mesh seçeneği seçilmiştir. Analiz sonucunda yaprak yayda oluşan von misses gerilmeleri, deplasman miktarları ve emniyet katsayısı değerleri elde edilmiş ve kritik bölgeler model üzerinden incelenmiştir.

Dingil ve Porya Seçimi

Römorkun taşıdığı yükün dingil üzerinde etki ettiği noktalar önemli olup kendi üzerinde taşıdığı yükü doğrudan karşılaması gerekmektedir. Şekil 5'te dingil üzerinde yaprak yayların bağlantı noktalarındaki H mesafesi arttıkça dingilin güvenli taşıma kapasitesi azalmaktadır. Tek dingilli olarak tasarlanan römork platformunun genişlik ölçüsü ve taşıma kapasitesi dikkate alınarak standart üretimi yapılan frensiz tip bir dingil için seçim yapılmış ve özellikleri çizelge halinde belirtilmiştir. Porya seçimi dingil ölçüleri dikkate alınarak yapılmıştır (Çayırova, 2019).
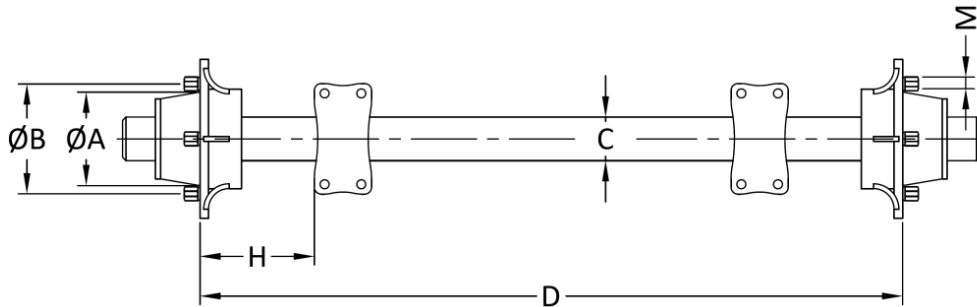
Şekil 5. Dingil - porya ölçüleri ve yaprak yay bağlantı noktası (Çayırova, 2019).
Figure 5. Axle - wheel hub dimensions and leaf spring port (Çayırova, 2019).

Jant ve Lastik Seçimi

Porya için belirlenen jant göbek çapı ($\varnothing A$), bijon ekseni çapı ($\varnothing B$), bijon sayısı ve bijon ölçüsü (M) değerleri dikkate alınarak jant seçimi yapılmıştır. Lastik seçimi, jant özelliklerine göre belirlenmiştir.

Toplam Genişlik ve Yerden Yüksekliğin Belirlenmesi

Dingil, lastik ve jantın katı modeli oluşturulmuş ve montaj çizimler üzerinden römorkun en büyük genişliği, platform tabanının yerden yüksekliği, yaprak yayın montaj yeri ve yay açıklığı belirlenmiştir.

Kriko ve Kaplin Seçimi

Tek dingilli römorkların çeki demirine kolay monte edilebilmesi ve park konumunda dengede kalabilmesi için kriko kullanılmaktadır. Kriko seçiminde platformun yerden yüksekliği ve çeki demirine transfer olan ağırlık değerleri kullanılmıştır. Römorku çeki demirine bağlamak için kullanılan kaplinin seçimi için römorkun maksimum taşıma kapasitesi dikkate alınmıştır.

Toplam Ağırlığın Belirlenmesi

Römork platformunu oluşturan tüm bileşenlerin ağırlıkları tespit edilmiş ve toplam ağırlık hesaplanmıştır.

BULGULAR ve TARTIŞMA

Römork Platformu Statik Yük Analizi

Farklı çelik malzemelerden tasarlanan römork platformunun tam yükleme koşullarında oluşan gerilme ve deformasyon analizi sonuçları S355 çeliği için Şekil 6a'da ve S235 çeliği için Şekil 6b'de gösterilmiştir. Kesit ölçüleri farklı her iki platformda maksimum gerilme çeki noktasında oluşmuştur. En fazla deplasman ön platformun yan kanatlarında gerçekleşmiştir. Her iki malzeme için en büyük gerilme ve deplasman değerleri 40×40×3 mm kesitli S355 çeliğinde saptanmıştır. Malzemenin mukavemet sınırı dikkate alındığında en yüksek emniyet katsayısı S235 çeliğinde belirlenmiştir.

Statik yükleme sonucunda elde edilen değerler Çizelge 2'de özet halinde karşılaştırmalı olarak verilmiştir. S355 çeliğinde oluşan maksimum gerilme S235 çeliğine göre yaklaşık 2 kat; deplasman miktarı ise yaklaşık 2.4 kat daha fazla oluşmuştur. S235 çeliğinde belirlenen emniyet katsayısı S355'e göre daha yüksektir. S235 çeliğinden üretilen römork platformunun kütlesel ağırlığının S355'e göre 1.5 kat daha yüksek olduğu belirlenmiştir. Maliyet açısından yapılan karşılaştırmada mukavemet sınıfı yüksek olan S355 çeliğinin birim fiyatı diğerine göre daha yüksek olduğundan üretim maliyeti 2.6 kat artmıştır.
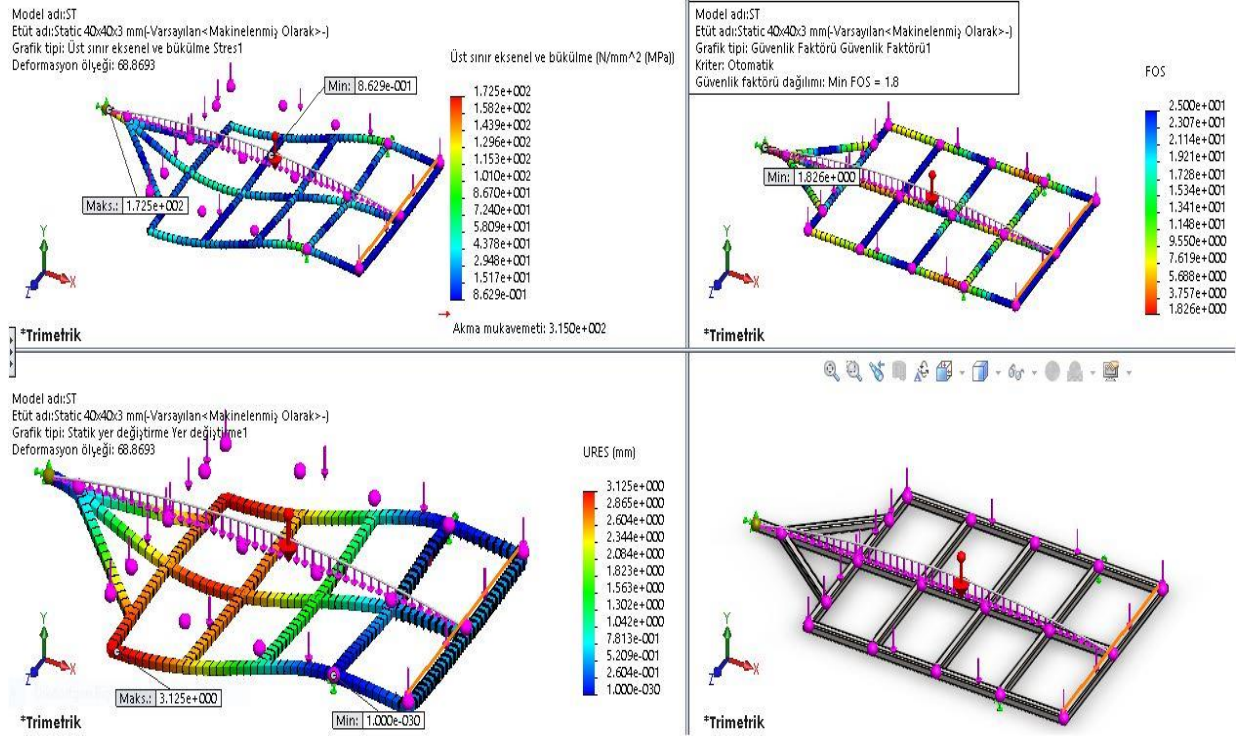
(a) Mukavemet sınıfı S355 ve kesit ölçüsü 40×40×3 mm kare kutu profil-Tam yükleme
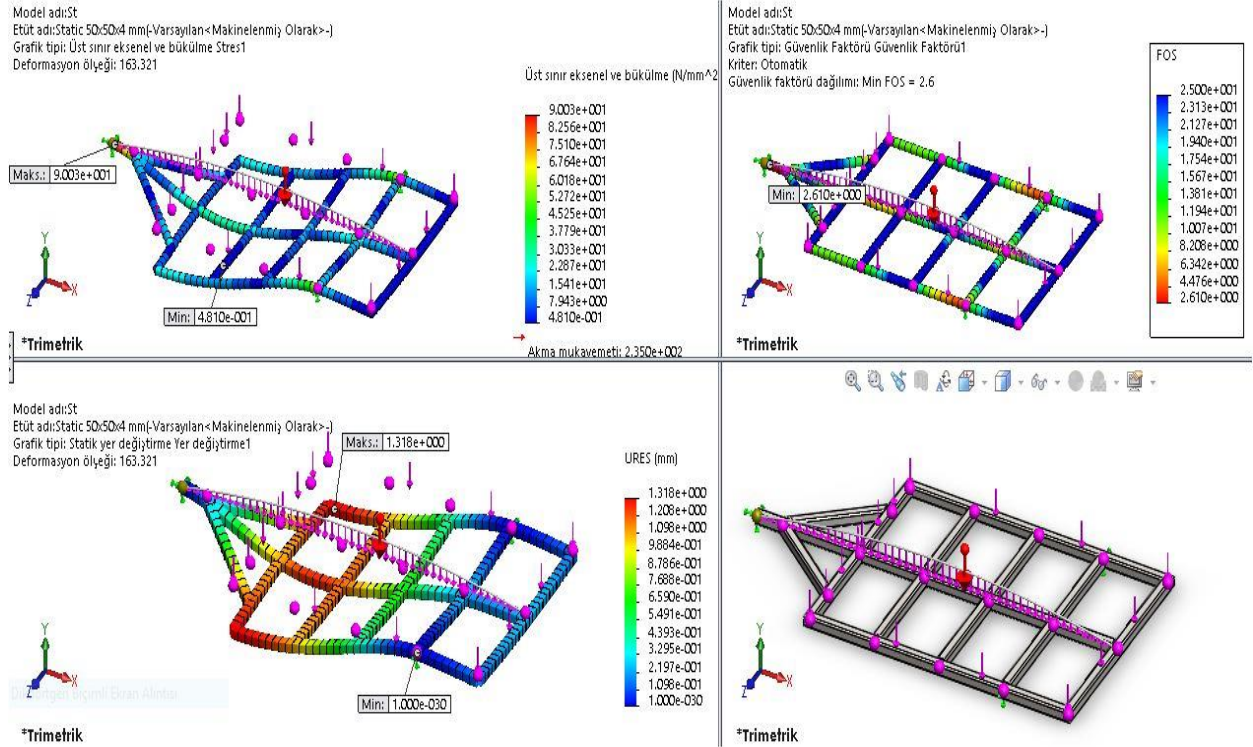
(b) Mukavemet sınıfı S235 ve kesit ölçüsü 50×50×4 mm kare kutu profil-Tam yükleme

Şekil 6. Statik yükleme şartlarında iki farklı malzeme ve kesit ölçüsü için römork platformunda oluşan gerilme, emniyet katsayısı ve deplasman analizi sonuçları.

Figure 6. Results of stress, safety coefficient and displacement analysis on trailer platform for two different materials and cross-section dimension under static loading conditions.

Çizelge 2. S355 ve S235 malzemelerinin statik analiz ve maliyet açısından karşılaştırılması.

Table 2. *Static analysis and cost comparison of S355 and S235 materials.*

Malzeme sınıfı	S355	S235
Kesit ölçüleri (mm)	40×40×3	50×50×4
Akma dayanımı (MPa)	315	235
Maksimum gerilme (MPa)	172.5	90.0
Maksimum deplasman (mm)	3.125	1.318
Emniyet katsayısı	1.83	2.60
Ağırlık (kg)	40	60
Kullanılacak profil uzunluğu (m)	12	12
Birim fiyat ($ m^{-1})	9.5 $*	3.7 $*
Toplam fiyat ($)	114 $*	44 $*

*: Nakliye ve vergi giderleri dahil edilmemiştir. 16 Nisan 2020 tarih ve 31101 sayılı Resmi Gazeteye göre T.C. Merkez Bankası Dolar Kuru (1 ABD Doları = 6.85 TL) esas alınmıştır.

Dingil Bağlantısı ve Yük Dağılımı

Katı modeli oluşturulan römork platformu üzerinden $W_F = 800$ N ve $W_D = 6867$ N olarak belirlenmiştir. Römorkun ve yüklenen ağırlığın temas noktalarına etki eden toplam kuvvet $F_T + F_A = 800 + 6867 = 7667$ N olarak hesaplanmıştır. Hesaplamalarda römorka etki eden toplam kuvvetin ancak %20'sinin çeki noktasına etki ettiği kabul edildiğinden $F_T = 7667 \cdot \%20 = 1533.4$ N'luk kuvvetin transfer edildiği belirlenmiştir. Buna göre lastiklerin yere temas noktasında $F_A = 7667 - 1533.4 = 6133.6$ N'luk bir kuvvetin etkili olduğu bulunmuştur. Uzunluk değerleri katı model üzerinden $L_3 = 1.20$ m ve $L_4 = 1.35$ m olarak belirlenmiştir. Çeki bağlantı noktasına göre alınan moment eşitliği kullanıldığında römorkun çeki demirine bağlandığı noktadan itibaren aks mesafesi $L_5 = 800 \cdot 1.2 + 6867 \cdot 1.35/6133.6 = 1.7$ m olarak hesaplanmıştır.

Yaprak Yay için Hesaplamalar

Yaprak yaya gelen toplam yük (F_A'), 6133.6 N olup tek bir yay gözüne gelen kuvvet $F = F_A'/4 = 6133.6/4 \cong 1535$ N olarak hesaplanmıştır. Yük etkisi altında yayın deplasman (çökme) miktarı, yay katsayısına (C_o) bağlı olarak değiştiğinden bu katsayı $C_o = 1.36$ olarak bulunmuştur.

Yaprak yayda oluşan eğilme gerilmesi $\sigma_e = 1535 \cdot 350 \cdot 6/(5 \cdot 50 \cdot 7^2) = 263$ MPa olarak belirlenmiştir. Yayı zorlayan değişken gerilme genliği $\sigma_g = 263/2 = 131.5$ MPa olarak hesaplanmış ve ortalama eğilme gerilmesi $\sigma_{ort} = 263 + (263/2) = 394.5$ MPa olarak bulunmuştur.

Eğilme durumundaki yaprak yayın tam değişken eğilme dayanımı $R_{fet} = 0.44 \cdot 1350 = 594$ MPa olarak belirlenmiştir. Numune ölçüsü 10 mm'ye kadar olan malzemelerde K_b faktörü 1; soğuk çekilmiş malzemelerde K_y faktörü 0.65; sağlamlaştırma için herhangi bir dayanım arttırıcı işlem yapılmadığından K_s faktörü 1 ve yaprak yaylar için önerilen yorulma dayanımı K_f faktörü 1.5 alınmıştır. Buna göre tam değişken eğilme yorulma dayanımı $R_{fet}' = 1 \cdot 0.65 \cdot 1 \cdot 594/1.5 = 257.4$ MPa olarak hesaplanmıştır.

Yaprak yayın eğilme etkisi altında genel değişken gerilme genliği $R_{feg} = 257.4 \cdot [1 - (394.5/1350)^2] = 235.4$ MPa ve emniyet katsayısı $S = 235.4/131.5 = 1.8$ olarak bulunmuştur. Bu koşullarda yaprak yayda meydana gelen çökme miktarı $\delta = 4 \cdot 1535 \cdot 350^3 \cdot 1.36/210000 \cdot 5 \cdot 50 \cdot 7^3 = 21.88$ mm olarak belirlenmiştir.

Römorkun taşıyacağı maksimum yük ve platformun kendi ağırlığının etkisiyle yaprak yayda meydana gelen gerilme ve deplasman değerleri hesaplanmış olup emniyet katsayısına göre seçilen yaprak yayın uygun olduğu sonucuna varılmıştır.

Yaprak Yay için Yük Analizi

Analiz sonucunda yaprak yayda oluşan gerilme, deplasman ve emniyet katsayısı değerleri Şekil 7'de gösterilmiştir.
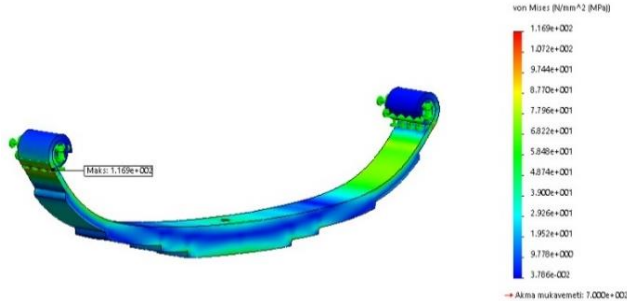
(a) Von misses gerilmesi
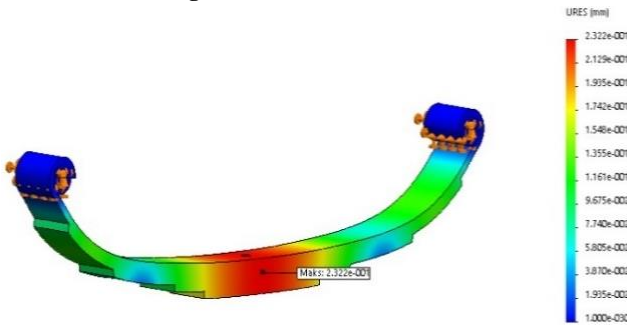
(b) Deplasman
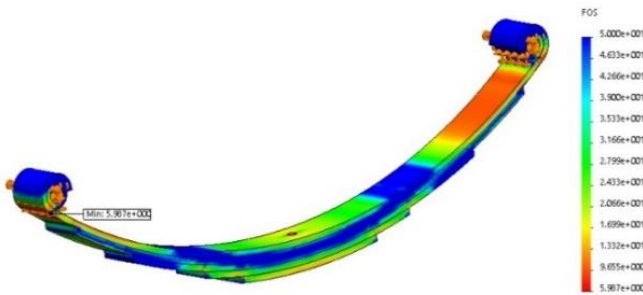
(c) Emniyet katsayısı

Şekil 7. Yaprak yayda yük analizi sonuçları.
Figure 7. *Results of load analysis for leaf spring.*

Analiz sonuçlarına göre statik yükte maksimum gerilme kuvveti en uzak noktada, yani yay bağlantı gözlerinin arka kısmında oluşmuş olup değeri 116.9 MPa'dır. Maksimum gerilmenin bulunduğu noktada emniyet katsayısı 5.98 ile en küçük değeri almıştır. Maksimum deplasman, kuvvetin etki ettiği nokta olan merkez civatası bölgesinde görülmüş ve miktarı 23.2 mm olarak okunmuştur. Genel anlamda sonuçların analitik çözüme göre farklı çıkmasının nedeni; analitik çözümde değişken gerilme değerlerinin dikkate alınmasından kaynaklanmaktadır. Model üzerinde yükleme koşulları statik olup yaprak yayın uygunluğu konusunda fikir vermektedir. Analitik çözüm ile beraber düşünüldüğünde seçilen yaprak yayın römorkun maksimum yük kapasitesine uygun olduğu kanaatine varılmıştır.

Dingil ve Porya Seçimi

Platform genişliği 1100 mm ve taşıma kapasitesi 700 kg olarak tasarlanan tek dingilli römork için seçilen dingil ve poryanın özellikleri Çizelge 3'te verilmiştir. Dingil ve porya seçimi Çayırova (2019)'nın ait ürün kataloğundan yapılmıştır.

Çizelge 3. Frensiz tip dingilin bazı ölçüleri.
Table 3. Some dimensions of non-brake type axle.

Dingil/Porya	Özellik/Tanım	Ölçü
Dingil	Aks mili kesiti (*O*), mm	50 (Kare kesit)
	Yay bağlantı uzaklığı (*H*), mm	180
	Dingil jant açıklığı (*D*), mm	1250
	Taşıma kapasitesi, kg	900
Porya	Jant göbeği çapı (*A*), mm	Ø58
	Bijon ekseni çapı (*B*), mm	Ø98-149
	Bijon sayısı (adet)	3-4
	Bijon ölçüsü (*M*, metrik)	M12

Jant ve Lastik Seçimi

Poryanın teknik özellikleri dikkate alınarak belirlenen jant ve lastiğin ölçüleri Çizelge 4'te belirtilmiştir. Jant ve lastik seçimi Çayırova (2019)'nın ürün kataloğundan yapılmıştır.

Çizelge 4. Jant ve lastik özellikleri.
Table 4. Specifications of rim and wheel .

Jant/lastik	Tanım	Ölçü/Özellik
Jant	Jant ebadı	4.50×13
	Tipi	Dubleks
	Bijon sayısı	4
	Porya göbeği, mm	58
	Bijon merkezi çapı, mm	98
	Dış çap, mm	330
	Genişlik, mm	114
	Göbek kalınlığı, mm	4
	Kasnak kalınlığı, mm	3
Lastik	Ölçüsü	165/80 R13
	Tip (Grup)	Radyal
	Dış çap, mm	594
	Genişlik, mm	165
	Hız, km h^{-1}	190
	Yük, kg	487

Toplam Genişlik ve Yerden Yüksekliğin Belirlenmesi

Katı modeli çizilen dingil, porya, jant, lastik ve yaprak yayın montaj görünümleri Şekil 8'de verilmiştir. Montajdan sonra römorkun en büyük genişliği 1575 mm ve platformun yerden yüksekliği 445 mm olarak ölçülmüştür. Yaprak yayların montajı yapıldıktan sonra aralarındaki açıklık 1103 mm olarak belirlenmiştir.
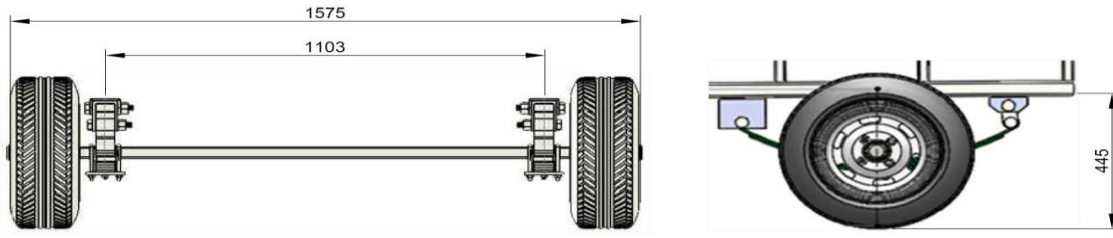
Şekil 8. Dingil, porya, jant, lastik ve yaprak yayların bazı montaj ölçüleri.
Figure 8. Some mounting dimensions of axle, wheel hub, rim, wheel and leaf springs.

Kriko ve Kaplin Seçimi

Römorkun çeki demirine transfer olan ağırlığı 1535 N ve platformun yerden yüksekliği yaklaşık 450 mm olduğundan bu değerlere uygun kriko seçimi yapılmıştır. Kaplin seçiminde römorkun 700 kg'lık maksimum taşıma kapasitesi dikkate alınmıştır. Kriko ve kaplin seçimi Çayırova (2019)'nın ürün kataloğundan yapılmış ve özellikler Çizelge 5'te verilmiştir.

Çizelge 5. Kriko ve kaplinin özellikleri.
Table 5. Specifications of jack and coupling.

Kriko/kaplin	Tanım	Ölçü
Kriko	Strok boyu, mm	500
	Toplam uzunluk, mm	930
	Statik yük, kg	200
	Kapasite, kg	800
Kaplin	Uzunluk, mm	266
	Kapasite, kg	1400

Tek Dingilli Römorkun Montaj Görünümü

Taşıma kapasitesi 700 kg olan römorkun yürür aksamı, çeki demiri ve krikosuyla birlikte montaj görünümü Şekil 9'da gösterilmiştir. Römork platformu 50 cm kabin yüksekliğine sahip olup taşıyıcı yapı elemanlarından oluşan bir model oluşturulmuştur.
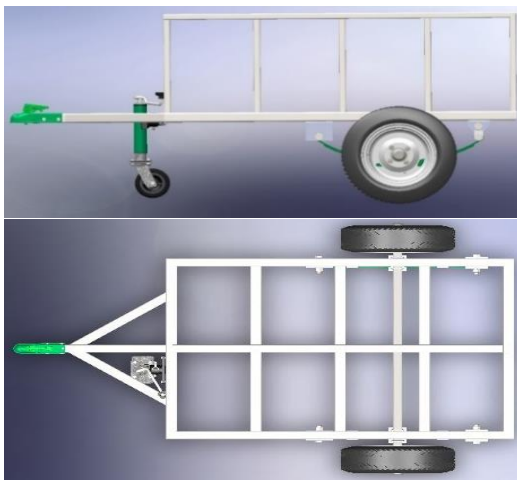
(a) Yan ve üst görünüm
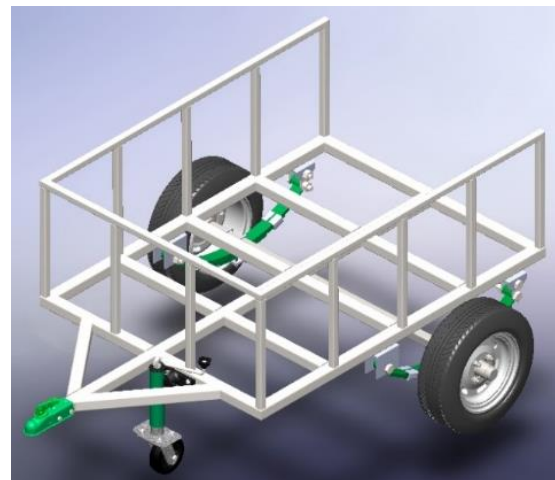
(b) İzometrik görünüm

Şekil 9. Tek dingilli römorkun montaj görünümü.
Figure 9. Mounting views of single axle trailer.
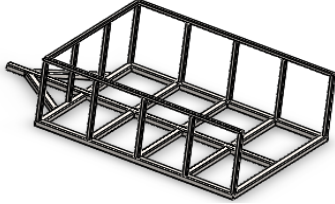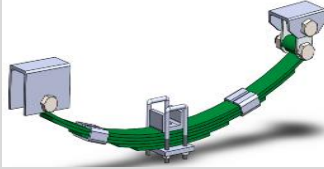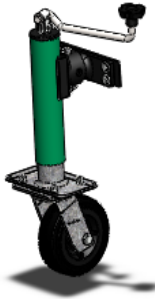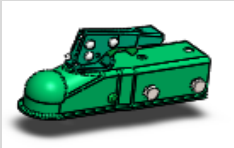
Toplam Ağırlık ve Maliyet

Römork platformunu oluşturan tüm bileşenler için piyasa araştırması yapılarak ağırlık ve satın alma fiyatları Çizelge 6'da belirtilmiştir. Buna göre toplam ağırlık 171.5 kg ve toplam ürün fiyatı 367.4 $ olarak hesaplanmıştır. Platformun kütlesel ağırlığına civata ve somunlar, kaynak, sac levhalar, arka kabin kapağı, menteşe, pim, zincir vb. bileşenler dahil edilmemiştir. Ayrıca toplam ürün fiyatına işçilik bedeli, boya, kaynak gideri, vergi ve nakliye gibi giderler eklenmemiştir.

Çizelge 6. Römork platformu bileşenlerinin ağırlığı.
Table 6. Mass of trailer platform components.

Bileşenler	Görsel	Sayı	Ağırlık (kg)	*Fiyat ($)
Römork platformu		1	82	56.2 $
Yaprak yay ve bileşenleri		2	27	46.7 $
Dingil ve porya		1	24	62.8 $
Jant ve lastik		2	29	138.7 $
Kriko		1	8	42.3 $
Kaplin		1	1.5	20.7 $
Toplam			**171.5 kg**	**367.4 $**

*: 16 Nisan 2020 tarih ve 31101 sayılı Resmî Gazete'ye göre T.C. Merkez Bankası dolar kuru (1 ABD Doları = 6.85 TL) esas alınmıştır.

SONUÇ

Mukavemet sınıfı açısından iki farklı malzeme kullanılarak yapılan römork platformu tasarımında gerilme ve deplasman değeri en yüksek S355 çeliğinde belirlenmiştir. Emniyet açısından S235 çeliğinden üretilen platformun emniyet katsayısının statik yüklenme durumunda yeterli düzeyde olduğu kanaatine varılmıştır. Kesit ölçüleri 50×50×4 mm olan S235 çeliğinin malzeme maliyeti 40×40×3 mm ölçülü S355'e göre daha düşük bulunmuştur.

Bu çalışmada 700 kg taşıma kapasiteli tek dingilli bir römorkun düşük maliyette imalatı için statik yüklenme durumunda gerekli hesaplama ve analizleri yapılmış, yürür aksam için temel bileşenler ortaya konmuş ve mukavemet açısından kritik bölgelerde gerilmeyi emniyetle karşılayacak nitelikte kontroller yapılmıştır. Römork platformunun dinamik zorlanma koşullarında değişken yükler için ayrıca yorulma analizlerinin yapılması ve bağlantı yerlerinde kaynak hesaplamalarının yapılması gerekmektedir. Römork platformunun kullanım alanı geniş olduğundan bu alanda yapılacak çalışmaların imalat sektörüne katkı sağlayacağı düşünülmektedir.

ÇIKAR ÇATIŞMASI

Yazarlar çalışmanın planlanması, yürütülmesi ve makale olarak yazılması konusunda herhangi bir çıkar çatışması içerisinde olmadıklarını beyan ederler.

YAZAR KATKISI

Yazarlar, makalenin altta belirtilen iş planına göre yürütüldüğünü beyan ederler.

Bahadır Sayıncı: Araştırmanın planlanması; tasarım parametreleri ve sınır şartlarının belirlenmesi, malzeme seçimi, makalenin yazılması

Ali Tektaş: Tasarım ve analiz; mühendislik hesaplamaları, literatür tarama, piyasa araştırması

İsmet Aslan: Tasarım ve analiz, mühendislik hesaplamaları, literatür tarama, piyasa araştırması

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A Study on Rupture Resistance of Groundnut (cv. SAMNUT 22) Kernel

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ABSTRACT

This study was done to assess the influence of compression loading rate and kernel size on the rupture resistance of groundnut (cv. SAMNUT 22) kernel. These groundnut kernel mechanical parameters (rupture force, deformation at rupture, rupture power, firmness and toughness) were evaluated under three loading rates (15 mm min^{-1}, 20 mm min^{-1} and 25 mm min^{-1}), and three size categories (small, medium and large). The groundnut kernels were harvested at peak maturity stage, and tested in accordance to ASTM International standards. Results obtained from the tests showed that the rupture resistance of SAMNUT 22 kernel was highly dependent on its size and the loading rate. Generally, as the loading rate increases, the mechanical parameters values declined significantly ($p \leq 0.05$). Rupture force, deformation at rupture point, rupture power and the firmness increased as the kernel size increases; but in contrast, the kernel toughness decreases as its size increased. An average force of 57.96 N ruptured the large kernel, while a lower force of 27.35 N ruptured the small kernel. Moreover, the large kernel recorded the highest firmness (59.03 N mm^{-1}), when compared to the medium (51.69 N mm^{-1}) and small (44.98 N mm^{-1}) size kernel. In terms of rupture power, the small kernel power ranged from 0.1002 W (15 mm min^{-1}) to 0.084 W (25 mm min^{-1}); medium size kernel ranged from 0.115 W (15 mm min^{-1}) to 0.074 W (25 mm min^{-1}); while the large size kernel ranged from 0.135 W (15 mm min^{-1}) to 0.104 W (25 mm min^{-1}). These results portrayed importance of sorting of the groundnut kernels before processing unit operation, as it will help to conserve power and energy during the processing operation.

INTRODUCTION

Groundnut (*Arachis hypogea* L.), a leguminous oil crop comprises of two economical parts, which are the kernel and hull. The kernel contains large amount of edible oil (approximately 50%, depending on the cultivar) and protein (about 20%); while the hull can be processed into animal feed, insulation material, bio-fuel and manure (Bagheri *et al.*, 2011). It had been discovered that groundnut plant tolerates a wide range of soil pH, even though it does better in neutral and slightly acidic soils. Since groundnut plant just like other leguminous crops, can produce its own nitrogen through the nitrogen-fixing bacteria presents in its roots noodles, nitrogenous fertilizers are only useful to the plant during the early stage (within the first six weeks after germination), before the full establishment of the plant (Tsigbey *et al.*, 2003). Growing groundnut plants can improve the nitrogen content of the soil; at an approximate rate of 60 kg ha^{-1}. This is done by fixing the atmospheric nitrogen into the soil during lightning (Ndjeunga *et al.*, 2013; Uguru and Iweka, 2019).

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Institute for Agricultural Research and other seeds research centers have produced and registered about 20 disease resistant groundnut cultivars, within the past three decades. Some of these groundnut cultivars include are SAMNUT 10, SAMNUT 11, SAMNUT 22 etc.; which have high kernel and forage yields, and less susceptible to foliar diseases (Ndjeunga *et al.*, 2013; Uyeri and Uguru, 2018). According to the Food Agriculture Organization (FAO) data, Global groundnut total production in 2017 was about 48 million metric tons, with 2.4 million metric tons coming from Nigeria; while China and India were the two largest groundnut producing countries, producing 17.1 and 9.8 million metric tons respectively (FAOSTAT, 2019).

Agricultural products go through many static and dynamic pressures during harvest and post-harvest operations. This usually cause bruises, crushes and cracks to the products, thereby, increasing their susceptibility to deterioration during storage (Altuntas and Ozkan, 2008; Altuntas *et al.*, 2013; Uguru and Nyorere, 2019). Mechanical damage of agricultural products resulting from poor harvesting, handling or storage operations can caused physiological responses on the point of impact; causing complex physiological, metabolic, and enzymatic reactions; leading to unsuitable results (Pérez-López *et al.*, 2014; Akpokodje and Uguru, 2019; Umurhurhu and Uguru, 2019). The two main forces encountered by groundnut net/kernel during handling and storage operations are; compression force and impact force. These forces are experienced either by the whole nut/kernel or at a particular point of the nut/kernel. During the design of agricultural machines/equipment (with preference to groundnut), the knowledge of the mechanical parameters of the groundnut kernel, under quasi static compression are vital information needed by the engineers (Uguru and Iweka, 2019). Rupture force and energy are essential mechanical parameters required for the design and development of groundnut kernels' threshing, shelling and milling machines/equipment). Groundnuts are harvested and threshed to remove the pod, before shelled at lower moisture content to obtain the kernels. Groundnut shelling operation is a serious and delicate post-harvest unit operation, so that achieve high-quality groundnut kernels can be obtained (Bagheri *et al.*, 2011).

To date, many researches have been conducted on the effects of groundnut cultivar, kernel size, kernel orientation, and compression speed, on their physical characteristics

and mechanical properties. Their influence on various mechanical properties of groundnut pods and kernels had been reviewed by several researchers. Bagheri *et al.* (2011) observed that the rupture force of groundnut pod was highly dependent on the groundnut cultivar. Rupture force of groundnut (cv. Iraqi 2) pod was 61 N; while the values for Iraq 1, Goli and Valencia groundnut cultivars were 86 N, 69 N and 66 N (Bagheri *et al.*, 2011). According to Ince *et al.* (2009), groundnut kernel firmness increased from 43.07 N mm^{-1} to 59.74 N mm^{-1}, as its size increased from small to large size. Ince *et al.* (2009), further observed that groundnut kernel had a higher firmness when it is loaded along the perpendicular orientation (49.49 N mm^{-1}), when compared with the value obtained when the kernel was loaded along the longitudinal orientation (48.47 N mm^{-1}). Furthermore, another study conducted by other researchers (Uguru and Nyorere, 2019) showed that loading rate/speed significantly influenced the failure force of groundnut (cv. SAMNUT 11) kernels. Uguru and Nyorere (2019) reported that the kernel failure force decreased linearly (61.10 N to 27.61 N) as the loading speed of the compression machine increase from 15 mm min^{-1} to 25 mm min^{-1}, which is also similar to the results we obtained for SAMNUT 22 kernel. Ijabo *et al.* (2016) recorded a cracking force of 45.13 N for a groundnut (local cultivar) kernel when it was compressed along the helium position (plane containing the helium line), at a moisture content of 5.5% (dry basis). It has been reported that groundnut kernel failure is a major problem facing groundnut processors during handling, packaging and storage unit operations. Food engineers' major concern is how to remove the fragile groundnut kernel undamaged from the groundnut pod, during the processing and handling operations. This is because damaged (failed) groundnut kernel does not store well, will lose its viability, and becomes susceptible to fungi/bacterial attacks (Braga *et al.*, 1999; Uguru and Nyorere, 2019).

From relevant literature review, there is no study on the rupture resistance of groundnut (cv. SAMNUT 22) kernels, when measured at different kernel size categories, and different loading rates. Therefore, this study was aimed to evaluate some mechanical behaviours (rupture force, deformation at rupture, rupture power, firmness and toughness) of SAMNUT 22 kernels, at three size categories (small, medium and large) and three loading rates (15 mm min^{-1}, 20 mm min^{-1} and 25 mm min^{-1}). Data obtained from this study will be useful during processing operation of groundnut kernels.

MATERIALS AND METHODS

Plant of interest
The SAMNUT 22 groundnut kernels used for this study were obtained from ICRISAT Kano State, Nigeria. SAMNUT 22 groundnut cultivar produces large kernel and high yields and rich oil quality. It was developed by ILRI- ICRISAT and registered in 2001, with the code NGAH 01-22.

Groundnut cultivation and pre-harvest maintenance
The study was carried out inside the Research Station of Delta State Polytechnic, Ozoro, Nigeria. The groundnut (SAMNUT 22) kernels were cultivated under organic farming method. Groundnut plants did not responds well to nitrogen fertilizers about five weeks after planting (Ajeigbe *et al.*, 2014; Uyeri and Uguru, 2018); therefore, the compost

manure was mixed with the soil (at the rate of 3000 ton ha^{-1}), four weeks before the planting of the groundnut kernels. Compost manure releases its nutrients slowly into the soil; therefore, it is appropriate to incorporate it into the soil weeks before the propagation of crops (Akpokodje and Uguru, 2019).

Weeding was done manually, while sprinkler irrigation was employed to meet up with the groundnut water requirement. Any disease infested groundnut plant was uprooted and burnt outside the farm in a thrash pit. Insects were controlled with organic insecticide prepared from neem bark extract; while traps and nets were used to control pests' incursions.

Groundnut samples harvest and preparation

The groundnut plants from where the kernels used for this study were obtained were harvested at peak maturation period. This is when approximately 85% of the kernels physical appearance has showed their true colour, and the kernels were plumped (Ajeigbe *et al.*, 2014; Uyeri and Uguru, 2018). The harvested groundnut plants were dried under the sun for six days on a platform at ambient temperature of 30±4⁰C during the day. Then they were threshed cautiously (to minimize mechanical damage been done to the pods and kernels) using a stick to remove the pods from the groundnut plants. The pods were physically shelled to obtain the kernels; and the kernels were sun-dried for another twelve days, to lower their moisture content. In order to obtain healthy kernels to be used for the study; the dried kernels were manually inspected. Foreign bodies, premature and damage groundnut kernels, etc. were discarded from the lot.

Methods

Gravimetrical method was employed to determine the kernel's moisture content; and Equation (1) was used to calculate the moisture content (Uyeri and Uguru, 2018; Akpokodje *et al.*, 2018). The average moisture content of the kernels was 23% to 26% (wet basis).

$$Moisture\ content = \frac{Weight\ of\ wet\ sample - weight\ of\ dry\ sample}{Weight\ of\ wet\ sample} \times 100 \tag{1}$$

Groundnut kernel size determination

The kernel's principal dimensions, namely; length (L), width (W) and thickness (T) were measured with the aid of a digital vernier caliper (Mitutoya, Japan), with 0.01 mm accuracy (Uyeri and Uguru, 2018). The kernel's geometric mean diameter (GMD) and sphericity (ϕ) were calculated by employing Equations 2 and 3 (Mohsenin, 1986; Öztekin *et al.*, 2020). The size classifications of the kernels are presented in Table 1.

$$GMD = \sqrt[3]{L \times W \times T} \tag{2}$$

$$\phi = \frac{GMD}{L} \times 100 \tag{3}$$

Table 1. Size classification of the SAMNUT 22 groundnut kernels.

Size	Small	Medium	Large
L (mm)	$L < 6.25$	$10.00 \leq L \leq 6.25$	$L > 10.00$
W (mm)	$W < 5.55$	$8.55 \leq W \leq 5.55$	$W > 8.55$
T (mm)	$T < 5.15$	$8.15 \leq T \leq 5.15$	$T > 8.15$
GMD (mm*)	5.04	6.03	7.14
Sphericity* (%)	59.16	65.18	83.81

* = Mean value of the groundnut kernels

Mechanical test on the groundnut kernel

The quasi-static compression test of the SAMNUT 22 groundnut kernel was done by using the Universal Testing Machine (Testometric model, manufactured in England), with accuracy of 0.001 N. During the test, each groundnut kernel was placed inside the machine, ensuring that it is in alignment with the loading cell (Uyeri and Uguru, 2018). Then the kernel was loaded at a preset loading rate (speed), as shown in Figure 1. As the loading progressed, a force-deflection curve of the groundnut kernel was plotted spontaneously by the microprocessor of the machine (Figure 2) relatively to the kernel's compressive reaction to the quasi-static compression (Eboibi and Uguru, 2017; Uyeri and Uguru, 2018).

Figure 1. SAMNUT 22 groundnut kernel undergoing compression loading.
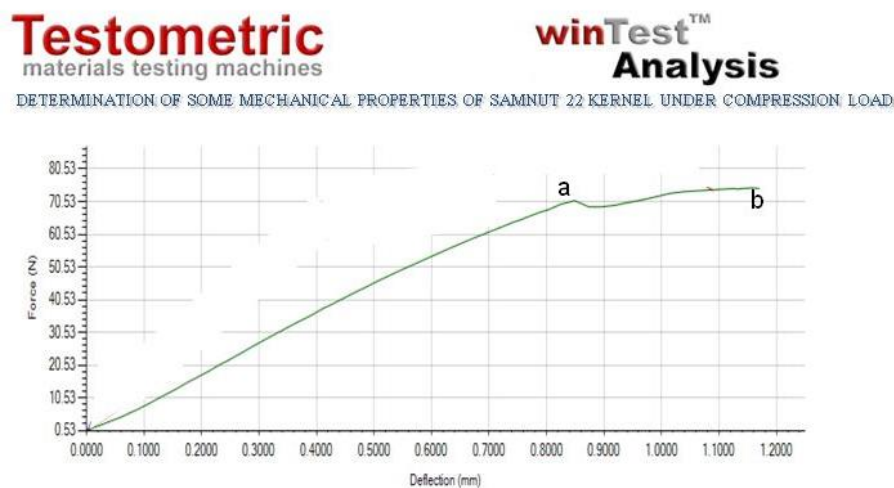
Figure 2. A force-deflection curve of SAMNUT 22 kernel under quasi compressive loading. a = Bio-yield point, also expressed as failure point (Steffe, 1996; Uyeri and Uguru, 2018)
b = Breaking point, also expressed as rupture point (Steffe, 1996; Uyeri and Uguru, 2018)

At the end of each test, the machine calculated these mechanical parameters (rupture force, deformation at rupture point, rupture energy) electronically. The tests were done at three loading rates (15, 20 and 25 mm min^{-1}), three kernel sizes (small, medium and large) at the kernel's *Y*-axis. The loading position was taken based on the orientation of the groundnut kernel. The line (axis) which parallel to the split plane was considered as the *X*-axis; the axis longitudinal to the split plane was considered as the *Y*-axis. Finally, the axis perpendicular to the split plane was considered as the *Z*-axis, as shown in Figure 3 (Uyeri and Uguru, 2018).

Groundnut kernel just like other biological materials has complex biomechanical behaviours; thereby, it is practically difficult to categorize it with simple constants (Lysiak, 2007; Uguru *et al.*, 2020). Bio-yield and rupture points are introduced, in order to calculate most of its mechanical properties (Uguru and Iweka, 2019). Bio-yield point (failure point) correlates to the microstructure failure of the sample, and it is linked to the initial disruption of the sample's cellular structure. Rupture point (breaking point) correlates to with macro-structural failure of the kernel, during compressional loading (Steffe, 1996; Eboibi and Uguru, 2017). Each test was replicated twenty times and the average value taken.
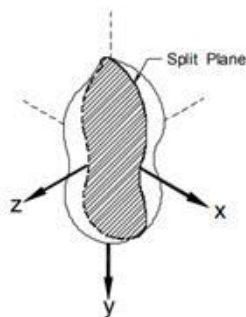
Figure 3. Graphical representation of groundnut kernel showing the three axes (Ince *et al.*, 2009).

Calculated parameters

The kernel's toughness, firmness and rupture power were calculated from the measured (rupture force, rupture energy and deformation at rupture point) values obtained from the Universal Testing Machine.

Groundnut kernel toughness is the energy the kernel can withstand before rupturing (Uguru and Iweka, 2019); it is calculated by dividing the rupture energy by the kernel's volume, as shown in Equation 4 (Umurhurhu and Uguru, 2019). Equations 5 and 6 were used to calculate the kernel's rupture power and volume (V). The kernel's firmness was taken as the ratio of its rupture force to deformation at its rupture point (Equation 7) (Khazaei *et al.*, 2002; Eboibi and Uguru, 2017).

$$T_o = \frac{E}{V} \tag{4}$$

$$P = \left(\frac{E \times S}{6000D}\right) \tag{5}$$

$$V = \frac{\pi \times L \times W \times T}{6} \tag{6}$$

$$F_r = \frac{R_f}{D} \tag{7}$$

Where:
T_o = toughness (N m);
P = rupture power (W);
E = rupture energy (N m);
S = loading rate (mm min^{-1});
F_r = firmness (N mm^{-1});
R_f = rupture force;
D = deformation at rupture point (m)

Statistical analysis

Results obtained from this study were analyzed using the Statistical Package for Social Statistics (SPSS version 20.0); while Duncan's Multiple Range Test (DMRT) was used to compare the mean at 95% confidence level.

RESULTS AND DISCUSSION

Rupture force

Results of the rupture force of the groundnut kernels are presented in Figure 4. With reference to the results (Figure 4), it can be seen that the average force require to initiate rupture of a kernel increased linearly as the kernel's size increases from the size to the large. The effects of loading rate and kernel size on the rupture force of the SAMNUT 22 groundnut kernel are shown in Tables 2 and 3. According to Table 2, the mean force required for the rupture of the kernel decreased significantly ($p \leq 0.05$) as the loading rate increase from 15 mm min^{-1} to 25 mm min^{-1}. With respect to the size of the kernel, the statistical analysis showed that the size of the kernel significantly ($p \leq 0.05$) influenced the kernel's rupture force (Table 3). Generally, the large kernels

had maximum rupture force (57.96 N); while the small kernels recorded the least rupture force (27.35 N). As shown in Tables 2 and 3, the rupture force values of the kernels at different loading rate and size of kernel were different statistically. These results are in similar trend with those reported by Uguru *et al.* (2020) and Ince *et al.* (2009). Uguru *et al.* (2020) stated that, when SAMNUT 11 groundnut kernel compressed along the *X*-axis, at a speed of 15 mm min⁻¹, a rupture force of 94.31 N was observed. Similarly, when a groundnut kernel was compressed along the *X*-axis by Ince *et al.* (2009), a rupture force of 122.76 N, was recorded. In addition, Sosa *et al.* (2012) stated rupture force of groundnut kernel can be influenced the compression speed of the processing machine. The disparities in the rupture force values recorded by different authors could be attributed to soil condition, agricultural practices, environmental conditions, harvesting time, and groundnut variety. Sadowska *et al.* (2013) observed a clear increment in the fracture force of grass pea (*Lathyrus sativus* L.) seed, as the seed size increases; despite its variability, accessions and varieties (Sadowska *et al.*, 2013).
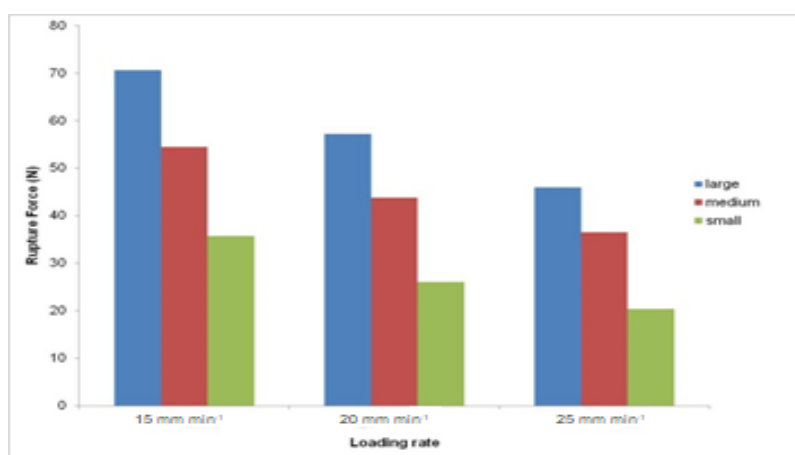
Figure 4. Effect loading rate and kernel size on the rupture force of groundnut kernel.

Table 2. Effect of loading rate on rupture force, deformation at rupture, rupture power, firmness and toughness of SAMNUT 22 groundnut kernel.

Loading rate	Rupture force (N)	Deformation at rupture (mm)	Rupture power (W)	Firmness (N mm⁻¹)	Toughness (mJ mm⁻³)
15 mm min⁻¹	53.58ᶜ	0.894ᶜ	0.117ᶜ	56.32ᶜ	0.166ᶜ
20 mm min⁻¹	42.36ᵇ	0.824ᵇ	0.103ᵇ	51.53ᵇ	0.116ᵇ
25 mm min⁻¹	34.30ᵃ	0.717ᵃ	0.091ᵃ	47.85ᵃ	0.071ᵃ

In each column, means with the same common letter (superscript) are not significantly different at p ≤ 0.05, Duncan's Multiple Range Test.

Table 3. Effect of kernel size on rupture force, deformation at rupture, rupture power, firmness and toughness of SAMNUT 22 groundnut kernel.

Loading rate	Rupture force (N)	Deformation at rupture (mm)	Rupture power (W)	Firmness (Nmm⁻¹)	Toughness (mJ mm⁻³)
Small	27.35ᵃ	0.653ᵃ	0.091ᵃ	44.98ᵃ	0.146ᵇ
Medium	44.94ᵇ	0.808ᵇ	0.101ᵇ	51.69ᵇ	0.121ᵇ
Large	57.96ᶜ	0.974ᶜ	0.118ᶜ	59.03ᶜ	0.103ᵃ

In each column, means with the same common letter (superscript) are not significantly different at p ≤ 0.05, Duncan's Multiple Range Test.

Deformation at rupture point

Figure 5 showed the deformation level of a groundnut kernel at rupture point. The study revealed that small kernel had lower relative deformation, when compared with the large kernel. This portrayed that, a large groundnut kernel has the capability of absorbing more force and energy during quasi static compressive loading, when compared with the small size kernel. The deformation rate experienced by a kernel was significantly ($p \leq 0.05$) influenced by its size and loading rate (Tables 2 and 3). At the speed (rate) of 15 mm min^{-1}, 0.894 mm deformation was recorded; when compared to when lower deformations, 0.824 mm and 0.717 mm recorded at higher loading rates of 20 mm min^{-1} and 25 mm min^{-1} respectively. From the results, the deformation obtained under quasi static compression loading for large and medium size groundnut kernel, was greater when compared to the value recorded for small size kernel. The mean deformation values recorded at rupture point in this study, varied significantly from 0.653 mm for the small size kernel, 0.808 mm for the medium size kernel, to 0.974 mm for the large size kernel (Table 3). These results affirmed the previous reports on *Gmelina arborea* fruits, where the larger fruits tend to possess larger elastic modulus and have the ability of absorbing more deformable power during compression loading, when compared to their smaller fruits counterparts (Oghenerukevwe and Uguru, 2018).

SAMNUT 10 and SAMNUT 11 groundnut kernels deformation patterns were similar to results obtained in this study. Uyeri and Uguru (2018) reported that the deformation of SAMNUT 10 groundnut kernel generally increases (0.687 mm to 1.399 mm), as its size increased from small to large; likewise, SAMNUT 11 groundnut kernel deformation also increases (from 0.599 mm to 1.156 mm), as its size increased from small to large. In addition, Khodabakhshian *et al.* (2010) stated that relative deformation of sunflower seed under quasi static compression loading, increase linearly with increased in its seed's size. But on the contrary, Ince *et al.* (2009) reported that the relative deformation of groundnut kernel under compression loading was greater in the small size kernel, when compared to the value obtained from the medium and large size groundnut kernels. In other words, Ince *et al.* (2009) stated categorically that the large size groundnut kernels were more fragile than their small size counterparts. Relative deformation is a vital mechanical parameter to be considered in the shelling of groundnut pods. The amount of deformation in the hull and kernel under compression force designates the splitting of the kernel during shelling (Uyeri and Uguru, 2018; Ince *et al.*, 2009).
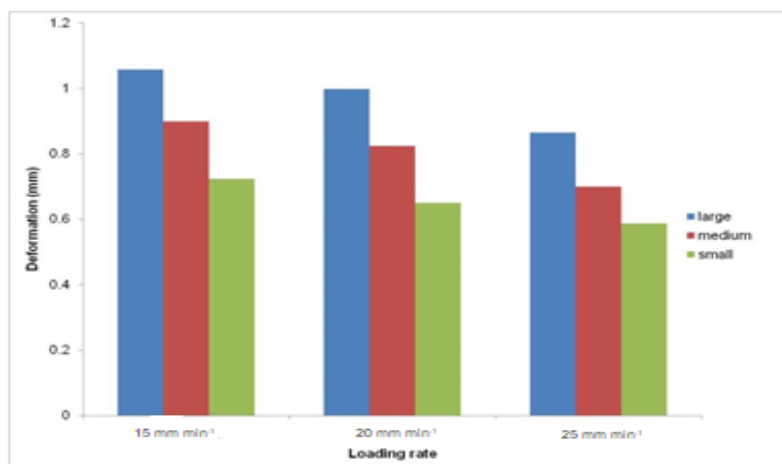
Figure 5. Influence of loading rate and size on the deformation of SAMNUT 22 kernel.

Firmness

From the results of this study as presented in Figure 6, a declined in the kernel's firmness was observed as its size decreases (from large size to the small size). Statistically, it can be seen that the loading rate and size of the kernel significantly ($p \leq 0.05$) influenced its firmness (Tables 2 and 3). Considering the loading rate, the highest value of firmness was recorded at 15 mm min^{-1}; while the lowest value of firmness was recorded at 25 mm min^{-1} (Table 2). According to Mohsenin (1986), kernel/seed firmness is highly dependent on the compressive force and the deformation. Therefore, these results portray that at higher loading rates, the rate at which the cellular structures of the kernel re-arranged themselves, following the distortion caused by the compression force dropped significantly. When plant tissue is subjected to mechanical test, it's (the tissue) anatomy greatly influenced the results obtained to a certain stress level (Niklas, 1992). Kutschera and Niklas (2007) reported that outer plants' tissues impose a strong mechanical restriction to the internal tissues expansion; therefore, this influences their mechanical properties during compression. Considering the plant's organs, tissue stresses that result from turgor, proliferation dynamics, structural variation of tissues, etc., create a tensional integrity within the organ (Kutschera and Niklas, 2007; Hernández-Hernández et al., 2014). With respect to the size of the kernel, there was no significant (0.05 level of significance) similarity among the three kernel sizes, as shown in the Duncan's Multiple Range Test results of the mean separation presented in Table 3. From the results presented in Table 3, the large kernel recorded the highest average firmness (59.03 N mm^{-1}), when compared to the medium and small kernel sizes that recorded the average value of 51.69 N mm^{-1} and 44.98 N mm^{-1} respectively. Groundnut kernel being an agricultural product, its structure is heterogeneous and anisotropic; therefore, mechanical properties are dispersed inhomogeneous within its tissues (Li et al., 2013; Uguru et al., 2020). Similar trends were also observed for the North Carolina-7 groundnut variety (Ince et al., 2009) and apricot pit (Vursavus and Özgüven, 2004). In the vase of the North Carolina-7 groundnut variety, the large groundnut kernel had the greatest firmness (54.77 N mm^{-1}), when compared to the firmness values 50.37 N mm^{-1} and 43.07N mm^{-1} obtained for the medium and small size groundnut kernels (Ince et al., 2009). In addition, Uguru and Iweka studied the variation in the kernel firmness of two groundnut cultivars (SAMNUT 10 and SAMNUT 11), when they are subjected to compression loading at a rate of 20 mm min^{-1}. They reported a kernel firmness of 61.76 N mm^{-1} for the SAMNUT 10 (large kernel) and 53.71 N mm^{-1} for SAMNUT 11 (large kernel) (Uguru and Iweka, 2019). These results obtained by the various authors are similar, with little variations, which can be attributed to human error, processing and handling methods, etc.
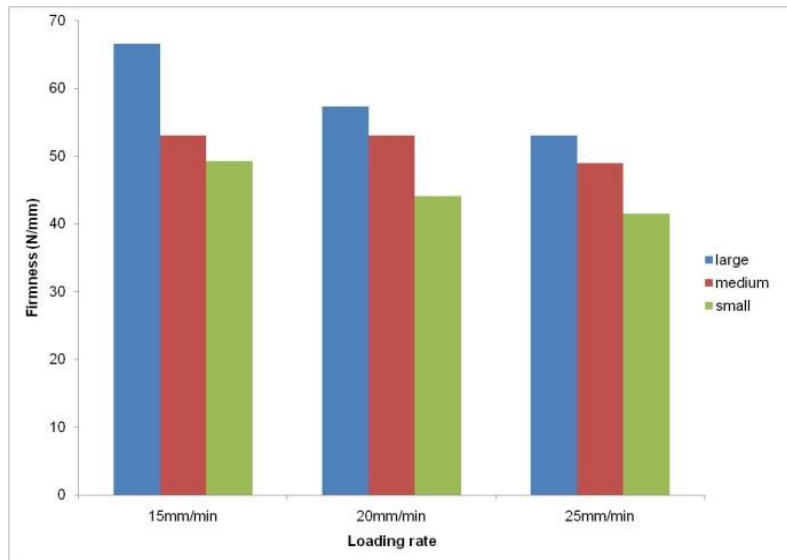
Figure 6. Influence of loading rate and size on the firmness of SAMNUT 22 kernel.

Toughness

The toughness of the groundnut kernel is presented in Figure 7. The study revealed that the toughness of the kernel, declined linearly as the kernel size and loading rate increases (Figure 7). Additionally, the kernel toughness statistical decreased significantly ($p \leq 0.05$) with an increase in kernels size (Table 3). No significant ($p \leq 0.05$) difference existed between the toughness of the small and medium size kernels (Table 3); whereas, the toughness of the medium kernel was significantly ($p \leq 0.05$) different from the toughness of the large kernel. Kernels/seeds density, cellular structure, and body mass highly influenced their toughness during compression (Uguru and Iweka, 2019; Fricke and Wright, 2016). Fricke and Wright (2016) reported that smaller seed tends to have greater tissues densities, when compared to larger seeds; therefore, seed toughness is strongly directly proportional to its mass and volume. Seed toughness, is highly influenced by its size, variety and microstructure (Khazaei et al., 2002).

In reference to the loading rate, the toughness differ significantly ($p \leq 0.05$) across the three loading rates (Table 2). Taking loading rate as a factor, at 15 mm min^{-1}, toughness of 0.166 mJ mm^{-3} was recorded; which later declined to 0.071 mJ mm^{-3} at 25 mm min^{-1} loading rate. The mechanical resistance of plant's tissues is greatly affected the nature the stress and the rate at which it was applied to the plant's tissues (Niklas, 1992; Uguru et al., 2019). This study confirmed earlier studies of (Uguru and Iweka, 2019; Ince et al., 2009; Uguru et al., 2020) for other groundnut cultivars, planted under similar field practices. The toughness of groundnut (cv. North Carolina-7) kernel decreased from 0.032 mJ mm^{-3} to 0.022 mJ mm^{-3}, as the kernel's size increased from small to large (Ince et al., 2009). In addition, Uguru and Iweka (2019) stated that small size groundnut (cv. SAMNUT 10) kernel had higher toughness (0.091 mJ mm^{-3}); when compared with large size kernel (0.041 mJ mm^{-3} toughness). Furthermore, Uguru et al. (2020) reported that the toughness of groundnut (cv. SAMNUT 11) kernel increased linearly (0.041 mJ mm^{-3} to 0.083 mJ mm^{-3}), as the loading rate increases (15 mm min^{-1} to 25 mm min^{-1}). Seed toughness highly influences its milling energy and ability to withstand mechanical damage, during post-harvest units operations (Khazaei et al., 2002; Nyorere and Uguru, 2018). The minor differences recorded in the kernel's

toughness (when compared other authors' results to our own) can be attributed to the different groundnut cultivars used by the various researchers, soil and environmental conditions. Plant cultivar, maturity stage, genetic modification, farming methods, environmental conditions (mostly sunlight and rainfall), soil condition, diseases and pests attacks, processing and storage conditions affect engineering properties agricultural materials (Radzevičius *et al., 2012*; Eboibi *et al., 2019*).
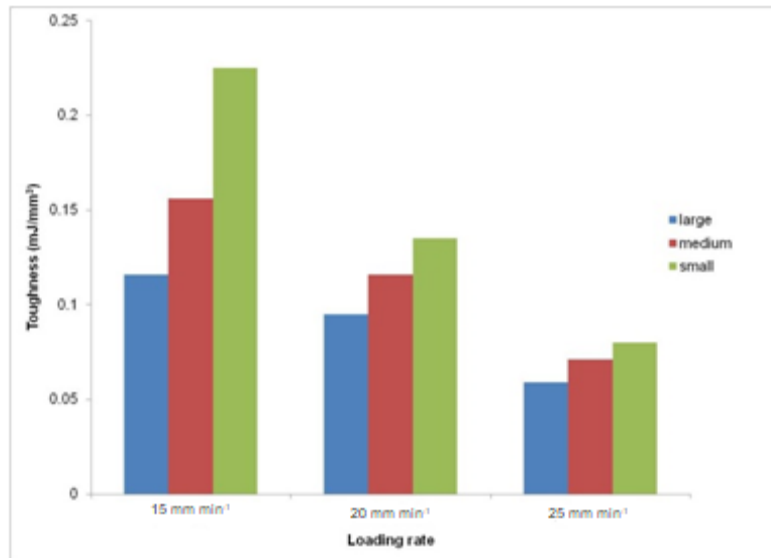
Figure 7. Influence of loading rate and size on the toughness of SAMNUT 22 kernel.

Rupture power

Rupture power of the groundnut kernels, when compressed at the various loading rates is presented in Figure 8. As shown in Figure 8, the rupture power value obtained for the large kernels was higher than those obtained for both the small and medium groundnut kernels. From the statistics results (Tables 2 and 3), the kernel size and loading rate significantly ($p \leq 0.05$) affected the rupture power of the kernel. The small kernel's rupture power ranged from 0.1002 W to 0.084 W, as the loading rate increased from 15 mm min^{-1} to 25 mm min^{-1}; while the medium kernel rupture power ranged from 0.115 W to 0.074 W, as the loading rate increased from 15 mm min^{-1} to 25 mm min^{-1}; lastly, the large kernel rupture power ranged from 0.135 W to 0.104 W, as the loading rate increased from 15 mm min^{-1} to 25 mm min^{-1}. There was no statistical significant ($p \leq 0.05$) similarity between the mean rupture power of the kernels calculated for the three loading rates, across the three kernel size categories. Similar results were reported by Khazaei *et al.* (2002) for almond kernel, and Uguru and Iweka (2019) for groundnut (cv. SAMNUT 10) kernels. According to Khazaei *et al.* (2002), the rupture power of the kernel generally increases with an increased in the size, but no significant ($p \leq 0.05$) difference existed between the rupture powers of the medium and big kernels. Citing Uguru and Iweka (2019), SAMNUT 10 kernel rupture power, when compressed at 20 mm min^{-1} ranged from 0.122 W (small kernel) to 0.193 W (large kernel). In addition, Altuntas *et al.* (2008), observed that the rupture power of almond (cv. *Nonpareil*) nut, when compressed along the X- axis, ranged from 0.20 W to 0.73 W. This study in collaboration with similar studies, revealed that lesser power will be consumed if the groundnut kernels are milled at a higher compression speed. Since high loading rates

can lead to high temperature, which can burn the groundnut oil, care should be taken when selecting the loading rate of kernel during groundnut oil production. The results from this study further portrayed that before milling or other processing operations of groundnut kernels is to be carried out, sorting should be done to save power and energy during the processing unit operations.
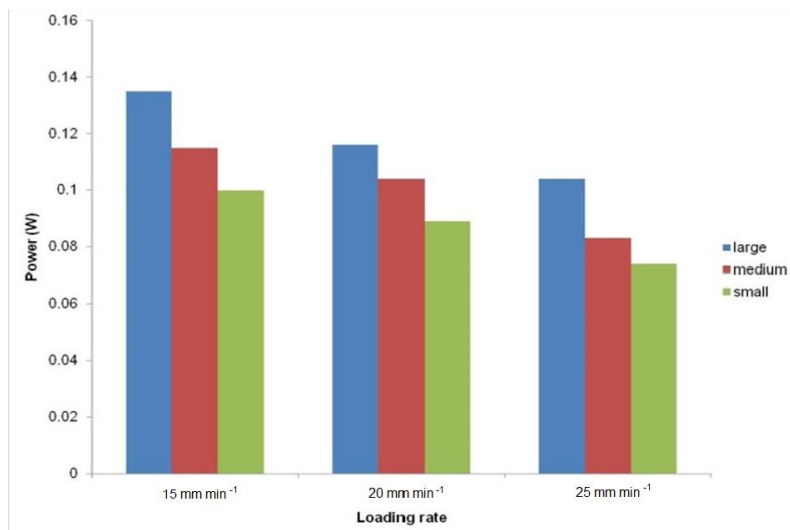
Figure 8. Influence of loading rate and size on the rupture power of SAMNUT 22 kernel.

CONCLUSION

This study evaluated the influence of loading rate and size on some mechanical behaviour of groundnut (cv. SAMNUT 22) kernel. The size categorizes were small, medium and large; while the loading rates categories were 15 mm min^{-1}, 20 mm min^{-1}, and 25 mm min^{-1}. The groundnut kernels were harvested at peak maturity stage, and tested in accordance to ASTM International Standard. Results obtained from this study specified that all the mechanical parameters (rupture force, deformation at rupture point, toughness, firmness and rupture power) were significantly ($p \leq 0.05$) dependent on the kernel size and loading rate. In terms of the loading rate, the large-size kernel recorded the highest force and deformation values at the rupture point; when compared with the results recorded for the medium and small size kernel. In addition, the results showed that the small-size kernel recorded significant ($p \leq 0.05$) highest toughness; when compared with the values recorded for the medium and large-size kernels. Furthermore, the study revealed that the firmness of the kernels increases with size; but decreases with loading rate. In addition, highest rupture power was recorded when the kernel was compressed at speed of 15 mm min^{-1}, when compared with the power values recorded from the loading rates of 20 mm min^{-1} and 25 mm min^{-1}. Therefore, it is important to consider kernel size and loading rate during the design of groundnut processing machine/equipment in order to minimize power and energy consumption, and maximized throughput capacity.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Hilary Uguru: Design the research and writing the original draft.

Ovie Isaac Akpokodje: Data analysis and review of the original draft.

Ebubekir Altuntas: Editing of the manuscript.

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Cattle Presence Development Trend and Projections in D-8 Countries

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ABSTRACT

The agriculture sector is one of the indispensable sectors with its place in its ancient history and its importance in the continuation of human life. Agriculture conceptually includes both vegetable and animal production. Today, the integration of these two production areas with each other and the relations of the agricultural sector with other sectors constitute the most important part of a sustainable life. It is stated that the less developed and developing countries in terms of both population and area in the world will reach a better point in the productivity and efficiency of agricultural production when they work together, not alone. For this reason, it is seen that countries around the world now act as groups / blocks. The aim of this study is to reveal the change in cattle breeding activities in D-8 countries, which is an economic cooperation organization, with time series data analysis. In the study, cattle numbers of D-8 countries were used between 1961-2018. As a result, it is predicted that there will be an increase in the number of animals in 6 countries (Turkey and Bangladesh will decrease). However, it can be stated that the number of animals per capita is in a decreasing trend in all countries. This situation may cause animal protein deficits to come to the fore in countries. For this reason, it is important to evaluate the issue at the point of sustainability with the relevant policy instruments and to take the necessary steps within the framework of food security.
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D-8 Ülkelerinde Sığır Varlığı Gelişim Trendi ve Projeksiyonlar

ÖZET

Tarım sektörü gerek kadim tarihindeki yeri gerekse insanoğlunun hayatının devamındaki önemi ile vazgeçilmesi mümkün olmayan sektörlerin başında gelmektedir. Tarım kavramsal olarak hem bitkisel hem de hayvansal üretimleri içermektedir. Günümüzde bu iki üretim alanının birbirleri ile olan entegrasyonu ve tarım sektörünün diğer sektörlerle olan ilişkileri sürdürülebilir bir hayatın en önemli parçasını oluşturmaktadır. Dünyada gerek nüfus gerekse alan bakımından az gelişmiş ve gelişmekte olan ülkelerin tarımsal üretimdeki verimlilik ve etkinliğinde ülkelerin tek başına değil ancak birlikte çalıştıklarında daha iyi noktaya gelecekleri ifade edilmektedir. Bu nedenledir ki Dünya üzerindeki ülkelerin artık gruplar/bloklar şeklinde hareket ettikleri görülmektedir. Bu çalışmanın amacı bir ekonomik iş birliği örgütü olan D-8 ülkelerinde büyükbaş hayvancılık faaliyetlerindeki değişimi zaman serisi veri analizi ile ortaya konulmasıdır. Çalışmada 1961-2018 yılları arasında D-8 ülkelerinin büyükbaş hayvan sayıları kullanılmıştır. Sonuç olarak Bangladeş ve Türkiye hariç diğer 6 ülkenin hayvan sayısında artış olacağı öngörülmektedir. Ancak, kişi başına düşen hayvan sayısının tüm ülkelerde azalış trendinde olduğu ifade edilebilir. Bu durum ülkelerin hayvansal protein açığının gündeme gelmesine neden olabilir. Bu nedenle ilgili politika enstrümanları ile konunun sürdürülebilirlik noktasında değerlendirilmesi ve gıda güvencesi çerçevesinde gerekli adımların atılması önemlidir.

GİRİŞ

Tarım sektörü özellikle az gelişmiş ve gelişmekte olan ülkelerde kalkınma sürecinde oynadığı rol, barındırdığı nüfus ve işgücü, gıda güvencesi ve güvenliği açısından taşıdığı önem ve diğer sektörlerle olan interaksiyonu nedeni ile daha fazla ön plandadır. Özellikle gelişmişliğin bir göstergesi olan hayvansal ürünlere erişim ve tüketim alışkanlığı ile beslenme diyetindeki hayvansal ürünlerin payı gibi göstergeler hayvancılık sektörünü önemli kılmaktadır. Hayvancılık sektörü sadece gıdanın kaynağı değil aynı zamanda sürdürülebilir tarım sistemleri içinde toprağın yapısının iyileştirilmesi, tarımsal üretim sisteminde bitkisel ve hayvansal üretimin entegrasyonunun getirdiği avantajlar, küçük aile çiftçiliğinin devamı içindeki önemi, yoksulluğun azaltılması gibi unsurlar yönüyle kırsalda önemli bir gelir aracı oluşturmaktadır. Gelişmekte olan ülkelerdeki yaklaşık 2.5 milyar insanın geçimlerini tarımdan kazandıkları düşünüldüğünde sektöre atfedilen önem bir kat daha ön plana çıkmaktadır (Doğan ve Saçlı, 2019).

Yoksulluğun azaltılması, açlığın sonlandırılması, sorumlu tüketim ve üretim bilincinin kazandırılması konuları 17 adet Sürdürülebilir Kalkınma Hedeflerinin (SKH-2030) 3 tanesini oluşturmaktadır (UN, 2015). Bu hedeflere ulaşmada başarının anahtarlarından biri de uluslararası alanda ortaklıklar ve birlikte çalışma olarak

gösterilmektedir. Yapılan birçok çalışmada yoksulluğun azaltılması, açlığın sonlandırılması, iklim değişikliği ile mücadele, gıda güvencesi, gıda güvenilirliği, çevre gibi önemli konularda küresel ortaklıkların önemi üzerinde durulmaktadır (UN, 2015; UN, 2018; Peker ve ark., 2019). Bu nedenle iş birliğinin arttırılma çabaları kapsamında ülkeler ekonomik bakımdan üretim kapasitelerini genişleterek verimliliği arttırmak ve bunun neticesinde de toplumsal refah düzeyini yükseltmek amacıyla ekonomik entegrasyonlara girebildikleri gibi bölgesel ve küresel sorunlara çözüm içinde birlikte çalışma kültürü geliştirebilmektedirler.

Ekonomik iş birliğine dayalı olarak küresel sistem içerisinde ortak hareket etmek amacı ile oluşturulan D-8 (Developping 8), Müslüman 8 ülkeden (Bangladeş, Endonezya, İran, Malezya, Mısır, Nijerya, Pakistan, Türkiye) oluşmaktadır. Temelleri Ekim 1996'da Türkiye Cumhuriyeti eski başbakanı Prof. Dr. Necmettin Erbakan'ın davetiyle, söz konusu ülkelerin temsilcilerinin katılımıyla İstanbul'da düzenlenen "Kalkınmada İş birliği Konferansı'nda atılmıştır. 22 Ekim 1996 tarihindeki "Kalkınmada İş birliği Konferansı'nı izleyen bir dizi hazırlık toplantılarından sonra 15 Haziran 1997 yılında İstanbul'da yapılan Devlet ve Hükumet başkanları zirvesinde D-8'in kuruluşu resmen ilan edilmiştir (İstanbul Deklarasyonu). D-8'in amacı, üye ülkeler arasındaki ticareti ve iş birliğini artırmaktır. D-8 girişiminin başlatılmasındaki amaç, büyük bir ekonomik potansiyeli, çeşitli kaynakları, geniş bir nüfus ve coğrafi alanı temsil eden 8 ülke arasında ticaret ilişkilerinde yeni fırsatlar yaratmak ve çeşitlendirmek, uluslararası düzeyde karar alma sürecine katılımı artırmak, daha iyi hayat şartları sağlamak, somut ortak projeler etrafında ekonomik iş birliğini geliştirmek ve gelişmekte olan ülkelerin dünya ekonomisindeki durumlarını güçlendirmektir. Tarım ve gıda güvenliği ile yenilenebilir enerji kaynakları, sanayi, ulaşım, turizm iş birliği içerisinde bulunulması beklenen ana konulardan bazılarıdır (D-8 OEC, 2020a).

D-8, bölgesel entegrasyondan daha çok küresel ortaklığı hedeflemesi başta DTÖ kararlarında gelişmekte olan ülkelerin haklarının gelişmiş ülkeler karşısında savunulmasında ortak platform oluşturmuştur. Bunun yanı sıra "Tarım ve Gıda Güvenliği", "Ticaret", "Ulaşım", "Endüstriyel Ortaklık", "Enerji ve Mineraller", "Turizm" ve "Diğer Ortaklıklar" başlıkları altında ortak çalışma alanlarıdır (D-8 OEC, 2020b). 650 milyondan fazla nüfusu ile Dünya nüfusunun yaklaşık %11'ini barındıran D-8 ülkelerinde tarım sektörü toplam GDP içinde önemli bir pay almaktadır. 2018 yılı itibari ile toplam GSMH içinde tarımın payı en yüksek 22.85 ile Pakistan olup bunu Nijerya (%21.20) ve Endonezya (%12.81) takip etmektedir. Tarımın payının oransal olarak en düşük olduğu ülke ise Türkiye'dir (%5.82) (The Global Economy, 2020).

D-8 ülkelerinin en önemli gıda kaynaklarından biri yerel hayvan varlıklarıdır. Hayvancılık toplam tarım sektörü içerisinde önemli bir pay oluşturmaktadır. 2018 yılı FAOSTAT verilerine göre D-8 ülkeleri toplam Dünya manda varlığının %17.93, inek varlığının %9.03, tavuk varlığının %22.03, keçi varlığının %25.09, koyun varlığının %14.24'ünü genelde ise %15.58'ini barındırmaktadır. Manda varlığında Pakistan, inek varlığında Pakistan ve Nijerya, tavuk varlığında Endonezya ve İran, keçi varlığında Pakistan, Nijerya ve Bangladeş ve koyun varlığında ise Nijerya ve İran önde gelen ülkelerdir (FAOSTAT, 2020). Önemli yerel hayvan gen kaynaklarını barındırması nedeni ile D-8 ülkeleri hayvancılık açısından bir gen merkezi konumundadır. D-8 ülkelerinin bu genetik varlığına sahip olması D-8 oluşumu içinde de hayvancılık konusunda ortak girişimlerin ve çalışmaların olmasını sağlamıştır. Ortak çalışma

alanları içinde "Tarım ve Gıda Güvenliğinin Sağlanması" başlığı altında hayvancılıkta yem temini konusunu öncelikli çalışma konuları arasında belirtilmiştir. Hatta bu konu 2009 yılında Malezya'da düzenlenen D-8 ülkeleri 1. Tarım Bakanları toplantısında tarım alanında ortak çalışma konularından biri olarak belirtilmiştir (D-8 OEC, 2020c) Dünya nüfusuna yönelik yapılan senaryolar nüfusun şu anki varlığı olan 7.2 milyardan 2050 yılına kadar %32 artarak 9.5 milyara, 2100 yılında ise %53 artarak 11 milyara artacağını öngörmektedir. Ekilebilir tarım alanlarının artık sınırda oluşu, su ve enerji konusundaki sınırlılıklar, artan gıda talebinin karşılanması için etkinlikte önemli bir artışın olmasını gerektirmektedir (Raynold *et al.,* 2015). Bu kapsamda hayvansal ürünler ise gıda güvencesi içerisinde önemli bir yer edinmektedir. Hayvansal ürünlerin yüksek kaliteli protein önemli mikrobesinlere sahip olması (WHO, 2003; Randolph *et al.,* 2007), yüksek kaliteli ürünlere karşı küresel talebin hızlı bir şekilde artması (WHO, 2003; Otte *et al.,* 2012; Herrero *et al.,* 2010), hayvancılığın sürdürülebilir tarım sistemi ve özellikle küçük aile çiftçiliği içindeki yadsınamaz rolü (Randolph *et al.,* 2007; Herrero *et al.,* 2010), hayvancılık faaliyeti ile çayır ve meraların yüksek kaliteli hayvansal ürünlere dönüştürülebilmesi ve iyi yönetildiğinde çayır ve meralarda biyoçeşitliliğin korunmasına ve sürdürülebilirliğine yönelik pozitif katkısı (Herrero *et al.,* 2010; Metera *et al.,* 2010; Capper, 2011) göz önüne alındığında hayvancılık gelişmekte olan ülkeler için hem gıda güvencesi, hem doğru ve dengeli beslenme hem de kırsal alanda yoksulluğun azaltılması için önemli bir üretim faaliyetidir.

Bu çalışmada, D-8 ülkelerinde mevcut büyükbaş hayvan varlıklarının ARIMA modeli ile değişimi incelenmiş olup, 5 yıllık projeksiyonlar yapılmıştır. Elde edilen sonuçlar ile bundan sonra yapılacak D-8 çalışmalarında başta büyükbaş hayvancılık olmak üzere hayvancılık ve hayvansal ürünler üretimi konusunda alınabilecek önlemler bir politika enstrümanı olarak önerilmeye çalışılmıştır.

MATERYAL ve YÖNTEM

Araştırmada, D-8 ülkelerinin 1961-2018 yılları arası sığır varlığı incelenmiş ve 5 yıllık projeksiyonu yapılmıştır. Projeksiyonlar yapılırken ARIMA modelinden yararlanılmıştır. Autoregressive ve Moving Average modellerinden elde edilen Autoregressive Moving Average en genel durağan Box-Jenkis modelleridir. I (0) olmayıp fark alma işlemi sonucunda durağan hale getirilen serilere uygulanan modellere "Bütünleşik Otoregresif Hareketli Ortalama" (Autoregressive Integrated Moving Average) modeli denir. Box-Jenkins modellerinde amaç zaman serilerine uyan modelin belirlenmesi ve öngörü yapılmasıdır (Çelik, 2013).

Doğrusal durağan modeller; "otoregresif", "hareketli ortalama" ve "otoregresif hareketli ortalama" modeli olarak 3 şekildedir.

a.Otoregresif modeli (AR),

$$x_t = \varphi_1 x_{t-1} + \varphi_2 x_{t-2} + \cdots + \varphi_p x_{t-p} + e_t \tag{1}$$

Burada;
$x_{t-1}; x_{t-2}; x_{t-p}$: *Serinin geçmiş gözlem değeri*
$\varphi_1; \varphi_2; \varphi_p$: *Geçmiş gözlem değeri katsayıları*
e_t : *Hata terimi*

p'nci dereceden otoregresif serisinin yani AR(p)'nin otokovaryans fonksiyonu,

$$_h = \varphi_1\,\gamma_{h-1} + \varphi_2\,\gamma_{h-2} + \cdots + \varphi_p\,\gamma_{h-p},\ h>0 \qquad (2)$$

formundadır. Buradan, okorelasyon fonksiyonu, aşağıdaki şekilde yazılabilir,

$$P_h = \varphi_1\quad p_{h-1} + \varphi_2\,p_{h-2} + \cdots + \varphi_p\,\gamma P_{h-p},\ \ h>0 \qquad (3)$$

Eşitlikte;
p=1 olması, birinci dereceden otoregresif modeli AR(1), ve p=2 olması, ikinci dereceden otoregresif modeli AR(2) şeklinde tanımlanır (Wei, 2006).

b. (MA), olarak tanımlanan hareketli ortalama model;

$$x_t = \varphi_1\,x_{t-1} + \varphi_2\,x_{t-2} + \cdots + \varphi_p\,x_{t-p} + e_t \qquad (4)$$

şeklinde tanımlanır. MA(q) yani q'ncu dereceden hareketli ortalama serisi olarak ifade edilir.

c. Otoregresif hareketli ortalama;
(ARIMA(p,q)) modeli, tek başına AR(p) veya MA(q) süreçleri tarafından ifade edilemediğinde aşağıdaki eşitlikle gösterilebilir.

$$x_t = \varphi_1\,x_{t-1} + \varphi_2\,x_{t-2} + \cdots + \varphi_p\,x_{t-p} + e_t - \varphi_1\,e_{t-1\,-}\varphi_2\,e_{t-2\,-}\,\ldots\,\varphi_q\,e_{t-q} \qquad (5)$$

Zaman serileri analizinin uygulanabilmesi için serilerin durağan olması ve beyaz gürültü (white noise) özelliğini sağlaması gerekir.

Durağan olmayan bir zaman serisini durağan hale getirmek için ihtiyaç durumuna göre serinin genellikle1 veya 2 defa farkı alınır ve "d" ile gösterilir. Durağan olmayıp farkı alınarak durağan hale getirilmiş entegre modeller belirli sayıda farkı alınmış serilere uygulanan AR ve MA modellerinin birleşimidir. AR(p), MA(q) ve bunların bileşimi olan ARIMA (p,q) modelleri durağan süreçlere uygulanırken, ARIMA (p,d,q) modelleri durağan olmayan süreçlere uygulanmaktadır. Eğer AR modelinin derecesi p, MA modelin derecesi q ve serinin de d kez farkı alınmışsa bu modele (p,d,q) dereceden otoregresif entegre hareketli ortalama modeli denir ve ARIMA (p,d,q) şeklinde gösterilir (Box-Jenkins, 1976). Bu durumda, model;

$$\left(1 - \varphi_1 B - \varphi_2 B^2 - \cdots \varphi_p B^p\right)(1-B)^d x_t = (1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q)e_t \qquad (6)$$

formunda ifade edilebilir.

Kabul edilen sürece uygun olabilecek model parametreleri belirlendikten sonra, modelin parametreleri test edilerek sürecin fiziksel yapısına uygun modeller arasından, incelenen sürece en uygun olan modelin belirlenmesi işlemi yapılmaktadır. Seriye en uygun modelin seçimi için Akaike bilgi kriteri (AIC) ve Schwartz Bayesci bilgi kriteri (BIC) gibi kriterler geliştirilmiştir. p ve q için çeşitli değerler denenerek en uygun model belirlenebilir. Çalışmada, en uygun model; ARIMA (p,d,q) şeklinde kullanılmıştır.

Burada;

p: Otoregresif modelin derecesi

q: Hareketli ortalama modelin derecesi

d: Serinin farkı olarak ifade edilmektedir (Çelik,2013).

BULGULAR ve TARTIŞMA

Araştırmada yapılan ARIMA modeli, bu modele ilişkin sığır sayısı projeksiyonu ve modele ilişkin bilgiler Çizelge 1'de verilmiştir.

Çizelge 1. D-8 ülkeleri 2020-2023 yılları arası sığır sayısı projeksiyonu ve ARIMA modellerine ilişkin bilgiler.

Table 1. *Cattle number projection and ARIMA models for d-8 countries between 2020-2023 years.*

Yıllar	Bangladeş	Malezya	Nijerya	Pakistan	Türkiye	Endonezya	İran	Mısır
				Sığır Sayısı Tahmini				
2020	23.708.514	767.388	22.244.442	49.080.223	17.324.539	16.989.875	5.512.853	4.790.082
2021	23.601.602	774.809	22.654.813	50.626.049	16.811.728	17.275.379	5.621.312	4.709.697
2022	23.527.585	782.230	23.062.824	52.203.683	16.463.713	17.565.680	5.715.474	4.690.430
2023	23.476.342	789.651	23.468.078	53.813.128	16.410.906	17.860.860	5.797.224	4.866.598
Model	(1,0)	(0,0)	(0,1)	(0,1)	(4,3)	(0,0)	(1,0)	(4,4)
AIC	31,28	22,91	-4,82	29,97	-3,57	-2,88	29,67	27,81

Çizelge 1 incelendiğinde, D-8 içerisinde bulunan ülkelerden Bangladeş ve Türkiye negatif ayrıştığında diğer 6 ülkenin 2018 yılına göre 2023 yılına kadar sığır varlığında devamlı bir artışın olacağı ifade edilebilir. ARIMA modeli çözümlemesi sonucunda elde edilen grafikler, model seçim kriterlerinden en önemlisi olan AIC göstergeleri ve projeksiyonların eğilimleri Şekil 1, 2, 3, 4'de verilmiştir. Bangladeş ve Malezya için sığır sayısı ve 2023 yılı projeksiyonu Şekil 1'de verilmiştir.
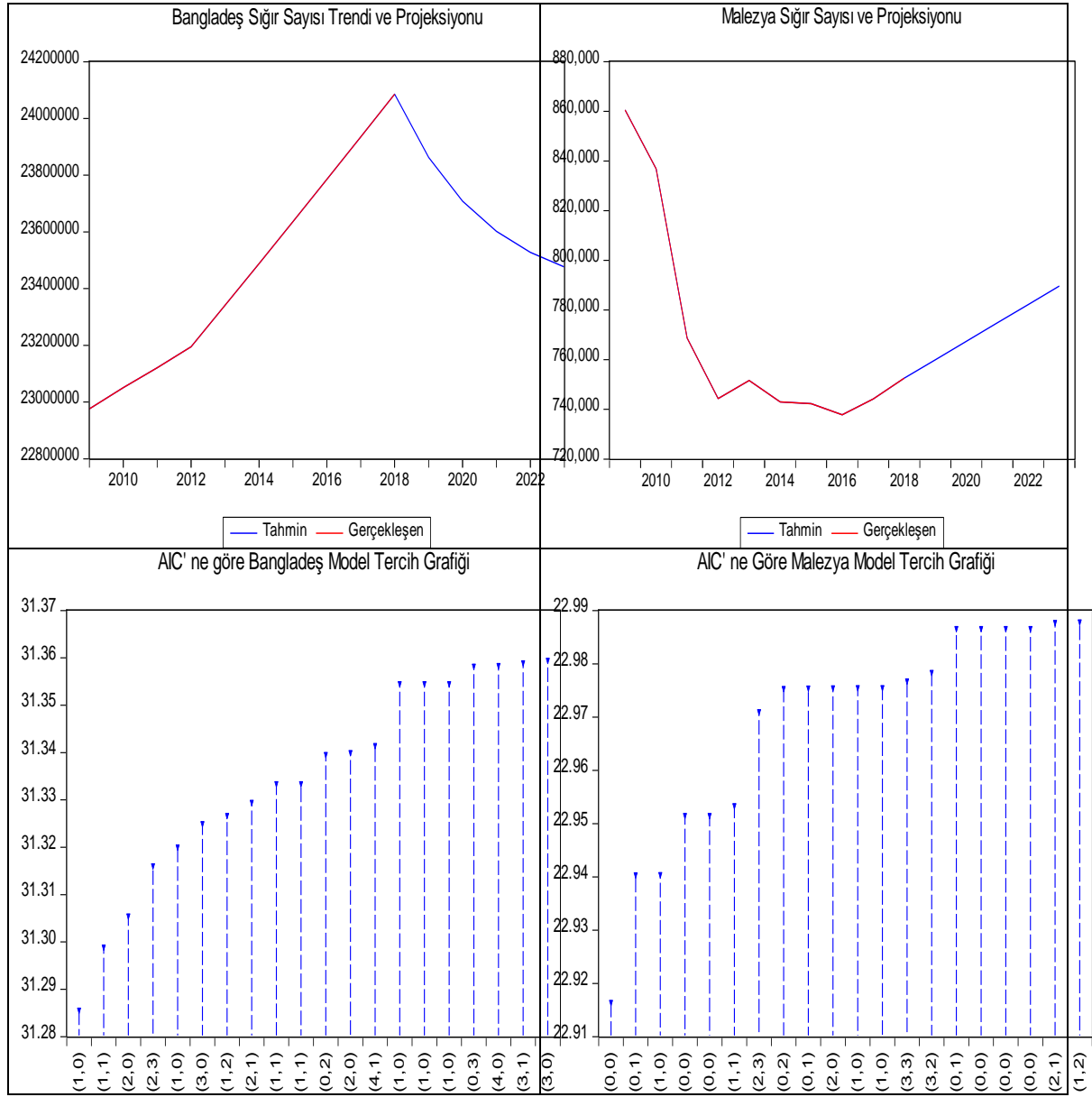
Şekil 1. Bangladeş ve Malezya sığır sayısı gelişim trendi ve 2023 yılı projeksiyonu.
Figure 1. Cattle number development trend and 2023 projection in Bangladesh and Malaysia.

Bangladeş'deki sığır varlığı inceleme dönemi olan 1961-2018 yılları arasında dalgalı bir seyir izlese de son 10 yılda yükselen bir trend içerisinde olmuştur. Ancak yapılan ARIMA (1,0) modeline göre, Bangladeş'de 2023 yılına kadar sığır varlığında gerileme eğiliminin olabileceği söylenebilir. Buna göre, 2018 yılı verilerine göre sığır varlığı 24 086 000 adet (FAO, 2020) olan Bangladeş'in 2023 yılı tahmini 23 476 342 olarak belirlenmiştir. Malezya'da ise 1961-2010 yılları arası artış gösteren sığır varlığı 2010 yılından sonra sürekli bir düşme trendinde olmuştur. 2018 yılı itibari ile, 752 547 adet sığıra sahip olan Malezya'nın (FAO, 2020) yapılan ARIMA (0,0) modeli tahminine göre 2023 yılı sığır sayısı 789 651 olarak ifade edilebilir. Nijerya ve Pakistan için sığır sayısı ve 2023 yılı projeksiyonu Şekil 2'de verilmiştir.
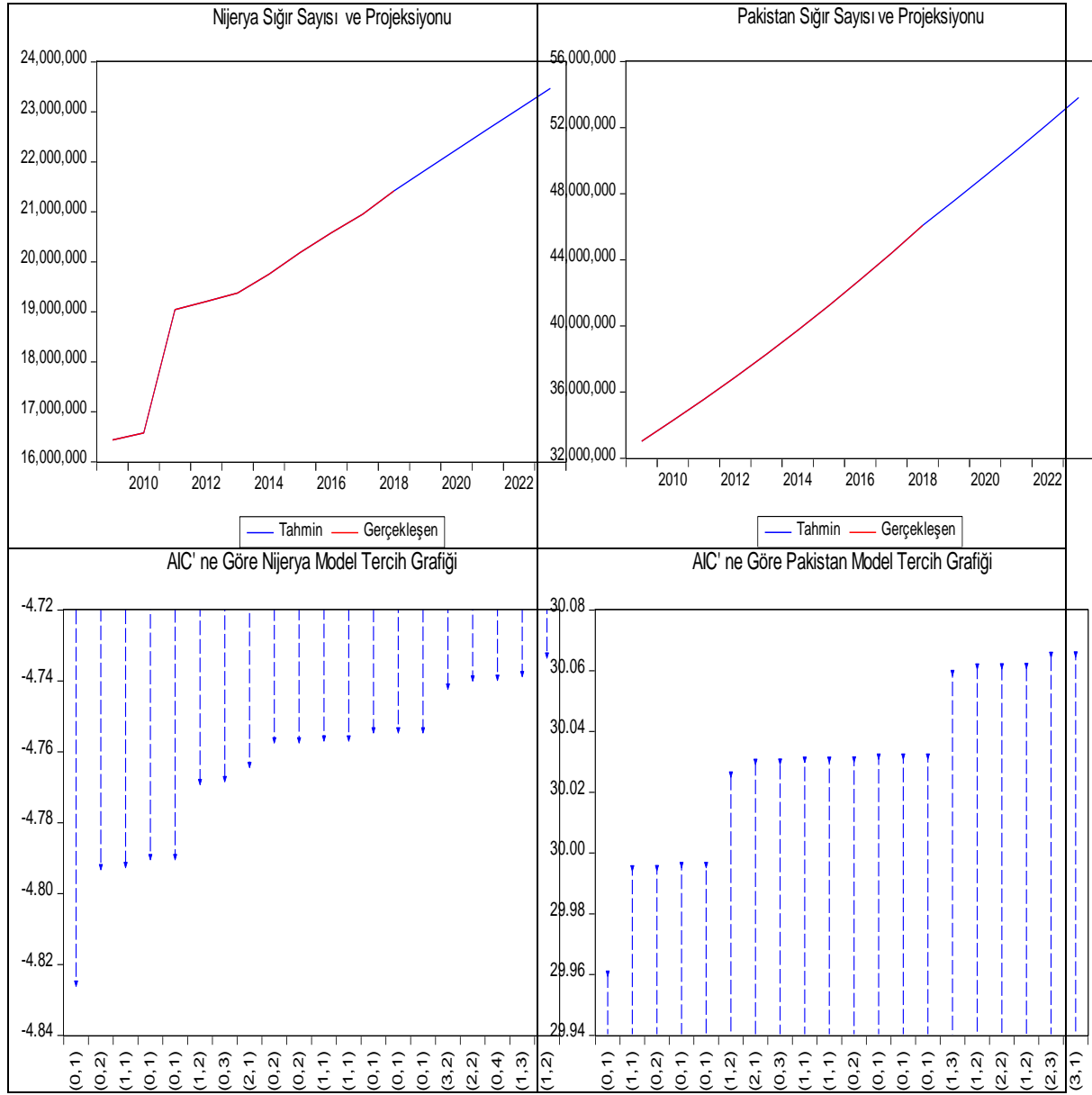
Şekil 2. Nijerya ve Pakistan sığır sayısı gelişim trendi ve 2023 yılı projeksiyonu.
Figure 2. Cattle number development trend and 2023 projection in Nigeria and Pakistan.

Şekil 2 incelendiğinde, Nijerya'da sığır varlığı inceleme dönemi içerisinde düzenli bir artış trendinde olduğu ifade edilebilir. Özellikle 2012 yılından sonra artış hızında dikkate değer bir hızlanma görülmektedir. Yapılan ARIMA (1,2) modeli tahminine göre, eğer koşullar bu şekilde devam ederse 2018 yılı sığır varlığı 21 418 189 adet (FAO, 2020) olan Nijerya'nın 2023 yılı sığır varlığı tahmini 23 468 078 adet olarak tahmin edilmiştir. Benzer durumu Pakistan için de söylemek mümkündür. Pakistan'daki sığır varlığı artış trendi inceleme dönemi olan 1961-2018 yılları arasında düzenli bir şekilde devam etmiştir. 2018 yılı itibariyle sığır varlığı 46 084 000 adet (FAO, 2020) olan Pakistan'ın 2023 yılı tahmini ARIMA (0,1) modeli tahminine göre 53 813 128 adet olarak ifade edilebilir.
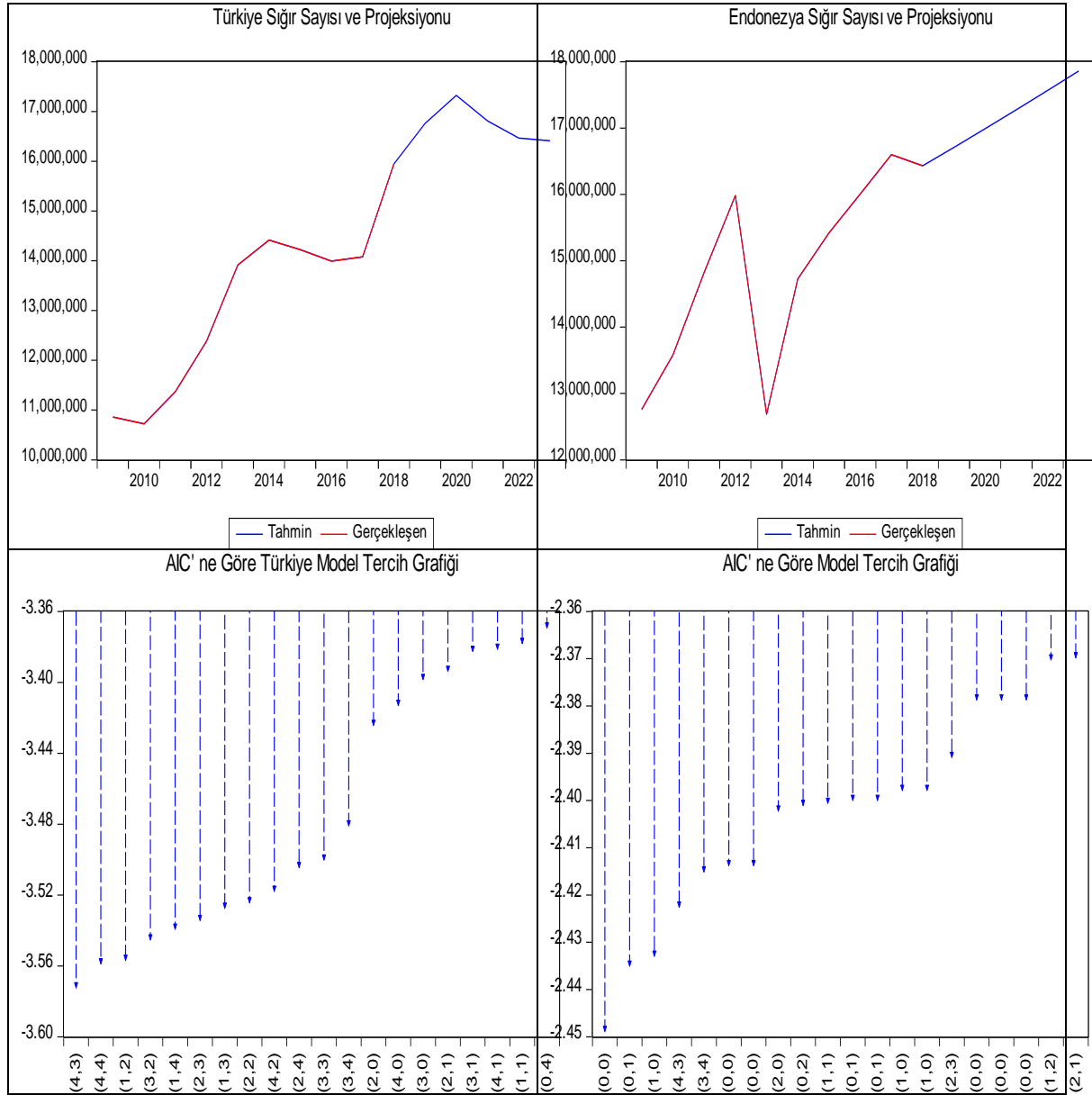
Şekil 3. Türkiye ve Endonezya sığır sayısı gelişim trendi ve 2023 yılı projeksiyonu.
Figure 3. Cattle number development trend and 2023 projection in Turkey and Indonesia.

Türkiye'de sığır sayısı Şekil 3'den incelendiğinde 1980'li yılların başından itibaren düşüş eğilimde olduğu ifade edilebilir. 2004 yılından itibaren ise yükseliş trendine geçen sığır varlığı 2015-2017 yılları arasında tekrar azalış gösterse de 2018 yılında 15 943 586 adet (FAO, 2020) düzeyine yükselmiştir. Yapılan ARIMA (0,1) modeline göre 2023 yılı projeksiyonu 16 410 906 adet olarak tahmin edilmiştir. Endonezya'daki sığır varlığı incelendiğinde, 1961-2018 yılları arası dalgalı bir seyir gösterdiği söylenebilir. Özellikle 2012 yılında ani bir düşüş gösteren sığır varlığı 2014 yılından itibaren tekrar yükselme yönünde bir trend göstermiştir. Yapılan ARIMA (2,1) modeline göre, Endonezya'nın 2023 yılı sığır varlığı 17 860 860 adet olarak tahmin edilmiştir.
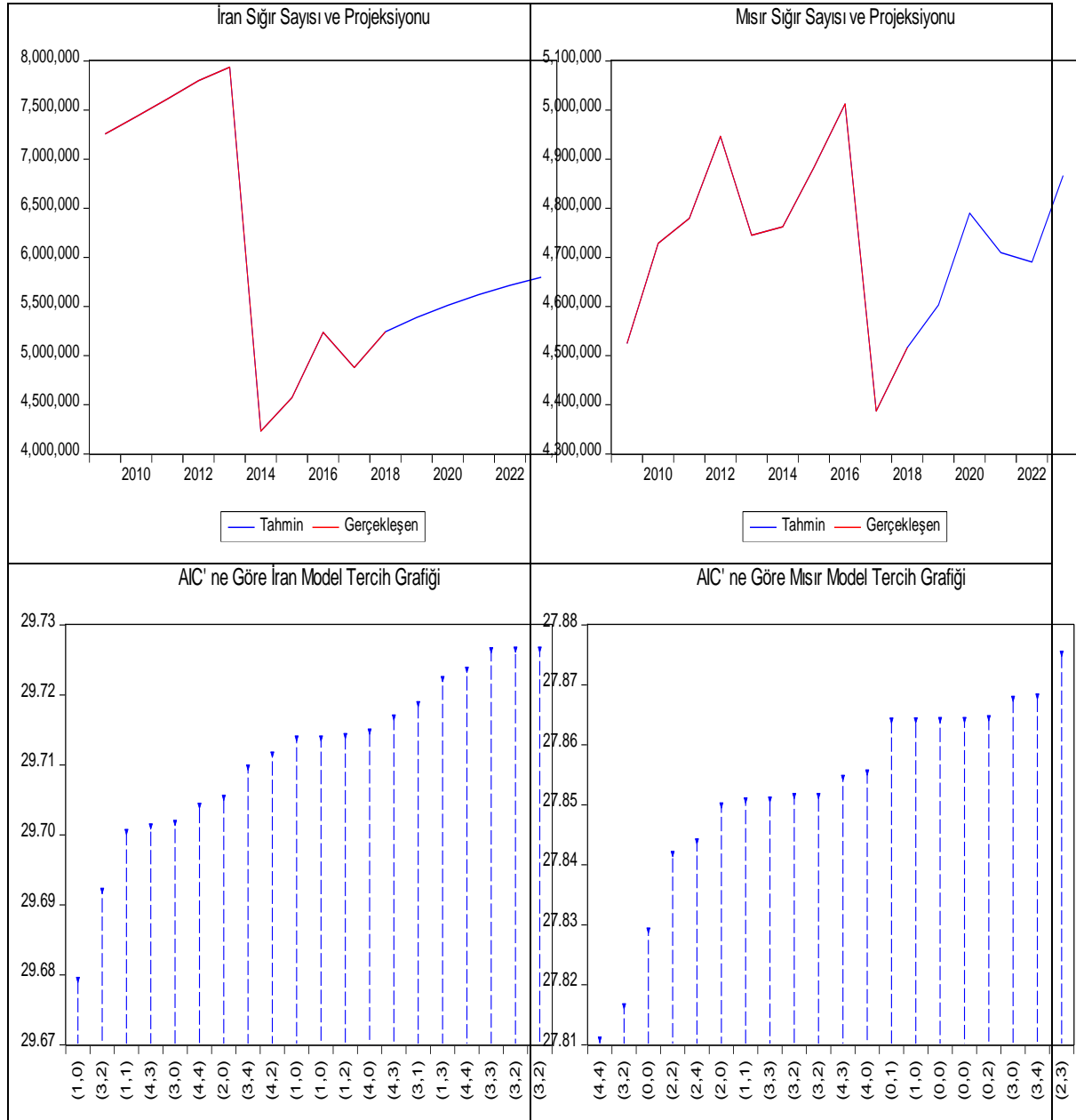
Şekil 4. İran ve Mısır sığır sayısı gelişim trendi ve 2023 yılı projeksiyonu.
Figure 4. Cattle number development trend and 2023 projection in Iran and Egypt.

Şekil 4 incelendiğinde, İran'daki sığır sayısı 2013 yılında ani bir düşüş göstermiş ancak 2014 yılından itibaren tekrar yükseliş eğilimine geçmiştir. 2018 yılında 5 244 031 adet hayvan varlığına (FAO, 2020) sahip olan İran'ın, yapılan ARIMA (1,0) modeli tahminine göre 2023 yılında 5 797 224 adet büyükbaş hayvana sahip olacağı öngörülmektedir. Mısır'daki büyükbaş hayvan varlığı incelendiğinde, ele alınan süreç içerisinde volatilite gösterdiği söylenebilir. Dönemsel iniş çıkışlarla birlikte en yüksek hayvan sayısına 2015 yılında ulaşan Mısır' da 2018 yılı hayvan varlığı 4 516 584 adet olarak gerçekleşmiştir. Yapılan ARIMA (4,4) modeline göre, Mısır' da 2023 yılı büyükbaş hayvan sayısı tahmini 4 866 598 adet olarak tahmin edilmiştir.

Araştırmada, diğer bir çerçeveden değerlendirilmesi yararlı olacağı düşünülen D-8 ülkelerinde inceleme dönemi içerisinde kişi başına düşen sığır sayısı da ele alınmıştır. Bu bağlamda, Şekil 5'te 1961-2018 yılları arası kişi başına düşen sığır sayısı trendleri verilmiştir.

Şekil 5. D-8 Ülkelerinde 1961-2018 yılları arası kişi başına düşen sığır sayısı.
Figure 5. *Number of cattle per capita in D-8 countries between 1961-2018.*

D-8 ülkelerinin 1961-2018 yılları arasındaki sığır varlığı trendi ARIMA modellerine ilişkin grafiklerde ifade edilmiştir. Söz konusu grafiklerde, ülkelerin sığır sayıları nominal olarak artış gösterdiği dönemler veya bazı ülkelerin süreğen bir artış içerisinde olduğu görülmüştür. Ancak, nüfus yoğunluk artışları ile birlikte değerlendirildiğinde, kişi başına düşen sığır sayısı eğilimleri daha rasyonel yorumlar ortaya koyabilecek sonuçlar içermektedir. Ülkelerin tamamında, inceleme dönemi içerisinde kişi başına düşen sığır sayısı devamlı bir azalış trendinde olmuştur. Bu durum, artan nüfusun beslenme olanaklarında ortaya çıkan/çıkacak problemler yönüyle bir gösterge olarak değerlendirilebilir. Öte yandan, ekonomik olarak da hem tarım sektörün hem de ülkelerin makro ölçekte aleyhine işleyecek bir süreç olarak düşünülebilir.

SONUÇ

Hayvancılık faaliyetleri tarımsal üretim içerisinde önemli bir alan olarak varlığını sürdürmektedir. İnsanların beslenme ihtiyacının karşılanmasında hayvansal orjinli protein kaynağı olarak önem kazanmıştır. Bu çerçevede özellikle büyükbaş hayvancılık faaliyeti ve ağırlıklı olarak sığır yetiştiriciliği ön plandadır. Son dönemlerde bölgesel çalışmaların ön plana çıktığı bilimsel araştırma yaklaşımları kapsamında, bu araştırmada da D-8 ülkelerinin sığır varlığı ve projeksiyonları irdelenmiştir. Elde edilen sonuçlar değerlendirildiğinde, araştırmaya konu olan ülkelerden Bangladeş ve Türkiye hariç diğer 6 ülkenin sığır varlığının artış trendinde olacağı öngörülmektedir. Ancak bu durum yalın olarak değerlendirildiğinde sağlıklı bir sonuç elde edilme olanağı zayıflamaktadır. Burada önemli olan husus, kişi başına düşen hayvan varlığıdır. İnceleme dönemi içerisinde, nüfus artış hızı sığır sayısı artış hızından daha ivmeli olduğundan zaman içerisinde kişi başına düşen hayvan sayısında mutlak azalışlar söz konusudur. Bu durum ilerleyen yıllarda da benzer durumda bir trend içerisinde olursa, ülkelerin beslenme olanakları yönüyle hayvansal kökenli bir protein açığından söz etmek gündeme gelebilir. Bu noktada alınacak önemler, ülkelerin hayvancılık politikalarını gözden geçirerek hayvan sayısı artış hızını toplumun ihtiyacını karşılayacak düzeyde tutmak, hayvancılık faaliyetlerinde sürdürülebilirlik ve üretim istekliliğini arttıracak politikalara yönelim sağlamak, özellikle hayvan beslemeye yönelik girdi politikalarında kısa orta ve uzun vadeli yaklaşımlar ortaya koymak, bölge ve yöre dinamiklerine uygun ırklarla hayvancılık faaliyetlerini yürütmek, hayvanlara verilen yemin kalite ve miktarı, besleme stratejileri, meraların mevsimsel olarak kullanılabilirliği, genetik çalışmalar (melezleme vb.), hayvan sağlığı, yem kaynaklarının ekim tarihlerini doğru bir şekilde ayarlama, barınak iklimlendirmesine yönelik doğru uygulamalar, zararlı ve hastalık kontrolünde doğru yaklaşımlar (izleme, ürün rotasyonu, çeşitlilik vb.), suyun daha etkin kullanılması ve toprak yönetimi gibi hususların sürekli izlenmesi olarak sıralanabilir.

ÇIKAR ÇATIŞMASI

Çalışmada yazarlar arasında herhangi bir çıkar çatışması bulunmamaktadır.

YAZAR KATKISI

Hasan Gökhan Doğan: Araştırmanın ekonometrik boyutunda ve sonuç bölümü.
Mustafa Kan: Araştırmanın kurgusal boyutu, literatür ve giriş bölümü.

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Evaluation of Sprinkler Irrigation Evaporation Losses in Ilaro, Ogun State, South Western Nigeria

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ABSTRACT

Under the prevailing climate change the world is currently facing, efficient irrigation water management is essential to ensure food security, especially in countries with similar climate to Nigeria. Hence, this study was undertaken at the Research Farm of Federal Polytechnic, Ilaro, Ogun State, Nigeria to evaluate evaporation losses during sprinkler irrigation between March and July 2019. Experiments were performed using 360° rotating sprinkler and single nozzle of diameter 3 mm, while due cognizance was taken of the prevailing climatic conditions. Three operating pressures, namely, 50 kPa, 100 kPa and 150 kPa, representing low pressure, medium pressure and high pressure, respectively, were used. The results showed that operating pressures influence droplet sizes, droplet heights and flow rate during the experiment. In addition, it was observed that at operating pressures of 50 kPa, 100 kPa and 150 kPa, mean percentage of evaporation losses were 8.88%, 13.21% and 16.46%, respectively, indicating that evaporation losses increased with increasing operating pressure. Further analysis showed that percentage evaporation losses increased at higher relative humidity, thereby emphasizing the predominance of air temperature and wind velocity as climatic variable influencing sprinkler evaporation losses. The relationship between wind velocity (Vw) and air temperature (Ta) and to predict evaporation losses (E) was a function of $E = 7.968Vw + 0.393Ta − 19.977$. Therefore, it was concluded that, both climatic factors and operating pressures influence the rate of evaporation losses during sprinkler irrigation, adequate attention should be paid to variation of climatic variables since sprinklers are sold with their specified operating pressures.

INTRODUCTION

The world all over currently faces the challenges of climate change such that it has become extremely difficult to rely on rain-fed agriculture to provide solutions to the problems of food insecurity, especially in Nigeria where population growth is at its alarming rate. McJannet *et al.* (2013) stated that under inadequate water supply from natural sources and food security concerns aggravated by growing population and climate change pressures, proficient use of available water supplies has become imperative. In this regard, there is the need to think beyond the natural water supply (rainfall) and embrace options through which water can be artificially supplied (irrigation) to the field when the need arises. However, the process of irrigation water application is also faced with the challenges of evaporation losses. Although water losses in form of evaporation can be of little percentage, Phogat *et al.* (2016) stated that water losses through evaporation during irrigation could be huge. Consequently, there is the need to pay adequate attention to such losses, given the prevailing global competing demands for water.

Many methods of irrigation exist among which is sprinkler system of irrigation. In this system, the application of water to the land takes the form of a spray. This system is becoming the favorite method owing to increasing paucity of water available for irrigation around the world especially in arid and semi-arid regions like Nigeria (Uddin, 2010). Moreover, a sprinkler irrigation system is less susceptible to erosion, not easily affected by topography and can be easily adapted for fertilizer application (fertigation), amongst other benefits. Nevertheless, efficient management of water during irrigation practice including sprinkler system requires adequate knowledge of water application efficiency (Dasila *et al.*, 2016). Irmak *et al.* (2011) suggested that as available water resources turn out to be uncommon, more prominence is given to efficient use of irrigation water for ultimate economic return and water resources sustainability. This means that all losses associated with irrigation water including spray droplet evaporation, soil evaporation, water use by unwanted plants, amongst others, should be monitored and minimized to ensure system efficiency. However, water application efficiency of a sprinkler system is majorly controlled by the amount of drift losses and evaporation (Bavi *et al.*, 2017). This is even as Stambouli *et al.* (2013) noted that gross sprinkler evaporation losses can be enormous to the extent of reducing irrigation application efficiency. Therefore, there is a need for an adequate understanding of the water losses under sprinkler irrigation systems to achieve greater sprinkler efficiency.

Meanwhile, sprinkler efficiency depends on the losses that occur during and after any sprinkler operation. Losses from sprinkler account for a large magnitude of portion of water discharged by the sprinkler. These losses are accounted for as the difference between the volume of water exiting the nozzle and water volume obtained with a grid of catch-cans (Kadam and Deshmukh, 2011). The amount of water losses to drift losses and evaporation depend on the prevailing operating and climatic situations. Many scientists have worked on various aspects of evaporation losses in sprinkler irrigation systems. For instance, Christiansen (1942) studied evaporation losses by making use of the catch-can method and discovered that losses varied from values of 19 to 42%. Nevertheless, no attempt was made to correlate the losses with any climatic variables. Sprinkler irrigation losses are approximately proportionate to operating pressure and

wind velocity and inversely proportionate to nozzle size and relative humidity of the air (Frost and Schwalen, 1955).

Moreover, evaporation and wind drift losses increased with the increased in the height of sprinkler's riser (Strong, 1961). Also, evaporation and wind drift losses varied from 3.4 to 17% while 36% of the losses was due to wind drift (Kraus, 1966). In the study conducted by Sternberg (1967), he found out that 60% of the total losses were wind drift losses. Kadam and Deshmukh (2011) studied the effect of nozzle size on evaporation and drift losses using a mini-sprinkler and reported that evaporation and drift losses increased with small nozzles but decreased with large nozzle size. Bavi *et al.* (2017) worked on the evaporation losses from sprinkler irrigation under various operating conditions in the western south of Koran. The results obtained from the study indicated that vapour pressure deficit and wind velocity were the most noteworthy factors influencing evaporation losses. The study further established exponential relationships between the evaporation losses, vapor pressure deficit and wind velocity.

Many methods have been adopted to evaluate evaporation losses in the field. Most conventional methods adopted in the field involve the use of volumetric determination of water obtained with the catch-cans. However, the fundamental challenge of this technique is that it estimates droplet evaporation loss during irrigation majorly from the evaporated water in the catch-cans. Additionally, accurate measurement of water that reaches the ground is also very difficult especially in windy conditions which increases the sampling area due to drift. Kohl *et al.* (1987) reported that measurements using catch-cans commonly have experimental errors. To avoid these difficulties of measurement, wind drift loss was often included with evaporation losses (McLean *et al.* 2000). Jensen (1980) pointed out that investigators have applied corrections to account for these errors, but accurate measurements are difficult to achieve. Recent studies conducted by Uddin *et al.* (2013a; 2013b) showed that the advanced eddy covariance (*ECV*) technique provides a better measurement of total evaporation losses during sprinkler irrigation. The technique also provides additional benefits of identification of the components of total evaporation with some other additional measurements.

Notwithstanding the foregoing studies, information on evaporation losses during irrigation in Nigeria, especially the sprinkler system, is sparse. Presently, there are reasons to suggest that the irrigation potential of the country has not been fully explored, Accordingly, only 45% of the total irrigation potential of the 2.0 million ha, is under irrigation, while the northern part of the country with very low average annual rainfall shares about 70% of the total irrigation potential, about 20% is spread over the humid south with the balance in the central and western plateau areas. FAO-Aquastat (2016) noted that, of the 293 117 ha area of land equipped for irrigation in Nigeria, only about 218 840 ha (75%) of its was actually irrigated. However, there is scarcity of information in respect of the use of sprinkler or any other systems of irrigation in the country.

Nevertheless, with high rainfall variability and climate change coupled with the challenges of adequate food production to meet the growing population and the need for economic diversification, embracing irrigation using the sprinkler system has become imperative. Nonetheless, any adoption of sprinkler irrigation system without adequate information on the inherent evaporation losses cannot be efficient. Thus, the present study is aimed at evaluating the magnitude of sprinkler evaporation losses under varied operating pressures and climatic conditions in Ilaro, south western Nigeria.

MATERIALS AND METHODS

The experiment was carried out at the Research Farm of the Federal Polytechnic, Ilaro, Ogun State, Nigeria between 1st March and 31st July, 2019. Ilaro as shown in Figure 1, is the headquarters of Yewa South Local Government Area of Ogun State, Nigeria. The town is located on latitude 6°53'11.5" N and longitude 3°1'13.8" E and at an altitude of 89 m above sea level. Also, Ilaro has a population figure of about 46 999 according the National Population Commission NPC (2006) census. It lies in the rain forest zone with a mean annual rainfall of between 1100 and 1300 mm and with an average temperature of 27.5°C. The onset of rainfall is usually March/April while cessation is around October/November. The pattern of rainfall in Ilaro is bimodal with the first peak occurring in June to July, and the second in September while in August there is a short dry spell known as the "august break". The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. At least 60% of the population of Ilaro is engaged in farming with cassava, maize, yam, and other grain crops being their major agricultural products.
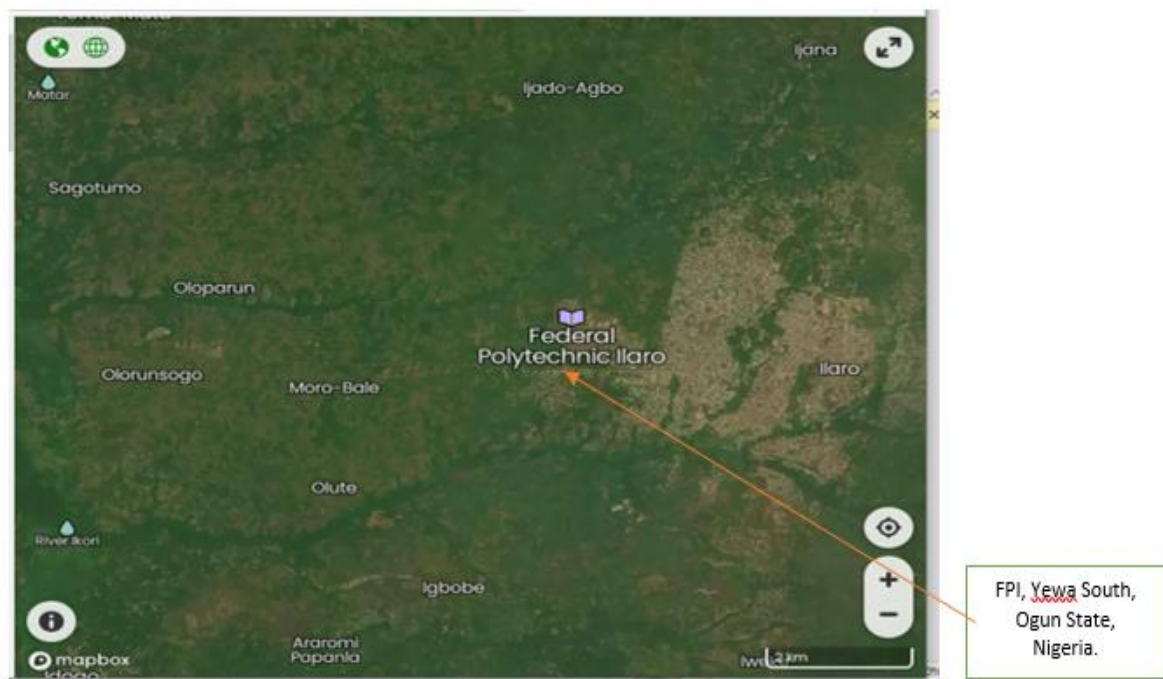
Figure 1. Geographical location of the experimental site.

Experimental Design Description

The set-up of the experiment consists of a water source from a bore hole located 45 m away from the study site connected to a pumping machine which pumps water to a water storage tank located on the field. Two valves were fitted after the pump to control the flow rate reaching the sprinkler device. A pressure gauge (up to 200 kPa) and flow meter were connected in series with the pressure regulator (Model 100 PRV) and sprinkler riser of height 1.2 meters. The pressure regulator was used to regulate the supply pressure to the test unit of sprinkler system. A set of PVC pipes of diameter 25 mm was used to convey water from the pumping site via the water storage tank to the sprinkler riser.

The design of the field trials was in line with sprinkler irrigation practices in terms of sprinkler spacing and range of operating pressure heads. The experiments were performed using 360° rotating sprinkler and a single nozzle of diameter 3 mm. The sprinkler was set up at a height 1.2 m and 27° as a trajectory angle. Three operating pressures, namely, 50 kPa, 100 kPa and 150 kPa (representing low pressure, medium pressure and high pressure, respectively) were used.

Measurement of the flow rate of sprinkler was done by connecting a flexible tube to the sprinkler nozzle and collecting known volume of water in a container over a specified period (5 min). The flow rate was calculated using the following formula (Melvyn, 1983).

$$Q = \frac{V}{t}$$ (1)

Where, Q is the flow rate of sprinkler in m³ h⁻¹, V is the volume of water collected in m³ and t is the time taken to collect the water in hours.

Water application rate of sprinkler was obtained with the aid of catch cans installed around the sprinkler under different treatments. This was calculated with the following formula (James, 1988).

$$A = k \frac{Q}{a}$$ (2)

Where, A is the application rate in mm h⁻¹, Q is the flow rate of sprinkler in L min⁻¹, a is the wetted area of sprinkler in m² and k is a dimensionless constant ($k = 60.0$ for A in mm h⁻¹, Q in L min⁻¹ and a in m²).

A mini automatic weather station consists of **multiple sensors** which provide data about air temperature, wind speed and direction (at 6 m), rainfall, snow depth, relative humidity, and solar radiation was installed very close to the experimental site during the study period to collect important climatic data (Table 1). Data were obtained from the station on hourly basis during the experiment. The effective winds direction during first three months of the study were from northwest, while it was southwest for the remaining months (June to July) of the study.

Table 1. Mean climatic variables during the experiment.

Month	Mean Wind Speed (m s⁻¹)	Mean Max. Air Temp. (°C)	Mean Min. Air Temp. (°C)	Mean Relative Humidity (%)	Precipitation (mm)
March	1.52 (±0.33)	33.70 (±0.25)	23.80 (±0.34)	52.6 (±2.10)	0.00
April	1.63 (±0.42)	34.10 (±1.02)	24.50 (±0.56)	50.5 (±1.76)	0.00
May	1.45 (±0.22)	32.80 (±0.41)	22.70 (±0.90)	53.3 (±1.87)	24.80
June	1.37 (±0.13)	31.60 (±0.17)	24.30 (±0.75)	56.7 (±1.56)	43.50
July	1.39 (±0.61)	29.45 (±0.43)	21.74 (±0.54)	68.2 (±3.22)	75.86

Water was supplied at a constant flow rate of the pump under each operating pressure of 50 kPa, 100 kPa and 150 kPa, respectively. The sprinkler spacing area was (10 m by 10 m) and divided into squares of 1 m². A total of 100 catch-cans, each of diameter 9.5 cm and height 14.0 cm, were used for the experimental area. The catch-cans were laid on the ground surface at equal elevation. A catch-can placed at the center of each square represented the precipitation falling on that particular area.

Evaporation losses were then conventionally determined as the difference between the quantity of water leaving the nozzle (measured by a flow meter) and the quantity of water precipitated into catch-cans over the duration of 60 minutes. Multiple tests were undertaken during mid-day when the sun was high in the sky with substantial evaporative flux. The arrangement and coverage area of the sprinkler is as shown in the Figures 2a to 2c. The results of evaporation losses obtained under various operating pressures and climatic conditions were measured, while the data collected were statically analyzed using multiple regression analysis as presented in the following section.
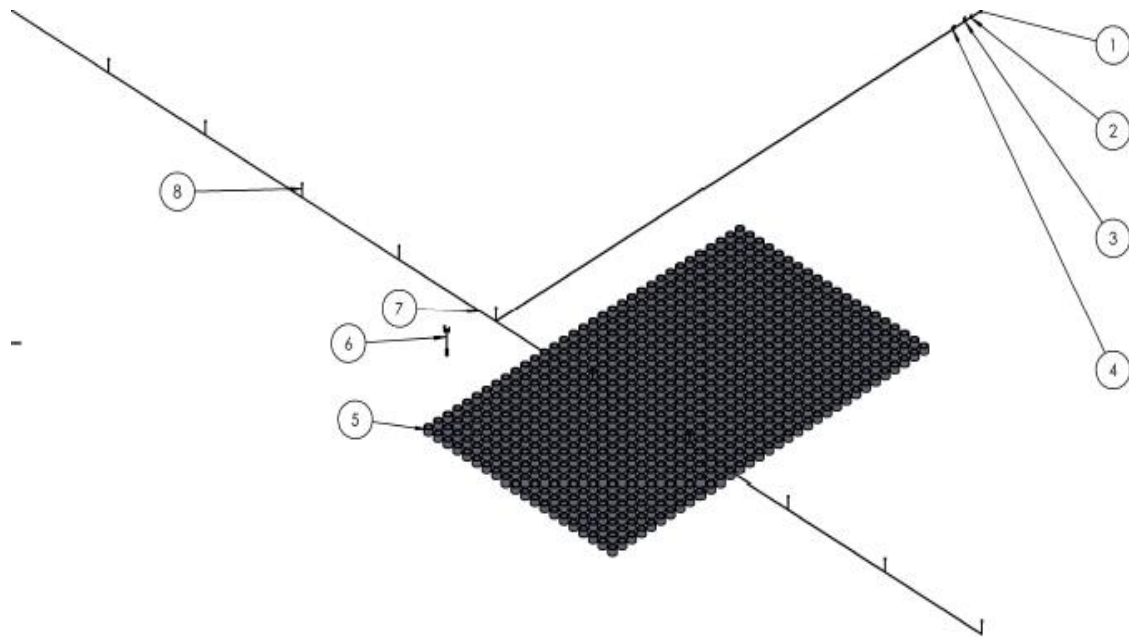
Figure 2a. Arrangement of the catch-cans around the sprinkler with the components.
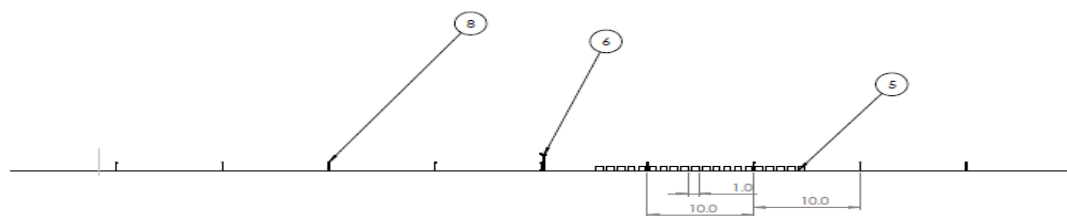
S/No	Components
1	Water Source
2	Pressure Regulator
3	Pressure gauge
4	Flow meter
5	Catch can
6	Weather Station
7	Lateral Pipe
8	Sprinkler

Figure 2b. Arrangement of the catch-cans around the sprinkler with dimensions.
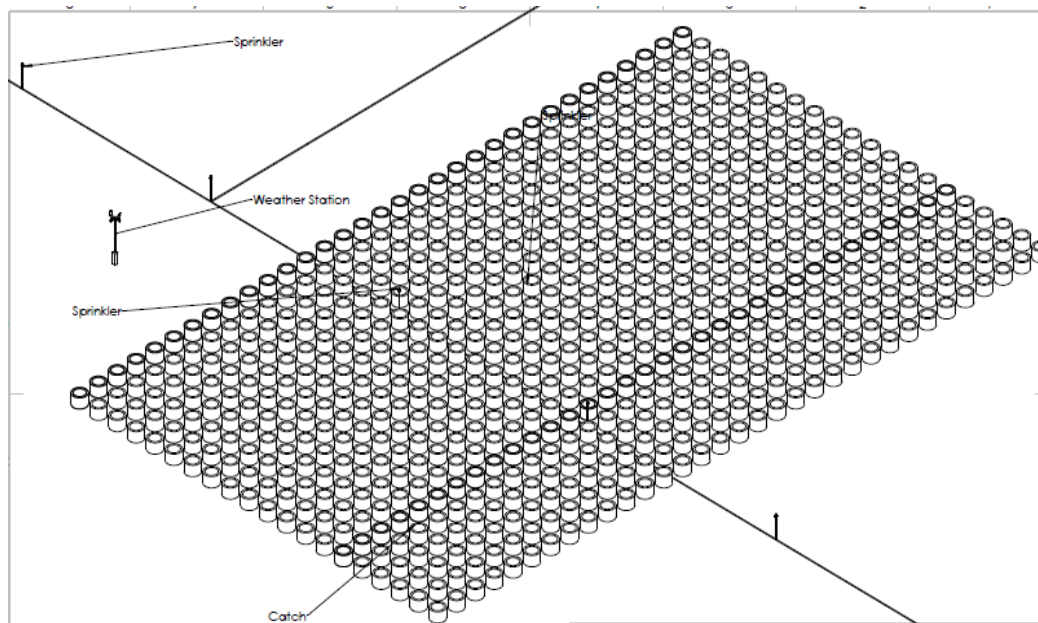
Figure 2c. Arrangement of the catch-cans around the sprinkler.

RESULTS AND DISCUSSION

The mean climatic variables during the five months of research were presented in Table 1. The maximum mean wind speed value of 1.63 m s^{-1} (±0.43) was recorded in the second month of this study which is April while the least value of 1.37m s^{-1} (±0.13) was recorded in the month of June. For the mean maximum air temperature, the highest value of 33.70°C (±0.25) was obtained in the month of March and the least value of 29.45°C (±0.43) was recorded during the month of July. During the course of this study (March to July), relative humidity recorded the highest mean value of 68.2% (±3.22) in the month of July while the least value of 50.5% (±1.76) was obtained in the month of April. The analysis of precipitation data during the study indicated zero precipitation for the months of March and April. The two months were very hot and dry. Furthermore, the month of July witnessed the highest mean precipitation value of 75.86 mm during the study.

A total of 36 evaporation loss tests were carried out. Twelve experimental tests were conducted for each operating pressure of 50 kPa, 100 kPa and 150 kPa, respectively and the analysis of results obtained were shown in Table 2-4. The mean values of the tests carried out for each operating pressure were obtained and values are as presented below (Table 5). The results show that the mean percentage evaporation losses at 50 kPa operating pressure was 8.88% at a relative humidity of 62.08%, air temperature (T_a) of 30.76°C and wind speed (V_w) of 1.22 m s^{-1}. Also, the mean percentage evaporation losses at 100 kPa operating pressure was 13.21% at a relative humidity (RH) of 64.67%, air temperature of 31.61°C and wind speed of 1.72 m s^{-1}. At 150 kPa operating pressure, mean percentage evaporation losses recorded was 16.46% at a relative humidity (RH of 65.17% and air temperature of 31.59°C and wind speed of 1.97 m s^{-1}. On the overall, the percentage evaporation losses at 50 kPa, 100 kPa and 150 kPa ranged from 6.94% to 9.93%, 12.43% to 14.23% and 16.02% to 17.32%, respectively. The mean values were further plotted to improve clarity and the understanding of the dependence of sprinkler

evaporation loss on the different variables (Figures 3 and 4). The results show that at higher relative humidity, percentage evaporation loss was higher. However, the multiple regression analysis results from the data pool of experimental I, II and III under operating pressure of 50 kPa, 100 kPa and 150 kPa in Table 6 showed that wind speed and air temperature play a significant role in predicting the percentage of water evaporated.

Table 2. Experimental results at low operating pressure, 50 kPa.

Trial No	Wind Speed (m s⁻¹)	Air Temp. (°C)	Operating Pressure (kPa)	Relative Humidity (%)	Flow Rate (L s⁻¹)	Droplet Height (m)	Volume Sprinkled (L)	Volume Precipitated (L)	Volume Evaporated (L)	Percentage Evaporated (%)
1	1.17	28.0	50	52.00	0.64	1.13	585.94	541.62	44.32	7.56
2	1.25	27.1	50	54.00	0.66	1.12	571.88	532.22	39.66	6.94
3	1.22	29.8	50	51.00	0.65	1.14	584.38	535.80	48.58	8.31
4	1.20	30.1	50	50.00	0.67	1.15	576.33	526.21	50.12	8.70
5	1.24	29.1	50	52.00	0.63	1.13	568.23	520.32	47.91	8.43
6	1.26	33.7	50	51.00	0.64	1.16	576.15	520.90	55.25	9.59
7	1.18	28.9	50	52.00	0.65	1.12	563.26	517.94	45.32	8.05
8	1.21	34.2	50	53.00	0.66	1.14	582.11	525.68	56.43	9.69
9	1.27	32.8	50	52.00	0.64	1.15	586.13	531.38	54.75	9.34
10	1.19	33.9	50	55.00	0.65	1.12	578.43	525.51	52.92	9.15
11	1.16	33.0	50	51.00	0.67	1.13	579.34	523.13	56.21	9.70
12	1.30	33.5	50	52.00	0.64	1.15	576.83	519.54	57.29	9.93
Average	1.22	30.76	50	52.08	0.65	1.14	577.42	526.60	50.81	8.88

Table 3. Experimental results at medium operating pressure, 100 kPa.

Trial No	Wind Speed (m s⁻¹)	Air Temp. (°C)	Operating Pressure (kPa)	Relative Humidity (%)	Flow Rate (L s⁻¹)	Droplet Height (m)	Volume Sprinkled (L)	Volume Precipitated (L)	Volume Evaporated (L)	Percentage Evaporated (%)
1	1.64	29.00	100.00	58.00	0.71	1.22	631.25	552.81	78.44	12.43
2	1.75	30.10	100.00	56.00	0.76	1.20	637.50	551.47	86.03	13.49
3	1.69	31.00	100.00	52.00	0.74	1.19	621.88	542.96	78.92	12.69
4	1.67	28.80	100.00	57.00	0.75	1.18	634.33	554.67	79.66	12.56
5	1.69	31.00	100.00	54.00	0.74	1.21	625.45	540.53	84.92	13.58
6	1.85	32.10	100.00	55.00	0.76	1.22	636.35	553.58	82.77	13.01
7	1.72	33.50	100.00	51.00	0.72	1.18	642.13	555.81	86.32	13.44
8	1.81	32.40	100.00	53.00	0.74	1.22	640.22	554.87	85.35	13.33
9	1.69	31.60	100.00	55.00	0.76	1.19	632.81	548.14	84.67	13.38
10	1.73	31.80	100.00	58.00	0.73	1.21	631.82	547.46	84.36	12.35
11	1.76	34.20	100.00	56.00	0.72	1.22	626.93	537.72	89.21	14.23
12	1.69	33.80	100.00	51.00	0.76	1.23	632.65	543.87	88.78	14.03
Average	1.72	31.61	100.00	54.67	0.74	1.21	632.78	548.66	84.12	13.21

Table 4. Experimental results at high operating pressure, 150 kPa.

Trial No	Wind Speed (m s⁻¹)	Air Temp. (°C)	Operating Pressure (kPa)	Relative Humidity (%)	Flow Rate (L s⁻¹)	Droplet Height (m)	Volume Sprinkled (L)	Volume Precipitated (L)	Volume Evaporated (L)	Percentage Evaporated (%)
1	2.64	30.10	150.00	55.00	0.89	1.24	685.94	572.80	113.14	16.49
2	2.11	31.00	150.00	51.00	0.97	1.27	675.00	564.96	110.04	16.30
3	1.92	31.20	150.00	58.00	0.91	1.26	676.56	567.88	108.68	16.06
4	1.87	32.10	150.00	58.00	0.91	1.25	681.22	570.00	111.22	16.33
5	1.93	29.80	150.00	55.00	0.89	1.26	678.45	569.78	108.67	16.02
6	1.79	30.60	150.00	56.00	0.85	1.24	669.23	561.41	107.82	16.10
7	1.82	32.40	150.00	51.00	0.90	1.26	691.34	578.43	112.91	16.33
8	1.91	31.60	150.00	58.00	0.87	1.27	689.65	577.29	112.36	16.29
9	1.88	32.70	150.00	53.00	0.89	1.28	673.23	561.41	111.82	16.61
10	1.85	33.20	150.00	55.00	0.91	1.26	667.12	551.56	115.56	17.32
11	1.94	31.90	150.00	56.00	0.86	1.24	688.78	514.25	114.53	16.63
12	1.92	32.50	150.00	56.00	0.88	1.28	672.66	557.78	114.88	17.08
Average	1.97	31.59	150.00	55.17	0.89	1.26	679.10	562.30	111.80	16.46

Table 5. Mean values of variables influencing evaporation losses obtained from the three experiments.

Trial No	Wind Speed (m s⁻¹)	Air Temp (°C)	Operating Pressure (kPa)	Relative Humidity (%)	Flow Rate (L s⁻¹)	Droplet height (m)	Volume Sprinkled (L)	Volume precipitated (L)	Volume Evaporated (L)	Percentage Evaporated (%)
1	1.22	30.76	50.00	62.08	0.65	1.14	577.42	526.60	50.81	8.88
2	1.72	31.61	100.00	64.67	0.74	1.21	632.78	548.66	84.12	13.21
3	1.97	31.59	150.00	65.17	0.89	1.26	679.10	562.30	111.80	16.46
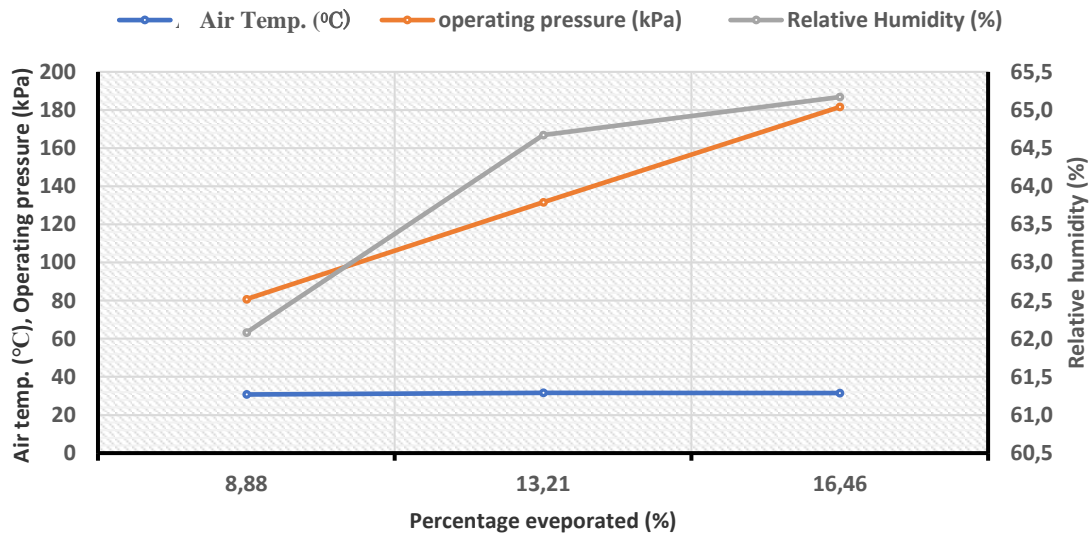
Figure 3. Variation of percentage evaporation losses with air temperature, operating pressure and relative humidity.
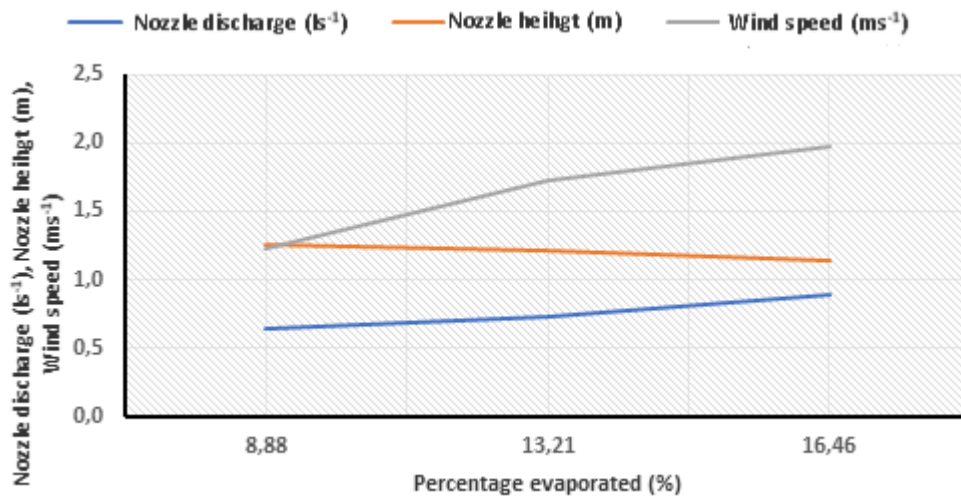
Figure 4. Variation of percentage evaporation losses with nozzle discharge, nozzle height and wind speed.

Table 6. Results of multiple regression analysis of the predictors and percentage evaporated water of the pooled data.

Predictors	Coefficients	Standard Error	t Stat	P-value
Intercept	-19.977	6.491	-3.078	0.004
Wind Speed (m s^{-1})	7.968	0.718	11.099	0.000
Air Temperature (°C)	0.393	0.117	3.350	0.002
Relative Humidity (%)	0.137	0.098	1.399	0.171

$$y = 7.968\ X_1 + 0.393X_2 - 19.977 \qquad (3)$$

Where y is the predicted evaporated water (%), X_1 is the wind speed (m s^{-1}) and X_2 is the air temperature (°C).
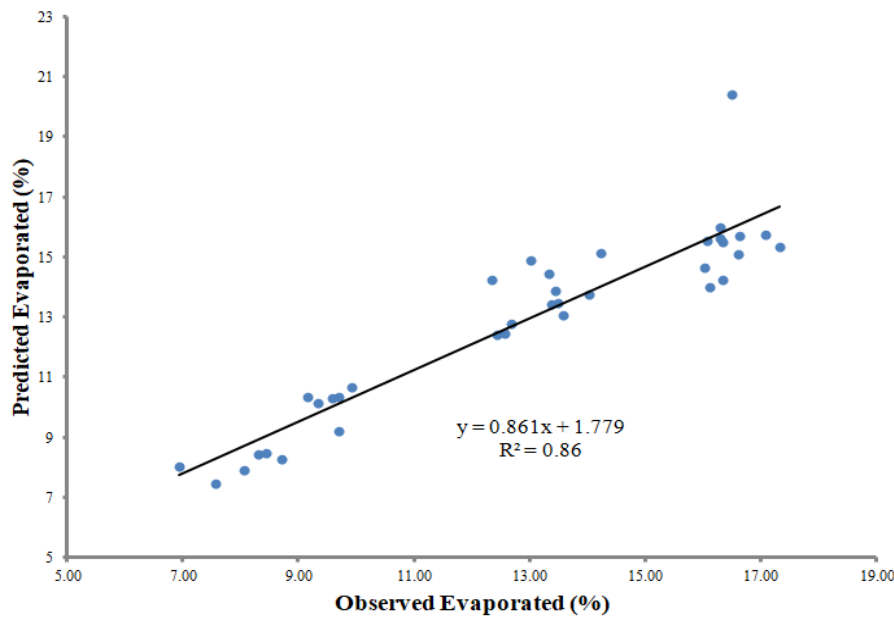
Figure 5. Relationship between the predicted and observed percentage evaporated water of the pooled data.

The occurrence of wind drift loss during irrigation is unavoidable (Bavi *et al.,* 2017; Kadam and Deshmukh, 2011). During the study, drift losses/ evaporation losses increased with increasing operating pressure due to a reduction in droplet sizes. The sizes of droplets produced during sprinkler operations varied with the operating pressure. Large water droplets obtained in this study at low operating pressure became smaller as operating pressure increased. The large water droplets became smaller as the operating pressure was increased from 50 kPa to 150 kPa. In the same vein, similar increment in the operating pressure also resulted in high evaporation losses, especially under the conditions of low relative humidity, high wind speed and high air temperature. Generally, the size of water droplets increased with decreasing operating pressure, while evaporation losses increased with increasing operating pressure. This is because, larger droplets sizes are not easily blown away by wind drift and as a result, the reduction was observed in evaporation losses (wind drift loss).

However, the foregoing results are not surprising as similar observations have been recorded by previous studies (Kohl *et al.,* 1987; Uddin *et al.,* 2010). While it may appear attractive to operate sprinklers at low pressure, given the result of the study, experts have recommended that sprinklers should be operated only under the operating pressure limit for which they are designed in order to avoid drift loss (McLean, 2000; Uddin *et al.,* 2010). In addition, operating sprinkler at excessively low pressure, may increase friction losses, reduce coverage area and overall sprinkler efficiency. Meanwhile, the operation of sprinkler irrigation systems when wind speeds are high should be avoided to prevent excessive wind drift loss. This is because, wind drift loss increases as wind speeds increase and droplet size decreases (Zazueta, 2011), Fortunately, in recent time, most companies that are manufacturing sprinkler nozzles specifically designed it to minimize effects of droplet size and wind drift loss (Uddin *et al.,* 2010).

Moreover, in this study, at higher relative humidity, percentage evaporation loss was higher. This is contrary to the established principle of lower evaporation at higher relative humidity, as moist air absorbs less water and vice versa. However, the result may have been the consequence of the countering of the higher relative humidity by the combined effects of wind speed and higher air temperature. While Zazueta (2011) recently emphasized the prime importance of wind speed, air temperature and relative humidity in the estimation of sprinkler evaporation loss, Lorenzini (2002) had earlier argued that evaporation losses are greatly impacted by air temperature with an exponential relation.

In addition, plots of the results in Figures 3 and 4, further confirmed the predominance of the variables amongst the factors affecting sprinkler evaporation loss. Likewise, it is also obvious that nozzle operating heights had less influence compared to nozzle discharges, although both directly influenced the percentage evaporation losses due to wind drift losses when operating pressure was increased from 50 kPa to 150 kPa. The result of this study is comparable with the findings of Uddin (2010), Frost and Schwalen (1960) and McLean (2000).

Moreover, in Table 6, the regression analysis showed the predictors, their coefficients and significance levels at $p < 0.05$. It can be interpreted that air temperature and wind speed are the major parameters that were significant on the influence of the experiment to predict the percentage evaporated water under those operating pressures of 50 kPa, 100 kPa and 150 kPa respectively in this location. While the relative humidity was a

predictor too, but it influences on the model (Eqn.3) generated by regression analysis to predict the percentage evaporated water was not significant at $p < 0.05$. Hence, it was played down on (removed). The graph in Figure 5, shows the relationship between the predicted and observed evaporated water. The graph shows a perfect linear relationship with a model *y = 0.861x + 1.779.* The model was found to be significant at $p < 0.05$. The coefficient of determination was a strong value ($R^2 = 0.87$). This indicates that model (*y = 7.968X$_1$ + 0.393X$_2$ – 19.977*) as the predicted can be used to generate the observed percentage evaporated water in this location with 87% accuracy under the operating pressure of 50, 100 and 150 kPa respectively. This is comparable with the findings of Uddin (2010), Frost and Schwalen (1960) and McLean (2000).

CONCLUSION

In conclusion, the present study was conceived to evaluate the magnitude of sprinkler evaporation losses under varied operating pressures and climatic conditions in Ilaro, Ogun State, Nigeria. Twelve experiments were performed at three (3) different operating pressures 50 kPa, 100 kPa and 150 kPa, representing low pressure, medium pressure and high pressure, respectively. We observed large water droplets at low operating pressure which became smaller as operating pressure increased. However, drift losses/ evaporation losses also increased with increasing operating pressure due to reduced droplet size. Furthermore, under increasing relative humidity, increasing evaporation losses were also noted as consequences of the combined effects of wind speed and air temperature. Consequently, we conclude that even at the optimum sprinkler operating conditions, climate demand (temperature, wind speed, wind drift) becomes the predominant variable determining evaporation loss. Hence, it is recommended that sprinkler irrigation should be operated with due cognizance to the prevailing climatic condition in general and particularly in Ilaro. From the statistical analysis, $y = 7.968X_1 + 0.393X_2 – 19.977$ may be recommended for predicting percentage evaporation losses at this site during this season winter/autumn. Additionally, the present study was conducted during the spring/summer season when relative humidity is usually high. Therefore, a similar experiment during the winter/autumn season may be necessary to further confirm the present results, and this will be the focus of our next research.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Samuel Dare Oluwagbayide: Conceptualization, methodology, investigation and writing of the original draft.
Olugbenga Fasanu: Data analysis and editing of drafted copy.
Ajayi Johnson Oloruntade: Data collection, original drafting and editing of drafted copy.

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Impact of Tillage Systems Equipped with Row Cleaners on Some Selected Soil Physical Properties under Wheat Cropping

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ABSTRACT

Availability of improved tillage and herbicides during the last decades has enhanced the acceptance of conservation tillage. The main constrain to this type of tillage, particularly, zero tillage is high level of crop residue, which reduces seeding quality, soil temperature, etc. Accordingly, a study was initiated by equipping row cleaners with no-till system under wheat cultivation. For this purpose, a field experiment was laid in a split-split plot design with three types of row cleaners, three sub-treatments of travelling speed, and two sub-sub treatments of tillage depth. The results indicated that the soil temperature was highly affected by percent of residue left. Measurement of penetration resistance indicated that hard pan was not a potential limiting factor for the crop root development. The soil water was increased by 8.83%, 15.33% and 12.54% under no-till without row cleaner (M1), no-till with narrow row cleaner (M2) and no-till with wide row cleaner (M3) respectively compared to that under conventional tillage (CT). The percentage of soil loss reduction under M1, M2 and M3 were 53.11%, 59.62% and 50.51% compared to that under CT. The water losses were also reduced by 46.19%, 48.65% and 46.86% under these treatments as compared with CT.

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To cite: Younis AF, Karim TH, Tahir HT (2021). Impact of Tillage Systems Equipped with Row Cleaners on some Selected Soil Physical Properties under Wheat Cropping. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2(1), 60-73. *https://doi.org/10.46592/turkager.2021.v02i01.005*

INTRODUCTION

Many problems arise from continuous conventional tillage practices worldwide. The severe soil disturbance under such tillage system can leave the surface soil subjected to wind and water erosion (Idowu *et al.,* 2019). Reicosky (2015) indicated that the main objectives of conservation tillage are soil protection from water and wind erosion through maintaining the surface residue cover and enhancing water infiltration into the soil. Conservation tillage like strip tillage can reduces soil erosion because most of

the soil remains covered with plant residue throughout the year (NDSU, 2017). Unger et al. (1997) indicated that surface cover can provide more time for water infiltration into the soil and can reduce soil particle transport via retarding water flow through the mulched surface. Siemens and Wilkins (2006) reported that the employment of conservation tillage systems like no-till can maintain more than 30% of crop residue cover on the soil surface and lessen soil erosion by 90%.

Conversely, leaving the crop residue of the soil surface can reduce the sowing quality or complicating sowing operations through blockage of furrowing and seeding devices, reducing soil temperature and consequently interfere with the rate and time of seed emergence (Wang et al., 2018). Younis et al. (2020b) used the modification of row cleaner for zero tillage planter to clean the seeding row from the residue by adding a half-cylindrical plate to cover the stem of furrow openers. Tahir (2020) noted that the traction power increased with depth and travelling speed. It was also revealed that when the seed opener is ridden over the crop residues, the seed germination is delayed and thereby causes early plant growth depression. In light of the above findings, some degree of soil disturbance or removing plant residues is required to enhance crop production. Kaspar and Erbach (1998) revealed that use of row cleaner attachment gave rise to a higher rate of seed emergence and larger emerged corn population on account of the fact that residue removal did not interfere with planter efficiency in no–till and encouraged soil warming. Therefore, it was suggested to remove crop residues to achieve higher crop yield (Siemens et al., 2004). Karuma et al. (2012) indicated that the success of any tillage system is directly related to the enhancement of the soil physical properties, which may affect finally crop growth and yield on account of various created soil conditions. The surface soil layers may become more compacted under zero tillage compared to that under conventional tillage (Ehlers et al., 1983). Atwell (1993) reported that there is an inverse relation between root growth and penetration resistance and this relationship can be described by linear, inverse or exponential functions. Penetration resistance beyond 2000 kPa leads to a significant reduction in root growth. Younis et al. (2020a) demonstrated that row cleaners were introduced to push the crop residues away from the seeding rows in front of row crop planter. They observed no negative effect of zero-tillage seeder with the modification and can be effectively used under rainfed farming. Accordingly, this study was initiated to examine the performance of two types of newly designed row cleaners through using residue concentration and some selected soil physical properties under wheat cropping as indicators.

MATERIALS AND METHODS

Site Description and Experimental Setup

The experiment was conducted at the Girdarasha experimental site of the College of Agricultural Engineering Sciences/University of Salahaddin (N 360 06' 48.9", E 440 00' 45.0" and at a mean altitude of 412 m amsl), Erbil, Iraq during the growing season of 2016-2017. It was conducted on a silty clay loam (%clay =37.78; %silt =52.37, %sand=9.85, EC_e = 0.51 dSm^{-1} and pH = 7.94). A Mediterranean climate dominates in the study area, giving rise to a cold and rainy winter, hot and dry summers. Mean annual temperature amounts to about 20°C with a maximum in July (44°C) and a minimum in January (5°C). A parcel of land previously cropped with wheat was selected and divided into three blocks of 55 m x 60 m. Each block with subdivided into

18 plots (2.11 m x 60 m). The experiment was laid in a split-split plot design with three types of row cleaners, three sub-treatments of travelling speed and two sub-sub treatments of tillage depth. The factors levels were:

1) Type of row cleaner: M1= seeder without row cleaner, M2 = seeder with narrow row cleaner (diameter = 7 cm and height =15 cm) and M3 = seeder with wide row cleaner (diameter = 9 cm and height =15 cm).
2) Travelling speed: S1= 8 km h^{-1}, S2 = 9 km h^{-1} and S3 = 11 km h^{-1}
3) Seeding depth: D1 = 4-5 cm and D2 = 6-7 cm

measurements were also done on a piece of land under conventional cultivation.

Measured Soil Properties

The studied soil characteristics encompassed soil temperature, penetration resistance, undrained shear strength, moisture content and soil and water losses. The obtained data were subjected to analysis of variance using SAS software ver.2009.

Soil Temperature Measurement

Soil thermometers Model Reotemp G (1 11" Dial) were also setup at a depth of about 8 cm below the soil surface to test the effect of different soil treatments on soil temperature (Wall and Stobbe, 1984) at 9:00 Am and 3:00 PM. Soil temperature was measured at three points along the seeding rows under each treatment during each day of the first month of growth, November, 2016.

Soil Penetration Resistance

The soil penetration resistance was measured at least 3 points selected at random along the seeding rows of each experimental unit with the proctor penetrometer Model 33-T0165 prior to applying the treatments (Preplaning stage) on November 4th, 2017 by following the procedure outlined by Davidson (1965). The depth of measurement was 0-60 cm. Representative soil samples were taken from the area surrounding the point of measurement for soil moisture determination. The obtained sample were kept in air tight bags and brought to the laboratory. The soil moisture was determined following gravimetric method by drying in an oven at 105-110°C for a period of 24 hours.

The penetrometer was pushed into the soil steadily until it penetrated 75 mm during 5 seconds and the maximum reading on the penetrometer was recorded in kg. The penetrometer reading at each point in kg was multiplied by the reciprocal of the end area of the penetrometer needle to obtain the soil penetration resistance in kPa. The abovementioned procedure was repeated directly after applying the treatments at a rate of five readings per each replicate of the combination treatments at planting, midseason and after harvest (Post harvest).

The Vane Shear Strength

The same procedure that has been used for measuring the penetration resistance was used for measuring the soil shear strength except that the proctor spectrometer was replaced by the vane instrument, Model G-128-26-3346. The vane shear test (ASTM D-2573-72) was performed by the test consists of forcing a vane with four orthogonal blades into the soil carefully pushing a vane with four orthogonal blades into the soil surface into a depth of 7.5 cm. A torque was then applied gradually, and the

peak value was noted with the aid of a non-return type pointer retains the test reading. The dimensions of the vane were 20 mm in width by 40 mm in height. The soil shear strength was calculated by applying the following equation (Cernica, 1995):

$$\tau = \frac{T}{\pi\left(\dfrac{D^2 h}{2} + \dfrac{D^3}{6}\right)}$$

(1)

τ = soil shear strength
T = the maximum applied torque (N m)
D = the diameter of the vane (blade) (m).
H = vane height (m).

Soil Water Content Measurement

Soil moisture condition was also monitored under the applied treatments during the growing season (measured at three dates after planting) at Girdarasha location. Soil samples were taken from 0.20 m to 0.60 m depths of the soil (0.00 - 0.20, 0.20 - 0.40, and 0.40-0.60 m) using a small manual auger with about 5 cm in diameter after the termination of each storm in a time interval of 24 hours (Tahir, 2020). The samples were kept in air-tight moisture tins after sampling and brought to the laboratory for soil moisture determination. The samples were oven-dried at 105-110°C for 24 hours. The auger holes were plugged with the same soil after each sampling. The soil moisture content was expressed on mass basis.

Measurement of Soil and Water Losses

Soil and water losses were estimated by implementing a separate experiment via establishing 8 runoff plots at Girdarasha site during the rainy season of 2016 -2017, each with dimensions of 2 m x 6 m down the slope. Each plot was bounded at the sides and top by plastic sheets of 3 m x 0.2 m, driven into the soil to a depth of around 0.1 m. At the lower end, a runoff collector system was placed, consisting of a trough to receive the eroded material from the plot, which was connected by a PVC pipe to a collection barrels located at the end of the plot, with 220 L. The barrel was covered and thus was protected against evaporation and rainfall.

The runoff plots were representing 4 treatments with two replicates in a separate experiment during the same season under wheat cropping.

The height of water in the tanks were measured and converted to liters by means of a calibration curve between height and volume of suspension in the tanks (Al-Banna et al., 1986). Following runoff volume measurement, the volume of collected runoff water was reduced by siphoning the relatively clear water. Thereafter, the remaining suspension (runoff and sediments) were transferred to metal containers and oven dried to determine the weight of sediment load.

RESULTS AND DISCUSSION

Soil Temperature

The measurement of soil temperature at a depth of about 8 cm below the soil surface signified that the average soil temperatures along the seed row during the first month

of plant growth ranged from a minimum of 8.60°C for the treatment combination of M1S2D2 to a maximum of 11.42°C for the treatment combination of M2S3D1 (Table 1).

Table 1. Some selected variables as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

Row cleaner type	Travelling speed	Tillage depth	Response variables		
			Residue cover (g m⁻¹)	Soil temperature (°C)	Yield (t ha⁻¹)
M1	S1	D1	30.37	10.65	1243.66
	S1	D2	19.43	11.16	2018.30
	S2	D1	48.53	8.90	2237.46
	S2	D2	60.73	8.60	1293.77
	S3	D1	46.67	9.90	1477.57
	S3	D2	57.26	8.82	1412.14
M2	S1	D1	23.23	10.98	1958.41
	S1	D2	19.33	10.82	1284.87
	S2	D1	19.27	11.16	1235.24
	S2	D2	20.00	11.13	1122.54
	S3	D1	16.67	11.42	2422.38
	S3	D2	21.83	11.24	2406.61
M3	S1	D1	25.70	11.13	1616.19
	S1	D2	25.90	10.86	1353.44
	S2	D1	20.70	11.10	1549.86
	S2	D2	23.89	10.95	1542.54
	S3	D1	29.67	9.82	969.80
	S3	D2	22.56	11.01	2569.21

The no-till system equipped with (M2) offered the highest soil temperature during the first month of growth followed by the no-till system equipped (M3). The order of effectiveness of the applied treatment on increasing the soil temperature was:
M2 > M3 > M1

The soil temperature under M2 was 1.46°C higher than the no-till system with M1, while that under the M3 was 1.14°C higher than that under M1. These findings support the work of Shen *et al.* (2018), who observed that tillage had significant effects on soil temperature in 10 of 15 weekly periods. Weekly average no-till soil temperature was 0–1.5°C lower than moldboard plowing. By contrast, (Siemens *et al.*, 2007) reported that a soil temperature difference of 0.5°C did not cause a difference in the emergence rates of corn seedling.

The warmer soil temperature during the first month after planting may explain more vigorous plant growth and greater crop yield under no-till with row cleaner attachment. As can be seen in Figure 1, there is a positive relationship between soil temperature during the early stage of growth and wheat yield. The variation in soil temperature explained only 6% of variation in wheat yield. It appears from these findings that the crop yield was affected by a host of factors besides the effect of soil temperature on the rate of seed emergence during the early stage of growth.

Higher soil temperature differences are expected under these two treatments at a depth of less than 8 cm due to a decreased dumping effect with a decrease in soil depth.
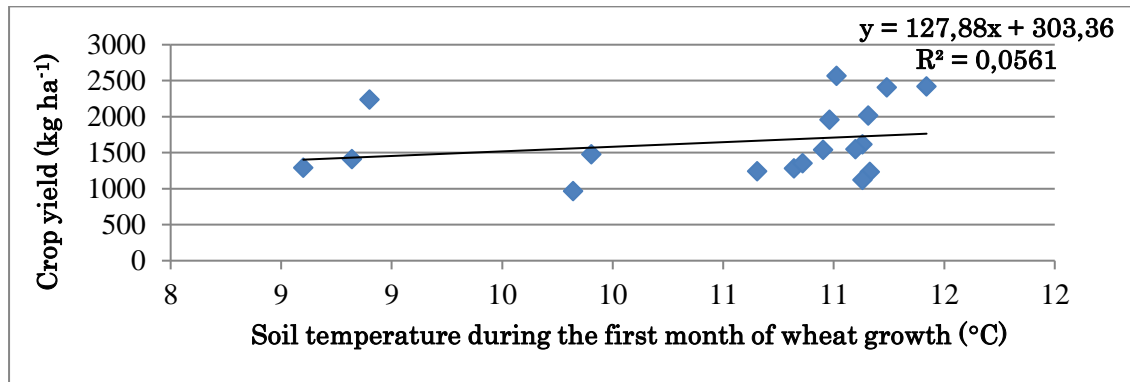
Figure 1. Wheat yield as influenced by the average soil temperature measured during the first month of wheat growth.

The results also revealed that the soil temperature was slightly and insignificantly affected by depth of seeding and travelling speed at $p \leq 0.05$). By contrast, it was noticed that the soil temperature was highly affected by percent of residue left on the soil surface. The lower the percent of residue left; the higher will be the soil temperature (Figure 2). More than 91% of variation in soil temperature at a depth of 8 cm below the soil surface can be explained on the basis of variation in percent of residue left on the soil surface after seeding. Additionally, the linear regression analysis pinpointed that the linear model slightly under predicted the soil temperature (Mean biased error, MBE = 0.008). The mean absolute percentage error of the linear model was 6.93%. On the other hand, the RMSE was 0.263. Judging from these performance indicators, it can be concluded that the soil temperature can be predicted with a reasonable accuracy from percent of residues left.
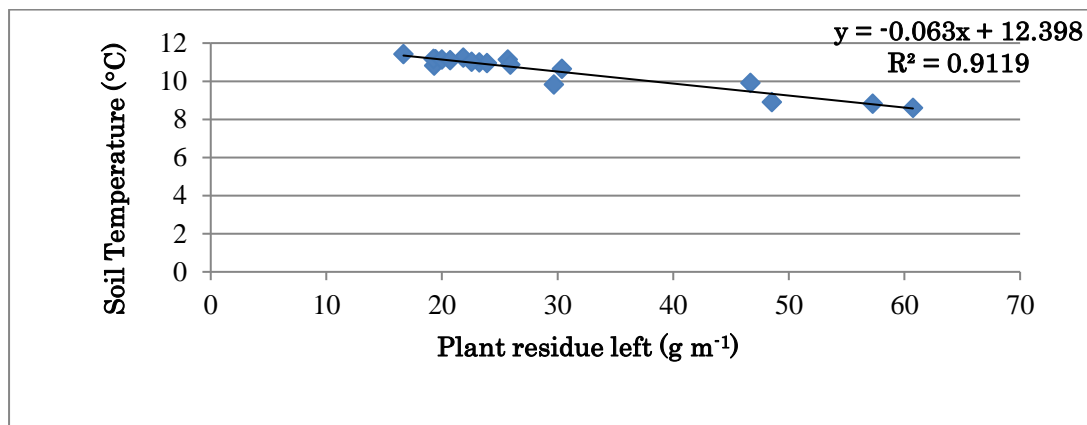
Figure 2. Soil temperature measured at a depth of 8 cm as influenced by quantity of residue left.

Soil Penetration Resistance (SPR)

Table 2 displays the soil penetration resistance measured at different depths under various treatments during the growing season of 2016/2017. The results indicated that it varied from as low as 895 kPa under the treatment combination of M2S2D1 at a depth increment of 0.0-0.1 m immediately after planting to a maximum of 22331 kPa under the treatment combination of M1S3D1 during the mid-growing season at a depth increment of 0.20-0.30 m. Overall this parameter was characterized by a high coefficient of variation ranging from about 26 to about 47%.

Table 2. Penetration resistance at different depths under different treatments measured immediately after seeding and at mid-season of in 2016/2017.

Main treatment	Sub treatment	Sub sub treatment	Penetration Resistance (kPa)					
			After seeding immediately			Mid-season		
			0-10 cm	10 -20 cm	20 -30 cm	0-10 cm	10 -20 cm	20 -30 cm
M1	S1	D1	1202	1550	1665	1450	1950	2015
	S1	D2	1288	1648	1778	1494	2028	2087
	S2	D1	1059	1391	1551	1229	1751	1806
	S2	D2	1269	1608	1762	1530	2008	2078
	S3	D1	1401	1761	1940	1690	2173	2231
	S3	D2	1257	1578	1734	1490	2001	2046
M2	S1	D1	1212	1545	1666	1421	1924	1990
	S1	D2	976	1296	1441	1263	1741	1802
	S2	D1	895	1175	1362	1109	1565	1632
	S2	D2	1013	1283	1405	1192	1679	1753
	S3	D1	988	1248	1449	1144	1659	1739
	S3	D2	1186	1488	1655	1332	1864	1913
M3	S1	D1	1166	1475	1660	1423	1920	1985
	S1	D2	1147	1467	1616	1422	1890	1976
	S2	D1	1005	1302	1514	1184	1706	1755
	S2	D2	933	1231	1400	1112	1626	1682
	S3	D1	1095	1398	1543	1308	1795	1868
	S3	D2	1254	1590	1804	1489	1996	2045

Overall, the average values of this parameter were 1680, 1445, 1522 kPa under M1, M2 and M3 respectively. It is apparent from the presented results that the no-till with a narrow row cleaner attachment (M2) resulted in a less compacted or soft soil, followed by M3 and M1 (Figure 3). The percents of the reduction under M2 and M3 were about 14.01% and 9.43% respectively compared to that under M1. It is commendable to refer that these differences were significant at ($p \leq 0.05$). The immediately after planting and midseason SPR measured in 2017 showed that the no-till treatment had significantly ($p \leq 0.05$). higher SPR compared to conventional tillage at all depths of measurement (1680 versus 1351 kPa). One can infer that no-till adversely affected the mean soil penetration resistance. This effect was not evident by the greater crop yield under no-till compared to that under conventional tillage.
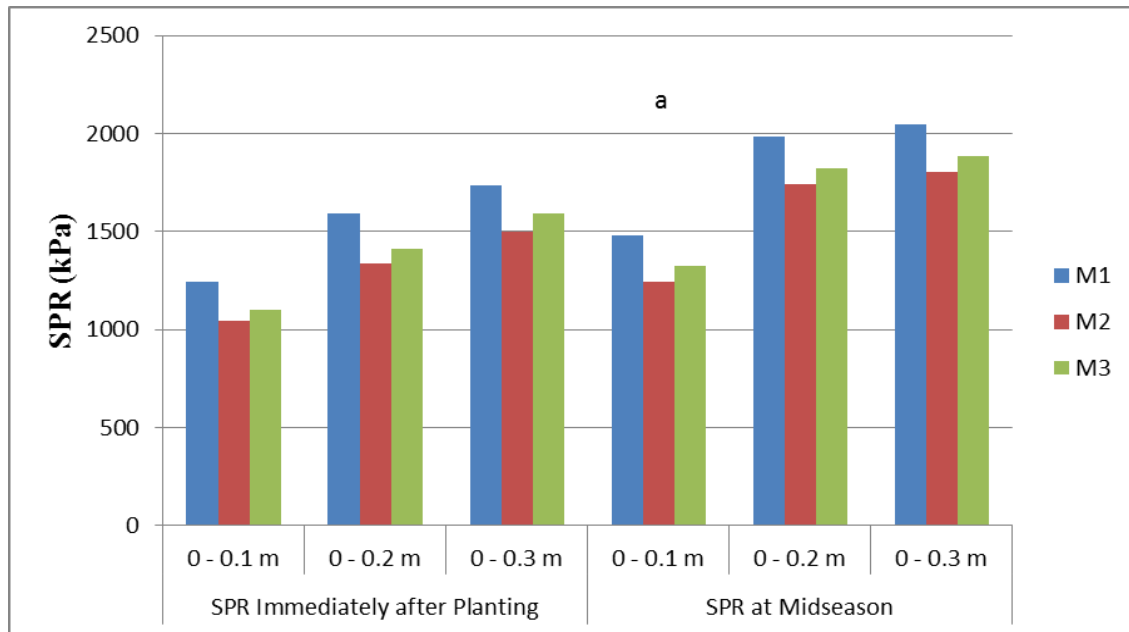
Figure 3. Soil penetration resistance as affected by different treatments during the growing season.of.2016/2017.

It is also interesting to note that no considerable differences were found between different treatments under no till system including travel speed and tillage depth in terms of soil strength (Figures 4 and 5).
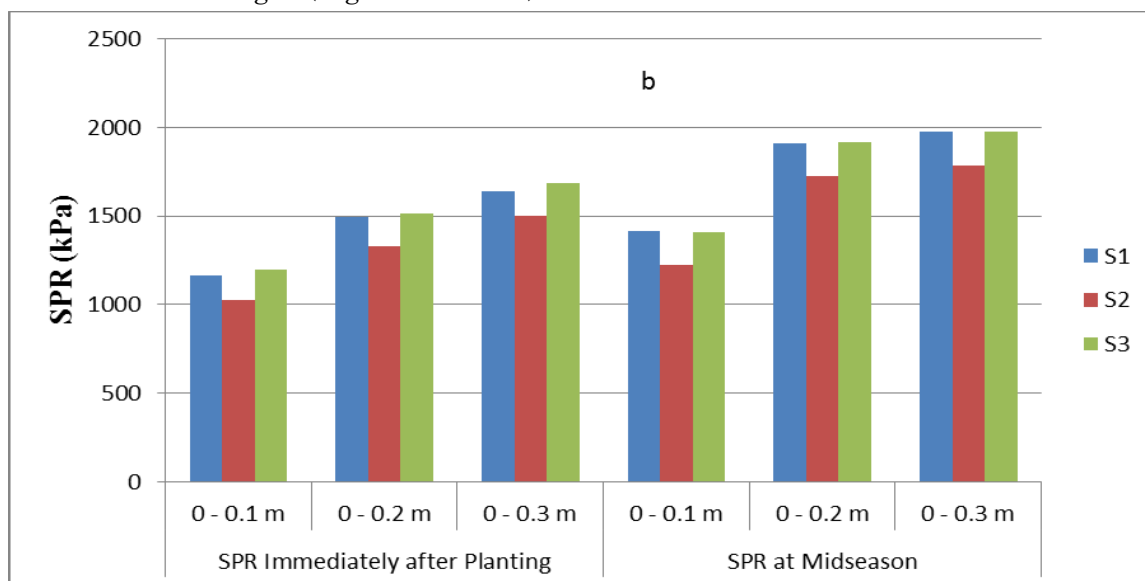
Figure 4. Soil penetration resistance as affected by different treatment during the growing season of 2016/2017.

It is obvious from the presented results that there was a substantial increase in SPR with time during the growing season. The immediately after planting readings had 18% lower than the measured values during the midseason (1395 vs. 1703 kPa). It is noteworthy that the SPR reading was not obtained at harvest on account of the very high resistance offered by the soil to the penetrating probe. The relatively high SPR during the midseason and very high resistance at harvest may mainly be due to lower soil moisture content compared to that during the early stage of plant growth.
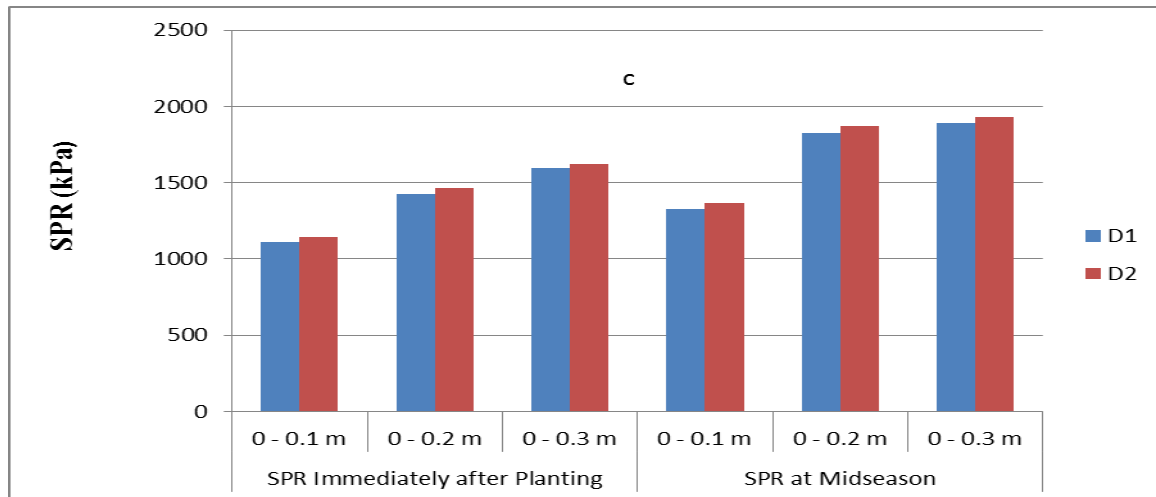
Figure 5. Soil penetration resistance as affected by different treatment during the growing season of 2016/2017.

Close examination of the results also revealed that the SPR tended to increase with an increase in depth of measurement. The results also indicated that 76% of the observation values were below 1800 kPa. This value of soil penetration resistance is considered an agronomical threshold value (Ehlers *et al.,* 1983). Hence, hard pan was not a potential limiting factor for the crop root development under the prevailing soil conditions during the growing season. The hard pan becomes a potential limiting factor as the soil dries (Francis *et al.,* 1987). This critical value can be different depending on the soil type and can be lower or higher than the 2500 kPa (Simmons, 1992). Further assessment, over a longer period of time, will be needed to confirm the long term of the study treatments on the values of this parameter.

Vane Shear Strength

Table 3 displays the measured undrained soil shear strength at depth of about 8 cm below the soil surface under different treatment combinations after planting using a vane shear test. It can be noticed that the treatment combination M2S1D1 offered the lowest value of nine kPa (Table 3). By contrast, the treatment combination M3S3D2 offered the highest un-drained soil shear strength of 12.67 kPa and those of the remaining treatments fell between these two extremes (Table 3). Similar to penetration resistance, the vane shear strength exhibited relatively a high coefficient of variation. The coefficient of variation ranged from as low as 24.39% under MSD to as high as 52.48% under MSD. As a whole, the measured shear strength was lower compared to those found in the literature. For instance, Stavi *et al.* (2011) observed that the vane shear strength under no-tillage and occasional tillages were 173.6 and 171.0 kPa respectively.

Table 3. Soil shear strength as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

Main treatments	Sub treatments	Sub sub treatments	Shear Strength (kPa)	
			Average value	Coefficient of variation (%)
M1	S1	D1	9.67	30.45
	S1	D2	11.83	44.85
	S2	D1	9.33	32.97
	S2	D2	11.17	35.56
	S3	D1	10.33	41.81
	S3	D2	10.33	46.48
M2	S1	D1	9.00	39.75
	S1	D2	10.83	52.68
	S2	D1	11.00	34.50
	S2	D2	11.00	24.39
	S3	D1	11.33	31.40
	S3	D2	10.83	42.27
M3	S1	D1	10.67	32.30
	S1	D2	12.00	35.36
	S2	D1	10.50	30.57
	S2	D2	10.17	30.10
	S3	D1	10.33	34.98
	S3	D2	12.67	24.80

Soil Moisture Conservation

Calculation of soil moisture to a depth of 60 cm showed that the no-till treatment irrespective of the attached row cleaner type offered higher soil moisture content compared with that under conventional tillage (Figure 6). The use of no-till resulted in maintaining most of the residues on the soil surface. Maintaining crop residues on the soil surface shades the soil, decreases soil evaporation, slow surface runoff and increases water infiltration. Thus, it simultaneously converses with soil water (Hedhbi *et al.,* 2005). The benefits of no-tillage with respect to improved soil water content have been well documented by (Ritchie and Nesmith, 1991).

The trend of the effect of tillage system on conserving soil moisture was:
No-till with a narrow row cleaner attachment (M2) > No-till with a wide row cleaner attachment (M3) > No-till without a row cleaner attachment (M1) > Conventional tillage (CT).
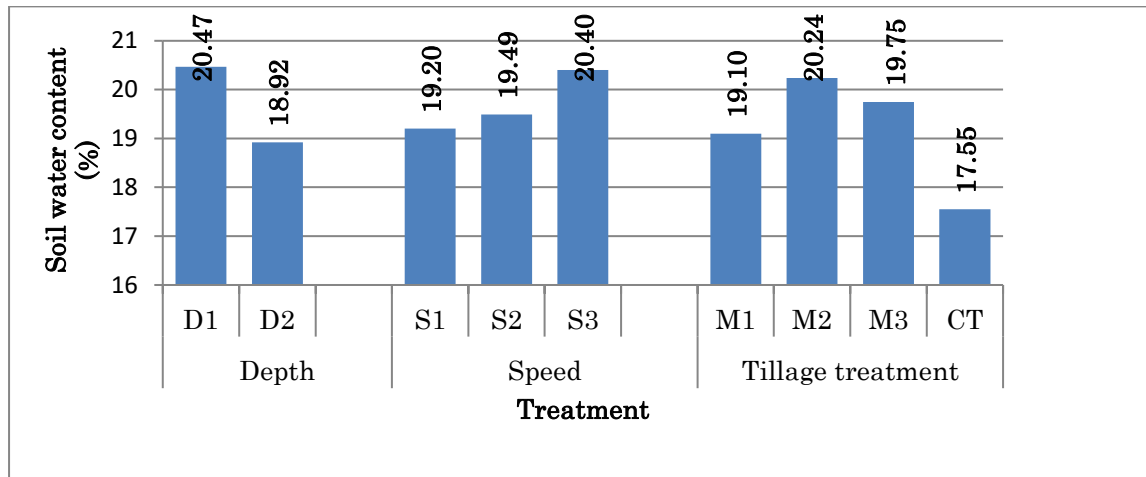
Figure 6. Soil water content of the upper 60 cm of the soil as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

The conserved soil water was increased by 8.83%, 15.33% and 12.54% under M1, M2 and M3 respectively as compared to that under CT. These differences were significant at the 5% probability level. It is worthy to note that the percent of increase in wheat yield was in concord with the percent of yield under these treatments. The results indicated that the percents of increase in yield were 34.48%, 44.86%, and 33.35% under M1, M2 and M3 respectively as compared to that under CT. The profound effect of no-till on the crop yield can be attributed to limited precipitation in the area, particularly during the year of the experiment. The benefits of using no–tillage generally were greatest in years where precipitation was limited (Unger *et al.,* 1997).

The results presented in Table 4 indicate the treatment combination (M3S3D1 offered the highest soil moisture content followed by the treatment M2S3D1. Conversely, the treatment combination M1S1D2 offered the lowest soil moisture content for the upper 60 cm stratum.

Table 4. Soil water content at different depth increments as influenced by different treatments at site during the growing of 2016-2017.

Main treatments	Sub treatments	Sub sub treatments	Soil water content (%) at depth increment			Overall soil profile water content (%)
			0.0-0.2 m	0.2 -0.4 m	0.4-0.6 m	
M1	S1	D1	23.20	16.30	15.90	18.47
		D2	18.14	15.12	14.51	15.92
	S2	D1	21.50	20.30	19.60	20.47
		D2	19.97	19.58	18.69	19.41
	S3	D1	22.75	20.68	19.50	20.98
		D2	20.30	19.10	18.70	19.37
M2	S1	D1	22.80	20.70	18.50	20.67
		D2	20.90	20.50	17.80	19.73
	S2	D1	23.15	20.65	18.90	20.90
		D2	20.30	19.10	17.94	19.11
	S3	D1	23.40	21.39	19.50	21.43
		D2	22.11	19.50	17.16	19.59
M3	S1	D1	21.70	20.20	19.30	20.40
		D2	21.10	19.90	19.10	20.03
	S2	D1	21.05	18.99	18.30	19.45
		D2	19.56	17.26	15.90	17.57
	S3	D1	23.30	21.20	20.00	21.50
		D2	21.10	19.50	18.00	19.53

The finding of the current study also revealed that the first depth D1 offered a higher soil water content compared with the second depth D2. Additionally, it was noticed that there was a continuous increase in soil water content with increasing travelling speed.

Soil and Water Losses

Although the soil and water losses were not significantly affected by the type of row cleaners, the no-till with a narrow row cleaner attachment (M2) produced the least amount of soil and water losses, followed by the no-till with without row cleaner attachment (M1) and the no-till with a wide row cleaner attachment (M3) (Figure 7). Compared with the conventional tillage, the soil and water losses under all the row cleaner types were significantly lower than those under conventional tillage. The percentages of reduction in soil loss under M1, M2 and M3 were 53.11%, 59.62% and 50.51% compared to that under the conventional tillage. Higher reduction in soil occurred under no-till system compared with those reported in the literature. For instance, Unger *et al.* (1997) observed that soil losses by erosion to wind or water are reduced to about 0.25 to 0.30 of the losses from the surface without residue. On the other hand, the water losses via runoff were reduced by 46.19%, 48.65%, and 46.86% under M1, M2 and M3 respectively compared to that under the conventional tillage. No-till practice is an effective technique for maintaining ground cover and crop residues on the soil surface is one of the most effective means of controlling soil erosion (Hargrove, 1990). This implies that reduced crop productivity due to soil erosion, frequent tillage and residue removal can be eliminated by conservation agriculture (Avci, 2011).
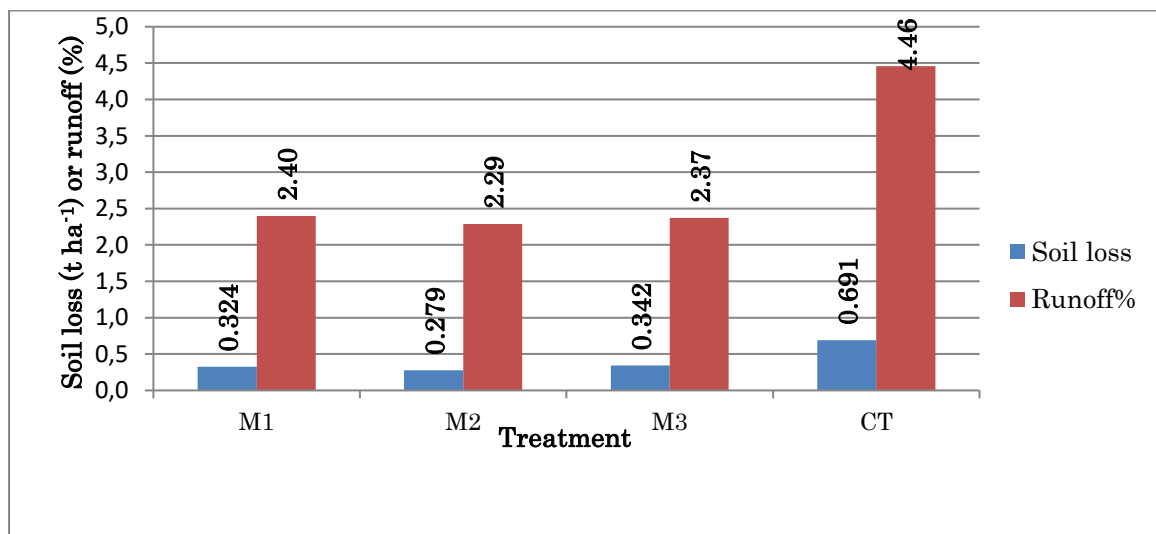
Figure 7. Annual soil loss and water loss due to runoff as influenced by different treatments during the growing season of 2016-2017.

These results are in conjunction with those reported in literature suggested maintaining residues on the soil surface under no-till are one of the simplest and surest methods of soil and water conservation. It is interesting to note that obtained results during this study reflect the combined effects of row cleaning, depth of tillage and operation speed all together. It is recommended to implement such type of experiments under different rainfall conditions for testing the performance of proposed row cleaners under plant residues with different densities.

CONCLUSION

1. The performance of each of narrow and wide row cleaners for reducing residue concentration was diminished with an increase in working speed and seeding depth.
2. The warmer soil temperature during the first month after planting under row cleaner attachment enhanced   plant growth and   yield under wheat cropping.
3. The wide row cleaner offered the highest performance compared with the other two types.

DECLARATION OF COMPETING INTEREST

The authors of this research article declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Abdullah Fathi Younis: Data collation, investigation, and writing the original draft.
Tariq Hama Karim: Literature review and review of the original draft.
Hussain Thahir Tahir: Methodology, design of experiment and data analysis.

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A New Proposal for Increasing Production Capacity and Energy Saving in Mixed Feed Production

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ABSTRACT

In this study, the feed production stages of a feed factory in Bursa province were analyzed and time analyzes were made at 20 feed parties. In the time analyzes, time analysis was performed for the dust turns and the lost times were recorded. Energy losses were calculated by time analysis of 59 feed time periods without dust return and dust return recorded in pellet presses. As a result of the calculations, dust return tanks are presented as a solution in order to increase capacity in the feed factory and to save energy. According to the records received, 20 min time is gained in the time of dust return and capacity increase will be ensured. The amount of dust feed in the feeds going through the monthly presses will be reset and 12 211,32 kWh of electricity required for this process will be saved. Turkey is located at the feed factories in October 2018 you considered approved and registered 14 750 business units. A significant amount of energy will be saved when dust return tanks are made in pellet press feeds in enterprises.

Karma Yem Üretiminde Üretim Kapasitesinin Artırılması ve Enerji Tasarrufu Sağlanması için Yeni Bir Öneri

ÖZET

Bu çalışmada, Bursa ilinde bir yem fabrikasındaki yem üretim aşamaları incelenerek 20 yem partisinde zaman analizleri yapılmıştır. Yapılan zaman analizlerinde pelet yemin pelet pres makinalarından geçme sürelerine bakılarak toz dönüşleri için zaman analizi yapılmış ve yaşanan kayıp zamanlar kaydedilmiştir. Pelet preslerinde kayıt altına alınan toz dönüşlü ve toz dönüşsüz 59 adet yem geçme süresinde zaman analizleri yapılarak, enerji kayıpları hesaplanmıştır. Hesaplamalar sonucunda yem fabrikasında kapasite artırılması ve enerji tasarrufu sağlanması için toz dönüş depoları çözüm önerisi olarak sunulmuştur. Alınan kayıtlara göre yemin toz dönüş zamanında 20 dk zaman kazanılarak kapasite artırımı sağlanmış olacaktır. Aylık olarak preslerden geçen geri dönüşlerdeki toz yem miktarı sıfırlanacak olup bu işlem için gerekli olan 12 211,32 kWh'lık elektrik enerjisinden tasarruf edilecektir. Türkiye'deki yem fabrikaları göz önünde bulundurulduğun da 2018 yılı Ekim ayında onaylı ve kayıtlı 14 750 adet işletme bulunmaktadır. İşletmelerdeki pelet pres yemlerinde toz dönüş depoları yapıldığında önemli miktarda enerji tasarrufu sağlanacaktır.

GİRİŞ

Bitkisel ve hayvansal üretimde öncelikli hedef; ekonomik, sürdürülebilir ve üretken işletmeciliğin sağlanmasıdır. Bu hedef doğrultusunda tarımsal üretimin önemli bir kolu olan hayvansal üretimde öncelikle et ve süt verimi yüksek ırklarla yetiştiricilik yapılması tercih edilmesidir. İkinci olarak hayvanların yeterli ve dengeli beslenmesi ile bireysel potansiyelden en yüksek düzeyde yararlanılmaya çalışılmasıdır. Üçüncü olarak ise hayvansal üretim sırasında en büyük kayıplara sebep olan hastalıklara karşı gerekli sağlık önlemlerinin alınması ve hastalıkların erken teşhisiyle gerekli müdahalelerin hemen yapılmasıyla ilaç kullanımının en aza indirilmesidir (Özgüven, 2018). Bilgi teknolojilerinde görülen gelişmeler sonucu verilerin iletilmesi, depolanması ve depolanan verilerin değerlendirme süreçlerine uygulanabilmesi için geliştirilen donanım, algoritma ve yazılımların hayvansal üretimde kullanılmasıyla hassas hayvansal üretim uygulamaları ortaya çıkmıştır. Hassas hayvansal üretim teknolojileri ile sürü yönetimi uygulamalarının doğru ve zamanında yapılmasıyla hayvanların bireysel potansiyelinden en yüksek düzeyde yararlanılmakta, maliyetlerde azalma, ürün kalitesinin artması, hayvan sağlığının korunması ve refah düzeyinin iyileştirilmesi sağlanmaktadır (Özgüven, 2017).

Tarım ürünlerini işleme süreci çok sayıda modern teknoloji ve ilave kaynak gerektirdiğinden bitkisel ürünlere bir kez daha değer kazandırabilmek, işletmenin bünyesinde yer alan hayvancılık şubesi ile mümkün olabilmektedir. Bu nedenle

hayvancılığın, insan beslenmesinde kullanılamayan veya başka bir kullanım şekli de olmayan çeşitli bitki ve bitki artıklarına katma değer kazandıran önemli bir rolü de vardır. Özellikle belirli kısa dönemlere sıkışmadan yılın her ayında ve sürekli gelir elde edilebilmektedir. Bu özelliği çiftçilerin gelirlerinin artmasında önemli bir rol oynamaktadır. Ayrıca toplumların beslenme düzeyinin yükseltilmesi ve ülkenin ileri gelişim aşamalarına ulaşmasında süt ve et gibi hayvansal ürünlerin üretildiği hayvancılık sektörünün diğer sektörlere nazaran daha önce ele alınması gerektiği konusunda görüşler ileri sürülmektedir (Işıklı, 1979; Akman ve ark., 1993; Öztürk ve Karkacıer, 2008).

Mera şartlarında yapılan hayvancılıkta genellikle kar elde edilme imkanı daha yüksektir. Bu nedenle çayır ve meraların hayvan yetiştiriciliğinde büyük önemi vardır. Ancak 1950'li yıllardan itibaren tarıma açılmış olan ülkemiz çayır ve meraları 40 milyon ha'dan 12 milyon ha'a düşmüştür. Ayrıca erken, aşırı ve kontrolsüz bir şekilde otlatılması sonucu mera arazilerine ağır zararlar verilmiş, verimliliği azalmış ve büyük ölçüde erozyona maruz kalmıştır. Bu nedenle mevcut meralar hayvan varlığının kaba yem ihtiyacını karşılayacak durumda değildir. Gelişmiş ülkelerde hayvansal üretim için gerekli kaba yem ihtiyacının %80-90'ı çayır meralardan karşılanırken, ülkemizde bu oran nadas alanları dahil sadece %38'dir (Anonim, 2018).

2019 yılı TÜİK verilerine göre toplam büyükbaş hayvan sayısı 17 milyon 872 bin baş, toplam küçükbaş hayvan sayısı 48 milyon 481 bin baş ve toplam kanatlı hayvan sayısı ise 348 milyon 785 bin baş olarak gerçekleşmiştir (TUİK, 2020). Ülkemiz büyük ve küçükbaş hayvan varlığı bakımından dünyada ilk sıralardadır. Ancak hayvanların yetersiz beslenmesi sonucu hayvan başına düşen et ve süt verimi düşüktür. Hayvansal ürünlerin bol ve ucuza üretilmesini etkileyen en önemli faktörlerden biri kaba yemin miktar ve kalitesidir. Hayvanlara doygunluk vermek, işkembeyi çalıştırmak ve geviş getirmek için gerekli olan kaba yemler ekonomik ve sağlıklı beslenmenin anahtarıdır (Adıyaman, 2009).

Hayvansal üretimi etkileyen faktörler çok çeşitli olmakla birlikte bunların bazıları; ıslah, bakım, sürü yönetimi, beslenme, hastalıklarla mücadele, pazarlama, organizasyon, kredi ve sigortadır. Beslenme probleminin başlıca sebebi ise yeterli yemin bulunmasında yaşanan zorluklardır (Acar, 1995). Yeterli kaliteli kaba yem olmayınca bu açık ağırlıklı olarak karma yem ile karşılanmaya çalışılmaktadır. Karma yem ise kaba yeme kıyasla daha pahalıdır. Hayvancılık işletme maliyetlerinin en büyük paya sahip olanı (%70-80) karma yemdir. Karma yem miktar ve kalitesi işletme karlılığını etkilemektedir. Hayvanlardan kaliteli ürün alınabilmesi için hayvanların dengeli ve yeterli düzeyde beslenmeleri gereklidir. Besin maddelerinin dengeli ve doğru miktarlarda verilmemesi verimde düşüşe ve bazı metabolik hastalıklara neden olabilmektedir. Bu nedenle hayvanların gereksinimlerini karşılayacak uygun rasyonların ekonomik olarak hayvanlara sağlanması gerekmektedir (Şahan, 2016).

Kaliteli yemde, besin maddeleri ve yem katkıları yemin içinde homojen olarak dağılmış olmalıdır. Bunun için, karma yem üretiminde yemin içindeki hammadde ve katkı maddelerinin homojen olarak karıştırılması, yem hazırlama prosesinin kalite koşullarının ve başarı kriterlerinin başında gelmektedir.

Karma yem, birden fazla hammaddenin homojen olarak bir araya getirilmesiyle elde edilmektedir. Türkiye'nin 2009 yılında 9.4 milyon ton olan toplam karma yem üretimi 2019 yılında 24.9 milyon tona ulaşmıştır. Hayvan sayısının artmasıyla birlikte karma yem üretiminde de artış olmaktadır (Anonim, 2020).

Bu çalışmada; Bursa ilinde bulunan bir karma yem fabrikasında yem üretim kapasitesin artırılması ve enerji tasarrufu sağlanması için toz dönüş depoları çözüm önerisi olarak sunulmuştur. Pelet pres soğutucu sistemlerinde toz dönüşü için zaman analizleri yapılarak enerji kayıpları hesaplanmıştır.

MATERYAL ve YÖNTEM

Çalışmanın ana materyalini Bursa ilinde yer alan bir yem fabrikasında yem hazırlama prosesine kullanılan ekipmanlar oluşturmaktadır. Şekil 1'de görüldüğü gibi karma yem üretimi hammaddenin fabrikaya gelmesi ile başlamaktadır. Fabrikaya gelen hammaddelerden uygun şekilde numuneler alınıp laboratuvarda hammadde muayenesinden geçirilerek standartlara uygunluğu kontrol edilmektedir. Standartlara uygun hammaddeler hidrolik liftler sayesinde ızgaralı bunkerlere boşaltılmaktadır. Bu sırada meydana gelebilecek tozlanma aspirasyon fanları ile emilerek siklon yardımıyla geri kazanılmaktadır. Hammaddeler zincirli konveyör, kovalı elevatör, helezon ve ventilatör ekipmanlarıyla ilgili siloya taşınmaktadır. Hammadde taşınırken ilk önce mıknatıstan ve çöp eleğinden geçirilerek, hammaddede olası metal parçalar ve yabancı maddeler tutulmaktadır. Silolardan alınan hammaddeler, dozaj depolarına taşıma ekipmanları ile aktarılmaktadır. Belirlenen reçeteler dijital ortamda otomasyon sisteminin yazılımı yardımıyla sisteme tanımlanmaktadır. Otomasyon sistemine tanımlanan reçetelere bağlı olarak yem hammaddesinin dozaj işlemleri başlatılmaktadır. Prosesin tüm ünitelerinde olduğu gibi, dozajlama da %0.1 hata payı ile bilgisayar kontrolünde yapılmaktadır. Dozajlama ünitesinde yem bileşenlerinin büyük bir kısmını oluşturan tane yemler ve yağlı tohum küspelerinin, ana kütledeki oransal miktarlarına göre kütlesel ve/veya hacimsel miktarlarda homojen bir şekilde karıştırılması işlemidir.

Karma yem formasyonundaki dozajlama işlemi bittikten sonra tartılan hammaddeler taşıma ekipmanları ile değirmen üstü bunkere gelmektedir. Hammaddeler uygun elekle donatılmış bir çekiçli değirmende kırıldıktan sonra elenen materyal alt bunkerde toplanmaktadır. Kırma işlemi gerçekleşirken değirmen üzerinde bulunan besleme üniteleri değirmenin devrine göre miktarı ayarlamaktadır. Böylece o partideki tartma ve kırma işlemi gerçekleşmektedir. Kırma işlemi tamamlanan hammaddeler karıştırıcıya (miksere) taşınmaktadır. Karıştırıcı da her farklı yoğunluğa sahip yemin farklı bir karışım süresi vardır. Karışım anında vitaminler ve mineraller mikro dozaj ünitesinden mikser içerisinde katılmasıyla karıştırma işlemi tamamlanmaktadır. Karıştırma işlemi ardından reçetede melas var ise melasiyer veya melasör (melas mikseri) işlemi başlamaktadır. Karışım melasiyerden geçerken birim zamanda geçen yem miktarı otomatik olarak hesaplanıp flowmetre yardımı ile likit katkının yoğunluğuna göre likit katkılar melasiyere püskürtülmektedir. Melasiyerdeki padıllar yem ile likit katkıları yoğurarak yine homojen bir şekilde karışım sağlanmaktadır. Böylece melasiyerden çıkan yem, toz yem formunda olmaktadır. Yem toz olarak paketlenecek ise direk depolara, yemin pelet formunda olması isteniyorsa pelet preslerinin üst depolarına taşınmaktadır.
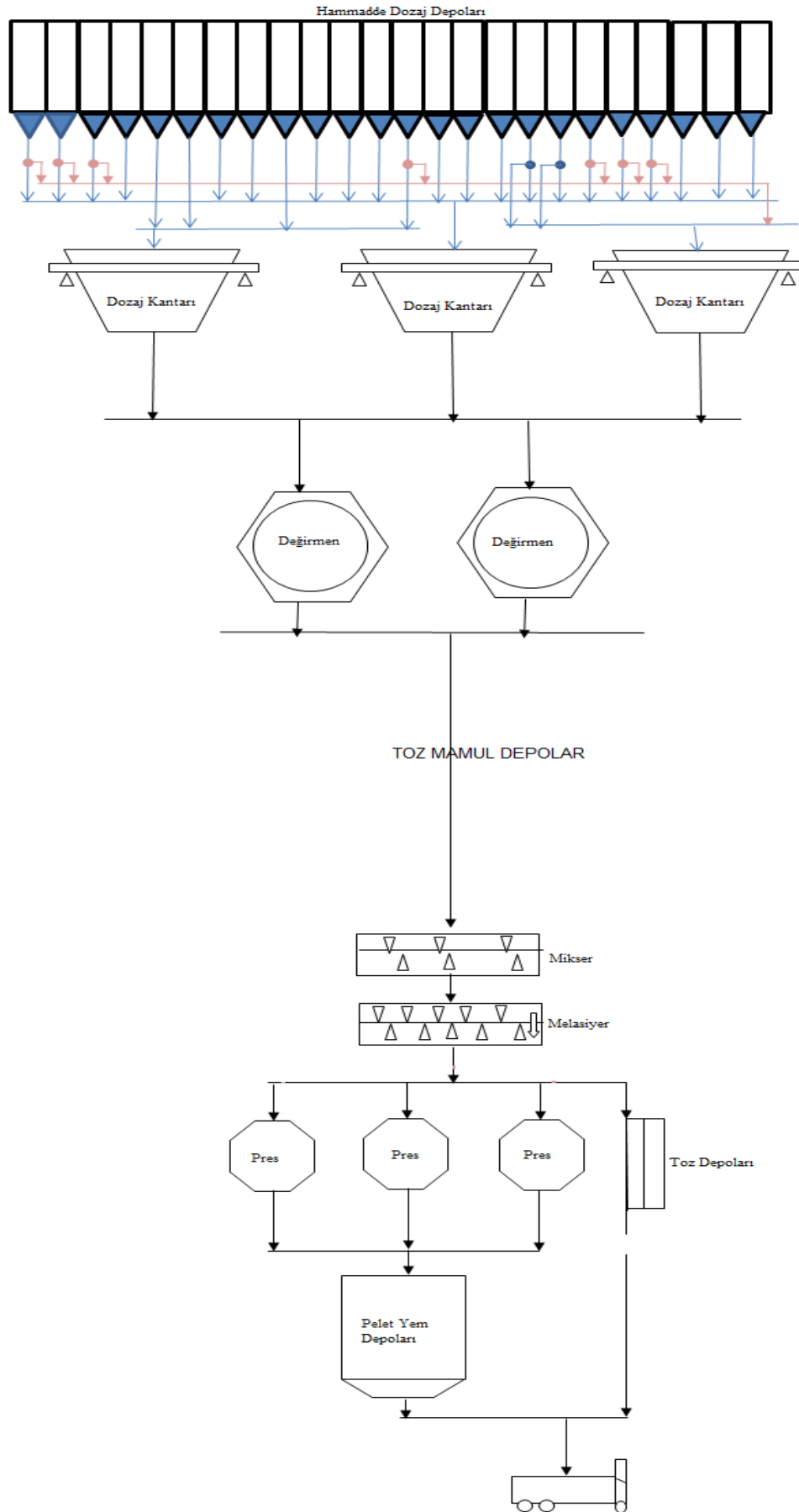
Şekil 1. Örnek fabrikanın proses akış diyagramı.
Figure 1. Process flow diagram of sample factory.

Pelet Presi

Pelet formda yapılacak olan yemler mikser ve melasyerin ardından toz halde pres üst depolarına gelmektedir. Pelet pres makinesine ilgili yem için gereken ebattaki pelet diski takılmaktadır. Pelet yapımında su buharı çok önemlidir. Pelet kalitesi, buhar kalitesi ile alakalıdır. Pelet presleri, toz yemin 85-90°C'de buharla karıştırılarak, disk ve rulo yardımı ile mekanik olarak sıkıştırılıp, üretimini sağlayan bir makinedir. Buharla pişirilen yem, içindeki nişastanın jelatinize olması sebebi ile hayvanlar için sindirimi daha kolay hale gelmektedir. Hayvanlar için zararlı, hastalık yapıcı bakterilerin (Salmonella) ölmesini sağlamaktadır. Toz yem şartlandırıcıdan geçerken buharla yoğrulup yaklaşık 85-90°C sıcaklığa ulaşınca disk ile rulo arasında basınçla diskten geçip istenilen seviyede ayarlanan bıçaklar vasıtası ile kesilerek soğutucuya inmektedir. Soğutucuda istenilen sıcaklığa kadar soğuduktan sonra soğutucu kapakları açılarak ilgili taşıma yolları ile elekten elendikten sonra mamul depoya taşınarak paketlenmektedir. Elenen partiküller ise peletlenmek üzere tekrar pelet pres toz depolarına gönderilmektedir.

Pelet Soğutucu

Presten pelet formunda sıcak olarak çıkan yemlerin, ortam sıcaklığına soğutulmasında pres soğutucular kullanılmaktadır. Pres soğutucular karşı hava akım prensibine göre çalışmaktadır. Dış ortamdaki hava, soğutucu içerisinde yem ile temas ettirilmesiyle yem sıcaklığı düşmekte ve ısınan havanın aspirasyon sistemi ile ortamdan uzaklaştırılmaktadır. Soğutucu üzerinde bulunan boşaltma sistemi ile soğutulan yem tahliye edilmektedir. Sıcaklık, gövde üzerinde bulunan sensörler ile kontrol edilmektedir. Aspirasyon ünitesine giden sıcak hava içindeki yem tozları, siklon ile tekrar sisteme geri gönderilmektedir. Soğutucu sonrası pelet yem, sertleşmekte ve böylece paketlemede tozlanma engellenmiş olmaktadır.

İnvertör

İnvertör, bir dönüştürme sistemidir. Enerji tasarrufu sağlamak amacıyla kullanılmaktadır. Bu anlamda enerji tasarrufunu sağlamak amacıyla devrelerdeki frekans ayarını düzenleyen cihazlara da invertör ismi verilmektedir. İnvertörler, alternatif akımı doğru akıma, doğru akımı da alternatif akıma çeviren ve 3 fazlı çalışma sistemine sahip olan, gerilim ve frekansları düzgün bir şekilde ayarlayan cihazlardır. Çalışmanın yapıldığı 2018 yılı Aralık ayında fabrikada 20 defa zaman analiz yapılmış olup, yem üretim aşamaları kayıt altına alınmıştır. Üretim aşamaları; dozajlama süresi, öğütme süresi, mikser karışım süresi ve melas mikseri karıştırma süreleri olmak üzere dört aşamada incelenmiştir. Üretim aşamalarında formül içeriğinde melas olup olmamasına göre iki aşamada inceleme yapılmıştır. İlk incelemeler melaslı yemlerde ikinci aşama melassız yemlerde yapılarak her birinde zaman analizleri incelenmiştir.

BULGULAR ve TARTIŞMA

Karma Yem Üretim Aşamaları ve Zaman Analizi

Yapılan zaman analizi ile ilgili değerlendirme Çizelge 1'de verilmiştir. Formülasyon içeriğine göre melaslı yemlerde ortalama bir parti yemin 603 s'de yapıldığı ölçülmüştür.

Analizi yapılan yem kodlarında ikinci dijit A, B, C olan yemler kanatlı yemleri, F, G, H, L olanlar ise büyükbaş ve küçükbaş yemlerinin kodlamaları olarak verilmiştir.

Çizelge 1. Yem geçiş sürelerine ilişkin zaman analizi (Melaslı yemlerde).
Table 1. Time analysis for feed transition periods (in molasses feed).

Yem Kodları	EGCB	GHBA	CBDA	EGCA	EHBA
Dozajlama Süresi (s)	182	165	65	142	130
Öğütme Süresi (s)	182	122	150	135	142
Mikser Karışım Süresi (s)	140	140	140	140	140
Melas Mikseri Geçiş Süresi (s)	165	188	145	196	180
Toplam (s)	**669**	**615**	**500**	**613**	**592**
Yem Kodları	GGLA	EAAM	EHBA	EHBA	EGDA
Dozajlama Süresi (s)	155	130	184	88	105
Öğütme Süresi (s)	99	198	116	135	150
Mikser Karışım Süresi (s)	140	140	140	140	140
Melas Mikseri Geçiş Süresi (s)	191	168	211	191	192
Toplam (s)	**585**	**636**	**651**	**554**	**587**
Yem Kodları	ECAA	EGCA	CHBA	EFBA	EHBA
Dozajlama Süresi (s)	102	164	110	165	145
Öğütme Süresi (s)	160	127	201	185	178
Mikser Karışım Süresi (s)	140	140	140	140	140
Melas Mikseri Geçiş Süresi (s)	165	201	162	152	132
Toplam (s)	**567**	**632**	**613**	**642**	**595**

Çizelge 1 incelendiğinde melaslı yemlerde en fazla geçiş süresi melas mikserinde, ardından mikserde ve öğütme aşamalarında saptanmıştır. Melas mikserine uğramayan yemlerde ise geçiş süresi ortalama 428 s olarak kaydedilmiştir. Çizelge 2'de ölçüm yapılan zaman analizleri verilmiştir.

Çizelge 2. Yem geçiş analizi (Melassız yemlerde).
Table 2. Feed transition analysis (in feeds without molasses).

Yem Kodları	ECDF	ECDF	EBEA	ECBG	ECDD
Dozajlama Süresi (s)	130	200	129	102	106
Öğütme Süresi (s)	145	161	108	168	195
Mikser Karışım Süresi (s)	140	140	140	140	140
Toplam (s)	**415**	**501**	**377**	**410**	**441**

Çizelge 2 incelendiğinde melassız yemlerde en fazla geçiş süresi öğütme, ardından mikser aşamalarında gerçekleştiği görülmektedir.

Yem yapılma analizlerine göre fabrikada bir vardiyada melaslı yem üretimi ve melassız yem üretimi yapıldığında bir parti yem ortalama 6 ile 7 dk arasında yapılmaktadır.

Pres Yem Geçiş Aşamaları ve Toz Dönüş Çalışma Süresi

17-22.12.2018 tarihleri arasında fabrikada pres yem geçiş süreleri ve preslerdeki yemin toz başlangıç ve bitiş süreleri incelenmiştir (Çizelge 3). Çalışma sırasında pelet presleri üç vardiya boyunca çalışmış olup geçen yemler kayıt altına alınmıştır. İncelemelerde pelet pres 1 ve pelet pres 2 yemlerini çalışan pres makinalarında büyükbaş ve küçükbaş yemleri yapılmakta olup, pres 3 de ise kanatlı yemleri yapılmaktadır.

Çizelge 3'te, pelet presi 1 den geçen yemin toz başlangıç ve bitiş süreleri incelendiğinde, ölçülen değerlerin ortalama değerleri olarak presin toz dönüş zamanı için çalıştığı süre 15 dk, pelet presi 2 de toz dönüş zamanı ortalama 17 dk ve pelet pres 3'te yemin toz dönüş zamanın tamamlanması için geçen süre 20 dk olarak hesaplanmıştır.

Çizelge 3. Pres yem geçiş analizleri.
Table 3. Press feed transition analysis.

Tarih	Pres No	Yem Kodu	Miktar (ton)	Çalışma Başlangıcı	Çalışma Bitişi	Toz Dönüş Başlangıcı	Toz Dönüş Bitişi	Toplam Çalışma Zamanı
17.12.18	2	EFBA	21	08:26	10:45	10:45	10:55	00:10
17.12.18	3	ECDD	18	09:00	11:10	11:10	11:35	00:25
17.12.18	3	ECAA	6	12:00	12:40	12:40	13:20	00:40
17.12.18	1	EFAA	9	13:15	13:45	13:45	14:00	00:15
17.12.18	1	EGCA	12	14:00	16:40	16:40	16:55	00:15
17.12.18	2	EGCA	15	16:00	17:10	17:00	17:25	00:25
17.12.18	1	FFCA	3	17:30	17:40	17:40	17:55	00:15
17.12.18	2	ELBA	30	17:50	20:10	20:10	20:30	00:20
17.12.18	3	EGCA	15	18:25	19:40	19:40	20:00	00:20
17.12.18	3	ECBG	18	20:10	21:55	21:55	22:10	00:15
17.12.18	2	ELBB	15	21:05	22:10	22:10	22:25	00:15
17.12.18	3	EBBA	21	00:00	01:50	01:50	02:10	00:20
17.12.18	2	EFAA	3	01:20	01:35	01:35	01:50	00:15
17.12.18	3	ECHD	15	02:10	03:30	03:30	03:50	00:20
17.12.18	1	ECHC	6	07:10	07:40	07:40	08:00	00:20
17.12.18	3	EBFA	18	07:10	08:35	08:35	08:50	00:15
18.12.18	1	ECDD	18	09:00	10:15	10:15	10:30	00:15
18.12.18	3	EBDA	18	08:55	10:10	10:10	10:25	00:15
18.12.18	2	GGHA	9	09:25	10:10	10:10	10:20	00:10
18.12.18	2	ELBA	45	10:25	13:45	13:45	14:15	00:30
18.12.18	2	EFDA	24	17:00	18:40	18:40	19:00	00:20
18.12.18	1	EFBA	18	18:45	19:55	19:55	20:15	00:20
18.12.18	1	ALBA	12	20:15	21:05	21:05	21:25	00:20
18.12.18	3	EBBA	30	21:15	00:00	00:00	00:40	00:40
18.12.18	3	ECDF	15	03:10	05:00	05:00	05:20	00:20
18.12.18	3	EBFA	12	04:50	06:40	06:40	06:55	00:15
18.12.18	3	EAAA	9	07:00	07:40	07:40	08:00	00:20
19.12.18	3	ECBA	18	09:20	10:50	10:50	11:15	00:25
19.12.18	1	ECDD	48	11:25	15:45	15:45	16:00	00:15
19.12.18	3	ECHC	15	11:50	13:05	13:05	13:25	00:20
19.12.18	3	EBED	12	13:20	14:20	14:20	14:35	00:15
19.12.18	3	ECHD	15	16:00	17:20	17:20	17:40	00:20
19.12.18	3	EBDA	12	17:50	18:45	18:45	19:00	00:15
19.12.18	2	ECBG	18	19:05	21:05	21:05	21:25	00:20
19.12.18	3	ECDD	15	21:25	22:40	22:40	23:00	00:20
19.12.18	3	EBBA	30	00:00	04:00	04:00	04:20	00:20
19.12.18	2	ELBA	27	02:50	04:40	04:50	05:00	00:10
19.12.18	1	ALBS	9	05:30	06:10	06:10	06:25	00:15
20.12.18	3	ECDF	15	09:15	10:45	10:45	11:05	00:20
20.12.18	1	ELCA	18	11:35	14:00	14:00	14:10	00:10
20.12.18	3	EBDA	30	12:25	15:00	15:00	15:25	00:25
20.12.18	3	ECDD	27	17:00	18:40	18:40	19:00	00:20
20.12.18	1	EFBA	18	18:50	20:00	20:00	20:10	00:10
20.12.18	3	ECBG	18	19:05	21:05	21:05	21:25	00:20
20.12.18	3	EBBA	9	00:00	00:50	00:50	01:10	00:20
20.12.18	3	ECDH	9	02:30	03:20	03:20	03:40	00:20
21.12.18	3	EFEA	6	10:45	11:10	11:10	11::20	00::10
21.12.18	3	EBEA	9	17:00	17:50	17:50	18:05	00:15
21.12.18	3	EHCD	18	19:00	20:35	20:35	20:55	00:20
21.12.18	1	EFBA	21	20:10	21:30	21:30	21:40	00:10
21.12.18	3	EBDA	12	21:00	22:15	22:15	22:35	00:20
21.12.18	1	EFAA	12	21:40	22:25	22:25	22:35	00:10
21.12.18	3	EBBA	24	01:00	05:00	05:00	05:30	00:30
22.12.18	3	ECDD	21	08:40	10:30	10:30	10:55	00:25
22.12.18	3	ABDA	3	12:00	12:20	12:20	12:40	00:20
22.12.18	1	EFCA	15	13:25	14:25	14:25	14:40	00:15

Toz Dönüş Çalışma Sürelerinin İnvertör Değerlerinin Okunması

Pelet preslerinde yapılan yem geçiş analizlerinde toz dönüş zamanları invertör değerlerinde incelenmiştir. Veriler fabrikada bulunan sistem üzerinden otomatik olarak okunarak kayıt altına alınmıştır. Çizelge 4, 5 ve 6'da görüldüğü üzere toz başlangıç kWh ve toz bitiş kWh verileri alınarak fark değerleri çıkartılmıştır.

Çizelge 4. Pelet pres 1 yem invertör verileri.
Table 4. Pellet press 1 feed inverter data.

Tarih	Toz Dönüş Başlangıç (kWh)	Toz Dönüş Bitiş (kWh)	Fark (kWh)
17.12.18	2 518 276.360	2 518 394.480	118.120
17.12.18	2 518 606.427	2 518 671.879	65.452
18.12.18	2 518 767.270	2 518 863.615	96.345
19.12.18	2 517 589.176	2 517 598.928	9.752
20.12.18	2 520 899.283	2 521 005.937	106.654
20.12.18	2 522 652.406	2 522 690.036	37.630
20.12.18	2 522 652.406	2 522 690.036	37.630
Ortalama fark değer (kWh)			67.369

Pres 1 de yapılan incelemelerde 7 kayıt incelenmiş olup Çizelge 4'te görülmektedir. Toz dönüş anında pelet presi 1 ortalama 67.37 kWh enerji harcamaktadır.

Çizelge 5. Pelet pres 2 yem invertör verileri.
Table 5. Pellet press 2 feed inverter data.

Tarih	Toz Dönüş Başlangıç (kWh)	Toz Dönüş Bitiş (kWh)	Fark (kWh)
17.12.18	2 175 603.629	2 175 678.548	74.919
18.12.18	2 176 214.883	2 176 215.527	0.644
19.12.18	2 178 005.379	2 178 087.909	82.530
20.12.18	2 181 145.612	2 181 240.886	95.274
Ortalama fark değeri (kWh)			63.342

Pres 2 de yapılan incelemelerde 4 kayıt incelenmiş olup Çizelge 5'de görülmektedir. Toz dönüş anında pelet presi 2 ortalama 63.34 kWh enerji harcamaktadır.

Çizelge 6. Pelet pres 3 yem invertör verileri.
Table 6. Pellet press 3 feed inverter data.

Tarih	Toz Dönüş Başlangıç (kWh)	Toz Dönüş Bitiş (kWh)	Fark (kWh)
17.12.18	1 931 562.326	1 931 633.969	71.643
17.12.18	1 932 528.123	1 932 606.901	78.778
18.12.18	1 935 033.488	1 935 116.699	83,211
19.12.18	1 937 394.278	1 937 473.453	79.175
20.12.18	1 938 437.817	1 938 501.873	64.056
21.12.18	1 939 741.655	1 939 803.331	61.676
21.12.18	1 941 418.132	1 941 418.165	0.033
Ortalama fark değeri (kWh)			62.653

Pres 3 de yapılan incelemelerde ise 7 kayıt incelenmiştir (Çizelge 6). Toz dönüş anında pelet presi 3 ortalama 62.65 kWh enerji harcamaktadır.

Enerji Maliyetlerinin Hesaplanması

Fabrikanın yem kayıt raporlarından alınan verilere göre; preslerden bir hafta boyunca geçen yemler incelendiğinde toplamda pres 1 de 58 yem, pres 2 de 47 yem ve pres 3 de 59 yem çalıştırılıp geçirilmiştir (15.02.2019 tarihi itibarıyla).

- ➤ Enerji bedeli (kWh başına); 0.437640 TL
- ➤ Pres 1 = 67.37*0.437640 = 29.48 TL
- ➤ Pres 2 = 63.34*0.437640 = 27.72 TL
- ➤ Pres 3 = 62.65*0.437640 = 27.42 TL

İncelemeler bir haftada pres 1 de 58 yem çeşidinde ortalama her yem sonrasında 15 dk toz dönüş için çalıştırılması;

➢ Pres 1 = 15*58 = 870 dk / 60 = 14.5 saat *29.48 TL= 427.46 TL/hafta

İncelemeler bir haftada pres 2 de 47 yem çeşidinde ortalama her yem sonrasında 17 dk toz dönüş için çalıştırılması;

➢ Pres 2 = 17*47 = 799 dk / 60 = 13.32 saat * 27.72 TL= 369.23 TL/hafta

İncelemeler bir haftada pres 3 de 59 yem çeşidinde ortalama her yem sonrasında 20 dk toz dönüş için çalıştırılması;

➢ Pres 3 = 20*59 = 1180 dk / 60 = 19.67 saat *27.42 TL = 539.35 TL/hafta toz dönüş için preslerin çalıştırılmasına sebep olmaktadır.

Toplamda preslerin bir aylık toz dönüş zamanları incelendiğinde tüketilen enerjinin miktarı; (427.46*4)+(369.23*4)+(539.35*4) = 5344.16 TL olmaktadır.

Yem fabrikalarında toz dönüş depoları yem çeşitliliğine göre ayarlanmakta ve kapasiteleri aylık ortalama yapılan yemlere göre hesaplanmaktadır. Yapılan depolardaki toz dönüş zamanında verilen yem, presler tekrar çalıştırılmaya başlandığında tekrardan prese gönderilerek üretim sürecine dahil edilmektedir. Planlanan örnek toz dönüş depoları Şekil 2'de gösterilmiştir. Ortak yollar yapılacak olup çalıştırılacak her bir presten yol verilmesi sağlanacaktır.
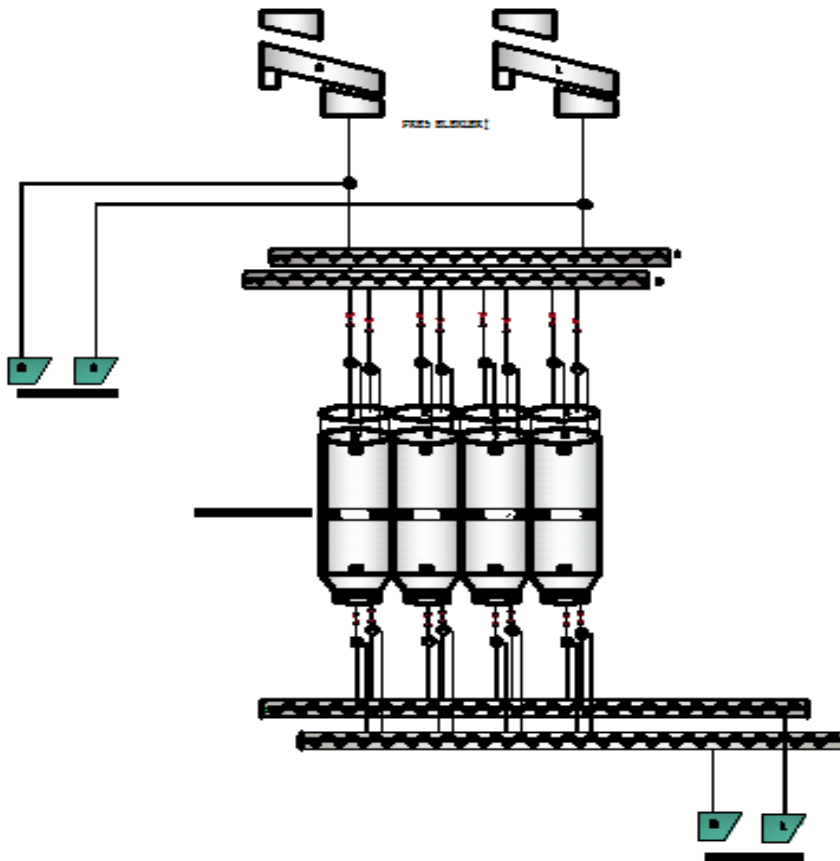
Şekil 2. Toz geri dönüş depoları.
Figure 2. Dust return tanks.

Pelet preslerinin toz dönüşünde kaybedilen zamanı kazanmak ve enerji verimliliği elde etmek için toz dönüş depoları çözüm önerisi olarak sunulmuştur. Toz dönüş depoları yemlerin çeşitliliğine ve fabrikalarda bulunan pres üst depolarının sayısına göre belirlenmesi gerekmektedir. Yem, pres üst deposunda bittiğinde elekten gelen geri

dönüş toz dönüş depolarına verilerek gelen az miktardaki dönüş yemi için pres soğutucu ve yolların çalışması durdurulacaktır. Toz dönüş depolarına verilen yem tekrardan yapıldığında pres üst deposunda bulunan yem ile birlikte çalışarak kayıp zamanın önüne geçilecektir.

Aylık olarak preslerden geçen geri dönüşlerdeki toz yem miktarı sıfırlanacak olup 5 344 TL elektrik enerjisinden tasarruf edilecektir. Fabrika kapasitesi göz önünde bulundurulduğunda toz geri dönüşlerdeki preslerin çalışmaları sıfırlanmış olacaktır. Toz geri dönüş depoları da 8 adet 3 tonluk altı konik ayaklı 4 mm saçtan fiyat teklifi alınmış olup maliyetinin bir depoda 9 500 TL olduğu görülmüştür. Önerilen sistemin yapılacak olan depo sayısına göre kendini kısa sürede amorti edeceği düşünülmektedir. Toz dönüş ile preslerde yemin bitmesinden elde edilen verilere göre zaman analizleri Şekil 3'te pelet pres toz dönüş analizleri (toz dönüş dahil) ve Şekil 4'te pelet pres yem geçiş analizleri (toz dönüşsüz) gösterilmektedir. İlk olarak alınan kayıtlarda toz dönüş zamanları eklenerek kaydedilen verilerde, toz dönüş depoları yapılır ise 20 dk zamandan kazanılarak yemin pelet pres ve soğutucu içerisinde hazır olma zamanı 4 dk 15 s inecektir.
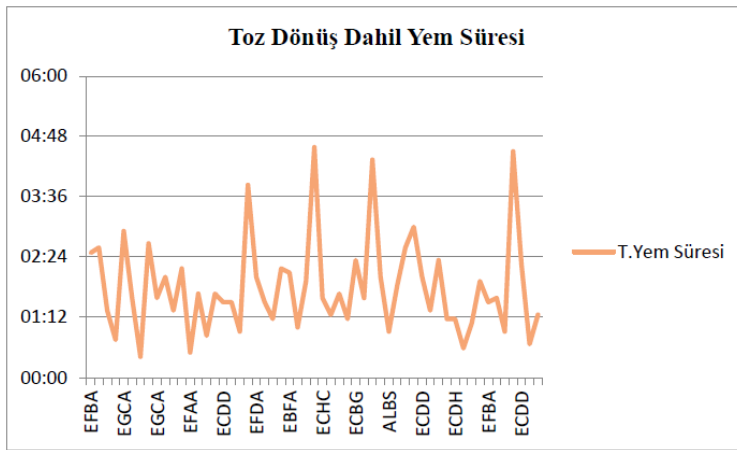
Şekil 3. Pelet pres yem geçiş analizleri (Toz dönüş dahil).
Figure 3. Pellet press feed transition analysis (including dust return).
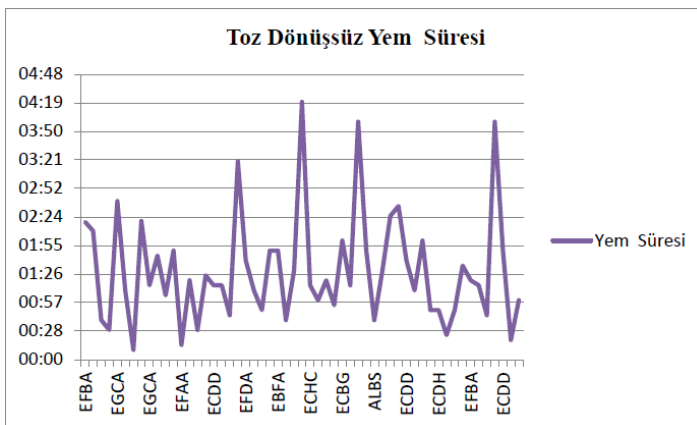
Şekil 4. Pelet pres yem geçiş analizleri (Toz dönüşsüz).
Figure 4. Pellet press feed transition analysis (without dust return).

Akdeniz ve ark. (2005) yaptıkları çalışmada, hali hazırda faaliyette olan karma yem fabrikalarının, kurulu kapasitelerinin önemli bir kısmını kullanamadığını ve bu nedenle de yeni karma yem fabrikası kurulmasında, pazar araştırması ve fizibilite

çalışmalarına göre karar verilmesi gerektiğini bildirmişlerdir. Karma yem fabrikası için yer seçiminde birçok faktörün yanı sıra, taşıma ve iletim giderlerinin en aza indirilmesi açısından hammadde kaynaklarına yakınlık ve ürünün pazarlama alanının ayrıntılı olarak etüt edilmesi gerektiğini ve kurulu fabrikaların kapasitelerini artırmak ve prosesi yenilemek amaçlı yeni teknik ve teknolojiler içeren yatırımlara destek sağlanması gerektiğini rapor etmişlerdir.

Boyar (2006) yaptığı çalışmada, iki yem fabrikasında üretimde yer alan bazı makinaları ayrıntılı olarak değerlendirmiş ve bunlara ilişkin tasarruf olanaklarını üç ayrı sınıfta ortaya koymuştur. İncelenen makinaların üretim kapasitelerinin altında çalıştırıldıkları, mevcut elektrik motorlarının yeterince yüklenmedikleri ve verimlerinin oldukça altında çalıştırıldıklarını raporlamıştır. Toplam enerji tasarruf potansiyelinin sırasıyla %10.24 ve %14.07 olarak belirlendiği, büyükbaş ve hindi yemi fabrikasında 100 841 kWh'lık tasarruf kaynağının %62.72'si, büyükbaş yem fabrikasında 99 696 kWh'lık tasarruf kaynağının %83.76'sının uygulanabilir olduğu bildirilmiştir. Bu nedenle, verimliliğin artırılması için makinaların hem akıllı yük kontrol sistemleri ile donatılıp materyal besleme ve yük kontrolünün yapılması hem de elektrik motorlarının yüksek verimli olanları ile değiştirilmesi önerilmiştir.

Basmacıoğlu (2004) yaptığı çalışmada, karma yem endüstrisinde pelet kalitesine etkili faktörleri incelemiştir. Buna göre, pelet yem gerek fiziksel (taşıma kolaylığı, azalan dehomojenizasyon ve artan yoğunluk) gerekse bu yemi tüketen hayvanların performansları üzerindeki olumlu etkilerinden dolayı gittikçe artış göstermektedir. Pelet yemin olumlu etkileri büyük ölçüde peletin fiziksel kalitesine bağlıdır. Pelet yem, üretimden hayvanın yemliğine kadar geçen sürede formun korunması amaçlanmalıdır. Yeme (fiziksel ve kimyasal özellikler, formülasyon) ve uygulanan teknolojiye ait özellikler (su buharı, tavlama, yağ ilavesi, matris özellikleri ve soğutma) pelet kalitesini etkileyen etkenlerdir. İstenen kalitede pelet yem üretimi söz konusu etkenlerin dikkate alınması ile mümkündür. Toz yemlerin sıkıştırılarak değişik boyutlarda pelet haline getirilmesi ile çiftlik hayvanlarında daha yüksek bir performansa ulaşılmaktadır. Ancak böyle bir oluşum yüksek kaliteli (fiziksel kalite=form) pelet yemlerin kullanılması ile gerçekleşecektir. Basmacıoğlu (2004)'na göre pelet kalitesi birçok etkenin etkisi altında olup kaliteli pelet yem üretimi bu etkenlerin dikkate alınması ile mümkündür. Araştırmacı günümüzde pelet yem üreticileri tarafından üretim maliyeti üzerinde önemle durulurken pelet kalitesinin çoğu zaman göz ardı edildiğini ancak pelet yem üretiminde kalitenin korunarak üretimin ekonomik bir şekilde gerçekleştirilmesi gerektiğini vurgulamıştır.

Haiba ve ark. (2017) yaptıkları çalışmada, pelet kalitesine etki eden birçok faktör bulunduğunu, kaliteli pelet üretiminin hem hammadde hem de pelet formülasyonu, partikül büyüklüğü ile üretim aşamasında tavlama, matris ve soğutma gibi etkenlere bağlı olduğunu; kaliteli pelet üretiminde dayanıklılık, sertlik, uzunluk, tozluluk gibi kriterlerin dikkate alınması gerektiğini ve pelet üretiminde yapılacak hataların gerek yem kayıpları, gerekse hayvan performansında düşüşe sebep olması nedeniyle büyük ekonomik kayıplara yol açabileceğini bildirmişlerdir.

SONUÇ

Bir karma yem fabrikasında, kayıt altına alınan verilere göre pelet preslerinden geçen çeşitli yemlerin toz dönüş zamanları incelenerek enerji tüketimleri hesaplanmış ve zaman analizleri yapılmıştır. 2018 yılı aralık ayında fabrikada üretim aşamalarında (dozajlama, öğütme, mikser karışım süresi, melas mikseri geçiş süresi) 20 defa yem analizi yapılmış melas ilaveli ve melas ilavesiz yemlerde veriler kayıt altına alınmıştır. Melaslı yemlerde 603 s melassız yemlerde ise 428 s'lik sürelerde üretim aşamalarının tamamlandığı görülmüştür.

Üretimleri gerçekleşen yemlerin toz dönüş zamanlarında harcanan enerji invertörlerden alınan veriler ile hesaplanmıştır. Hesaplamalar sonucunda yem fabrikasında kapasite artırılması ve enerji tasarrufu sağlanması için toz dönüş depoları çözüm olarak sunulmuştur. Toz dönüş depoları yapılması durumunda alınan kayıtlara göre yemin toz dönüş süresinde 20 dk zaman kazanılmış olup böylelikle kapasite artırımı sağlanmış olacaktır. Aylık periyotlarda preslerden geçen geri dönüşlerdeki toz yem miktarı sıfırlanacak olup 5 344 TL elektrik enerjisinden tasarruf edileceği sonucuna varılmıştır. Türkiye'deki 14 750 adet yem fabrikası işletme içerisinde karma yem üreten ve kendi yemini üreten işletmeler dikkate alındığında 1 329 adet işletme bulunmaktadır. Her işletmede ortalama 3 adet pres bulunduğu varsayılır ise yem çeşitliliği göz önünde bulundurularak aylık bir fabrikada 12 106 kW enerji harcanması durumunda 1 329 işletme için 16 088 874 kWh enerji harcanmaktadır. İşletmelerde pelet pres yemlerinde toz dönüş depoları yapıldığında harcanan elektrik enerjisi azaltılmış olacaktır. Ayrıca toz dönüş zamanı için preslerde zaman kaybı önlenmiş olup çalışma zamanları da daha verimli hale gelecektir.

Bu çalışmada bulgulardan elde edilen öneriler aşağıda sıralanmıştır.

1. Karma yem fabrikalarında kapasite analizlerinin yapılması ve kayıp zamanların çıkartılması gerekmektedir. Harcanan enerjiye bakılmalı ve kayıp zamanlar mümkün oldukça ortadan kaldırılmaya çalışılmalıdır.

Yapılan çalışma doğrultusunda soğutucularda bulunan kayıp zamanın toz geri dönüş depoları ile geri kazanılabileceği görülmüştür. Bu çalışmada önerilen depolar fazla yem çeşitliliği fazla olan fabrikalarda verim artışı sağlamak içindir.. Yem çeşitliliği az olan fabrikalarda tekrardan maliyet hesaplaması yapılması gerekmektedir.

2. Yapılacak olan toz geri dönüş depolarında çalışma yolunun uzunluğu önemli bir kriterdir. Yem çalışma yollarındaki enerji tüketimi hesaplanmalıdır.

ÇIKAR ÇATIŞMASI

Herhangi bir çıkar çatışması bulunmamaktadır.

YAZAR KATKISI

Bu makale Yüksek lisans tezinden hazırlanmıştır.
Duygunur Özcen: Çalışmanın giriş, materyal ve yöntem, sonuç bölümlerinin hazırlanması.
Mehmet Metin Özgüven: Çalışmanın giriş, materyal ve yöntem, sonuç bölümlerinin gözden geçirilmesi.

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Mechanical Behaviour of Unshelled *Moringa oleifera* Seeds at Varying Moisture Contents

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ABSTRACT

The determination of mechanical properties of unshelled Moringa oleifera seeds was studied under compression test at varying orientations and moisture contents for postharvest equipment design. A completely randomized block design (CRBD) was applied in designing the experiment. The impact of varying moisture content levels of (10.25, 17.33, 24.47, and 32.34% dry basis) on the applied force at bio-yield and rupture, deformation, energy at rupture, crushing strength, and elastic modulus of the seed samples were investigated. Polynomial functions of the 2nd order with coefficients of correlation ranging between $0.642 \leq R^2 \leq 0.999$ gave the best fit and described the resulting relationships between the studied properties with respect to moisture levels at the two loading axes. Results obtained showed that the seed samples had maximum values of 80.3 N, 110 N and 257.2 J, for bio-yield force, rupture and rupture energy respectively at (10.25% d.b., in the horizontal orientation; whereas minimum values of 31.5 N, 54.9 N and 51.3 J for bio-yield force, rupture force and rupture energy occurred at (32.34% d.b.) respectively in the vertical orientation. Also, the maximum compressive strength of 5.8 N mm^{-2} in the horizontal orientation of the seed samples at 10.25% d.b. whereas the minimum compressive strength (2.5 N mm^{-2}) occurred in the vertical orientation at 10.25% d.b. moisture content. The sample exhibited less resistive strength to crushing in the horizontal position as the moisture increased; whereas in the vertical position, the cell's vertical edges provide some form of shield against external pressure which resulted in increased crushing resistance per contact area of the sample.

INTRODUCTION

Moringa oleifera (synonymously called *M. pterygosperma* Gaertn) is the widely cultivated species of the genus in Moringa, which is the best genus inside the family of Moringaceae. It has fourteen species (Morton, 1991) which is tremendous all through the tropics. Moringa is a fast-growing, drought-resistant, evergreen, deciduous tree with an open crown of drooping fragile branches, feathery foliage of tripinnate leaves, white plant flowers and long pods, extensively cultivated in farms and compounds (primarily as fence) mainly within the Northern part of Nigeria and many nations in the tropical and subtropical Africa like Nigeria, Ghana, Kenya, Ethiopia, Madagascar, et cetera (Anjorin, 2010; Aviara *et al.,* 2013; Ndukwe *et al.,* 2014). In Nigeria, the plant is popularly known as the "miracle tree" or "tree of life" and it is recognized by way of various names, inclusively of Drumstick tree or Horseradish plant in English, Zogale in Hausa, 'Okwe oyibo' or 'Okwulu oyibo' in Igbo, Ewe Ile in Yoruba and Gawara in Fulani. Research had shown that Moringa was found to contain many essential nutrients that are humanly edible, for instance, vitamins, minerals, amino acids, beta-carotene, antioxidant, anti-inflammatory nutrients, omega 3 and 6 fatty acids which are the raw materials for medicinal, oil, pharmaceutical, cosmetic, food and feed industries in both tropical and subtropical countries (Fahey, 2005; Hsu *et al.,* 2006; Kasolo *et al.,* 2010). The powdered seed is used as an animal feed supplement, as a crop fertilizer and as an effective water purifier and the extracts can produce powerful pesticides that keep other plants healthy. In many communities, where the only drinking water available may come from a polluted lake, the standard of water purification is important (Oloyede *et al.,* 2015). It has been observed that Nigerian Moringa farmers both in the North, South, East and Western regions make do with manual means of processing its seed (Figure 1). This brings about drudgery, low production output and poor-quality product with low income generated at the end. With this hassle in mind, no matter the monetary significance of Moringa seed, no commercial production and industrial usage of the crop takes place in Nigeria. Akani *et al.* (2000), stated that research has been concentrated best on agronomics, while work on the processing of indigenous plants seems to have been neglected. In recent times, greater attention has been given to the use of under-exploited locally available agricultural products and by-products in developing countries for food/fiber processing. Such use would assist these countries, especially African countries, which are currently facing adverse economic problems.

Figure 1. Moringa seeds.

The properties such as size, shape, volume, bulk density, true (particle) density, porosity, angle of internal friction, rupture, arithmetic and geometric diameters, surface areas, sphericity, moisture content, one thousand and unit seed weights, repose angle, deformation energy static coefficient of friction, angle of repose, bio-yield point, bio-yield strength, yield force, rupture point and rupture strength of the seed were obtained by Adejumo and Abayomi (2012); Aviara *et al.* (2013); Ndukwe *et al.* (2014); Oloyede *et al.* (2015); Olayanju *et al.* (2018); Abubakar and Benjamin (2019). These and more data from studies will aid the design and development of machines for processing the seed which will in turn boost massive scale production of the plants by farmers and thereby create jobs and revenue. To design effective machines for handling, conveying systems, separation, processing units, storage facilities, drying, aerating and extracting oil from Moringa seed, there is a need to have more research on its mechanical properties (Ajav and Fakayode, 2013). Agricultural materials do not behave in a purely elastic, plastic or viscous manner due to their structural nature. As a substitute, they possess a blended solid-like and liquid-like behavior and their stress-strain relationship is not only dependent on the magnitude of the stress but also is a function of time. Materials with this type of behaviour are said to be viscoelastic. Studies have shown that agricultural products are viscoelastic and the determination of the engineering properties of biomaterials are difficult and complicated, since the properties are affected by moisture content, temperature and the rate of loading (Nwuba *et al.*, 1994; ASAE, 2004; Ardebili, 2012; Niveditha, 2013). From the data available, it appeared that the viscoelastic behaviour of biomaterial is non-linear (ASAE, 2004; Ardebili, 2012; Niveditha, 2013). Since non-linear viscoelasticity theory has not been well defined in the literature, the linear viscoelastic technique was applied in the study to define the behavior of Moringa seed under the influence of external load.

MATERIALS AND METHODS

Two hundred unshelled Moringa seeds were used for the completely randomized block design experiments and were taken to Civil Engineering Materials Laboratory at the University of Nigeria, Nsukka (UNN), for the compression tests.

Moisture Determination of the Seed

To obtain the moisture in the whole bulk, the quantity was bound and stored in a polyethylene bag for 78 hours. Some samples were taken randomly to determine the initial moisture content of the seed by drying the samples for 24 hours in an air-ventilated oven at 103°C (ASAE, 2001; Ozarslan, 2002). In addition to the initial moisture samples, the remaining mass was split into four parts, which were reconstituted by adding a measured volume of distilled water and sealing them in separate polyethylene bags and storing them in a refrigerator at 5°C for a week to enable the moisture to distribute uniformly throughout the sample (Sacilik, 2003; Garnayak *et al.,* 2008; Aviara *et al.,* 2013). The initial moisture contents (dry basis) of the seed samples were determined by the relationship (ASAE, 2001):

$$\% \ Moisture \ Content \ (d.b) = \frac{\{M_i - M_f\}}{M_f} \times 100 \qquad (1)$$

Where, M_i = initial mass of the seeds/kernels in grams and M_f = final mass of the seeds/kernels in grams when constant mass is detected.

Also, the quantity of distilled water added to the samples, to obtain the required moisture content of study was calculated through Equation 2 below (Tabatabaeefar, 2003; Adejumo and Abayomi, 2012; Ndukwe *et al.*, 2014):

$$W_2 = W_1 \times \left\{ \frac{M_2 - M_1}{100 - M_2} \right\}$$ (2)

Where, W_2 = the initial moisture content of sample in % dry basis, and M_2 = the desired moisture content of the sample in % dry basis.

Before starting the compression tests, the required quantity of the seed was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 hours (Singh and Goswami, 1996; Coskun *et al.*, 2006) and after which the reconstituted samples were checked for the moisture content using the method described by ASAE (2001); Sacilik (2003); Oloyede *et al.* (2015) and values obtained were 10.25%, 17.33%, 24.47% and 32.34% (on dry basis) for the tests. The samples were kept in sealed conditions to attain an ambient environment so that there is no chance of changing moisture.

The compression tests (Figure 2a and 2b) were carried out using Hounsfield Monsanto Tensometer, with a model number of S/W L8889 of ± 0.1% accuracy having a maximum loading rate of 1350 ± 160 N s⁻¹ at speed of 2.5 mm min⁻¹ to determine the stress-strain graphs of the unshelled seed samples. The test parameters of Moringa seeds were in terms of average force at rupture and bio-yield, deformation at rupture, rupture energy, compressive strength, strain and elastic modulus at two loading positions (horizontal and vertical positions) with varying moisture contents (Adejumo and Abayomi, 2012) of 10.250, 17.329, 24.471, and 32.343% (on dry basis).
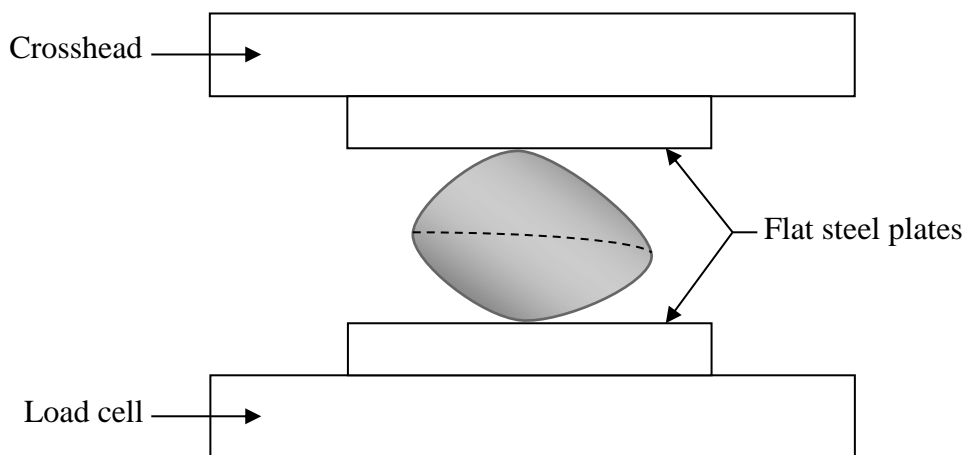
Figure 2a. Uniaxial compression of Moringa seed (Horizontal loading position).

Figure 2b. Vertical loading position.

The Moringa seed samples at the said moistures aforementioned were placed in two loading positions on the compression jaws, thereby making sure that the center of the tool was in alignment with the peak of the curvature of the Moringa seed sample. The loading arm of the tensiometer was spun at 2.5 mm min⁻¹ to apply force on the seed to a point of allowable rupture and this was accompanied by the corresponding plot of the force-deformation graph, which was concurrently done by the cursor and its attached needle, which mark the graph sheet at frequent intervals thereby recording the force and the corresponding deformation. The resultant graph produced by joining the successive marks shows the stress-strain curve, which pinpoints bio-yield spot and rupture force spot at the two loading positions and varying moisture levels. The test was repeated 10 times for each parameter at each moisture level under horizontal and vertical loading positions; the results were reported in Table1., for the unshelled seed. The functional relationship existing between the mechanical properties of Moringa seeds and moisture levels was established and expressed using regression equations of the Microsoft Excel 2007 Software package. The accuracy of measurement was 0.01 Newton for force and 0.01 millimeter for deformation (Ahmadi *et al.*, 2009; Niveditha, 2013). The room temperature during the test was 28ºC. Experimental data were analyzed using one-way analysis of variance and the means were separated at the 5% significance level applying DMRT (Duncan's New Multiple Range Tests in IBM SPSS software.

Determination of rupture energy of the seed energy for rupture, E_R, is the strength needed to rupture the seed, that is, the product of rupture force and deformation at rupture. Mathematically, the energy for rupture (Nwuba *et al.*, 1994) was computed as:

$$E_R = (\text{Seed deformation, mm}) \times (\text{maximum rupture force, N}) \tag{3}$$

Determination of Seed Deformation at Rupture From Machine Graph

The seed deformation was calculated from the machine graph as follows:

$$\text{Seed deformation, mm} = \frac{\text{Measured deformation, mm}}{4} \tag{4}$$

The graph has a magnification of 4:1

Determination of Seed Bio-Yield Force

From the machine graph plotted during loading, the bio-yield force is the force at a point on the stress-strain curve at which there occurs an increase in deformation with a decrease or no change of force (Nwuba *et al.*, 1994). The presence of bio-yield point is an indication of initial cell rupture in the cellular (micro) structure of the seed.

Determination of Seed Rupture Force

Rupture force is the force at a point on the stress-strain curve at which the axially loaded specimen ruptures or the seed was given complete damage (puncture of shell or skin, cracking or fracture planes) with the kernel exposed under load as obtained from the machine graph plotted (Nwuba *et al.*, 1994). The rupture point on the curve corresponds to a failure in the macrostructure of the seed.

Determination of Degree of Elasticity, $\boldsymbol{\beta}$ and Poisson's Ratio, $\boldsymbol{\mu}$, of Moringa Seed

The degree of elasticity was determined from loading and unloading tests performed for each specimen at the moisture contents of the study. The determination of Poisson's ratio of biomaterials is usually very involving. Trials with available instruments did not yield acceptable results. In the absence of adequate instrumentation, a Poisson's ratio of 0.35 was utilized for Moringa seed in uni-axial compression (ASAE, 2001). The chosen Poisson's ratio of Moringa seed falls within 0.25-0.49 which is the range of Poisson's ratio for agricultural products (Nwuba *et al.*, 1994).

Theoretical Consideration in Uni-Axial Compression of Unshelled Moringa Seed

The following equation from Hertz contact theory obtained from the American Society of Agricultural Engineers (ASAE) Standard: ASAE S368.4 (ASAE, 2004) and Niveditha (2013) was utilized in calculating the elastic modulus of Moringa seeds in uniaxial compression test.

$$E = \frac{0.531}{D^{3/2}} F(1 - \mu^2) \left[\left(\frac{1}{R_1} + \frac{1}{R_1^{/}} \right)^{\frac{1}{3}} + \left(\frac{1}{R_2} + \frac{1}{R_2^{/}} \right)^{\frac{1}{3}} \right]^{3/2} \tag{5}$$

Where,

E = modulus of elasticity, N mm^{-2}; F = force, N; $\boldsymbol{\mu}$ = Poisson's ratio, dimensionless

D = deformation, mm;　　　R_1, $R_1^{/}$, R_2, $R_2^{/}$ are radii of curvature.

It is assumed that for spherical Moringa seed:

$$R_2 = R_1 = R'_1 = R'_2 = \frac{d_e}{2} = \left[\frac{L(W+T)^2}{32}\right]^{1/3} \tag{6}$$

Where, d_e = Equivalent sphere diameter, mm

$$d_e = \left[\frac{L \times (W \times T)^2}{4}\right]^{\frac{1}{3}} \text{ (Joshi \textit{et al.}, 1993 and Koochaki \textit{et al.}, 2007)}$$

L = Length of seed, mm; W = width of seed, mm; T = Thickness of seed, mm

Based on this, the Hertz equation is reduced to:

$$E = 1.502F(1 - \mu^2)\left(\frac{4}{D_e^3 \times d_e}\right)^{1/2} \tag{7}$$

It is necessary to limit the deformation to the elastic zone in applying the above formula to biomaterials. Hence elastic deformation, D_e and not the total deformation, D, was used in calculating the elastic modulus of Moringa seeds. But for the application of Hertz contact theory, elastic deformation D_e, and not total deformation, D is required. Thus, the elastic deformation is calculated as:

$$D_e = \frac{\beta D}{100} \tag{8}$$

Where, β = % degree of elasticity,

Crushing strain, ε_c, is given as:

$$\varepsilon_c = \frac{D_e}{2R} = \frac{\beta D}{100(2R)} \tag{9}$$

Z is then estimated from:

$$\varepsilon_c = \frac{\left(\ln(2Z) + \frac{1}{2}\right)}{2Z^2} \tag{10}$$

Using Z, the half contact width, b, mm can be obtained.

$$Z = \frac{R}{b} \tag{11}$$

The maximum contact pressure, q_o, at the center of the contact surface is given by Hertz as the crushing strength, σ_c:

$$\sigma_c = q_0 = \frac{2F_c}{\pi l b} \tag{12}$$

Where, F_c = maximum crushing force, N; l = length of the cylindrical body in y-direction, mm.

RESULTS AND DISCUSSION

Results of the mechanical properties of unshelled Moringa seed were as shown in Table 1. The values of the mechanical properties of Moringa seed had been seen to be a feature of moisture content. The relationships existing between the parameters and moisture

content at horizontal and vertical loading positions had been greatly expressed in the polynomial equations of the second order.

Table 1. Table of mean comparison using DMRT for unshelled Moringa seed in the two principal axes at different moisture contents.

Property	Seed horizontal loading orientation				Seed vertical loading orientation			
	Moisture content (percent dry basis)							
	10.250	17.329	24.471	32.343	10.250	17.329	24.471	32.343
Bio-yield force (N)	80.297d ±4.728	51.022c ±7.722	34.666a ±4.476	44.127b ±0.499	36.116f ±0.151	42.958g ±7.715	38.215f ±0.248	31.294e ±0.332
Rupture force (N)	110.037b ±0.784	59.941a ±3.564	60.016a ±4.806	60.658a ±0.614	57.245ef ±1.837	59.334f ±1.713	65.793g ±0.463	54.925e ±5.664
Deformation (mm)	2.337c ±1.045	1.662b ±0.314	0.911a ±0.103	1.220ab ±0.042	1.736g ±0.425	1.151f ±0.185	0.868e ±0.042	0.935e ±0.080
Energy for rupture (J)	257.185b ±115.020	100.101a ±22.478	54.444a ±5.305	72.802a ±3.168	99.469g ±25.144	68.128f ±9.964	57.119ef ±3.0172	51.303e ±6.287
Compressive strength (N mm^{-2})	5.838b ±1.097	2.624c ±0.127	3.735d ±0.531	3.186d ±0.070	2.492g ±0.052	2.787g ±0.658	3.415e ±0.023	3.186g ±0.070
Modulus of elasticity (N mm^{-2})	140.295b ±74.797	130.503c ±10.963	53.472a ±11.420	94.191d ±1.720	69.169e ±0.935	102.878f ±53.982	143.188f ±6.031	135.869f ±53.539

*Means in rows with the same superscript are similar to each other at p ≤ 0.05 using Duncan's Multiple Range Test mean comparison technique.

The equations had very high coefficients of determination ($r^2 > 0.9$), which indicates that they described the relationships reasonably. These equations are of the form:

$$Y = a \pm b(MC) \pm c(MC)^2 \quad [R^2 - \text{value}] \tag{13}$$

Where: Y= mechanical property; a, b, c= regression coefficients; MC= moisture content (% d.b.)

The variations of the bio-yield force of Moringa oleifera seed with moisture content under horizontal and vertical orientation are respectively presented in Fig.3. This force decreased polynomially from 80.3 N to a minimum of 35.5 N (which is at 25.94% d.b) with increasing moisture content (from 10.25- 25.94% d.b) and then increased with more moisture (above 25.94% d.b) under horizontal loading orientation. But in a vertical position, the bio-yield force increased from 36.1 N to a maximum of 40.8 N (at 19.11%, d.b) as the moisture content increased from 10.25 to 19.11% (d.b) and decreased with similarly increase in moisture (above 19.11% d.b). This behaviour indicates an increase in intra-cellular resistance to applied pressure beyond the optimum moisture level. The minimum bio-yield force of *Moringa oleifera* seed was better at the vertical loading and occurred at a lower moisture level (at 19.11%, d.b) than that obtained under horizontal loading (at 25.94%, d.b). Table 1 showed that the bio-yield force at 10.25% MC (d.b) is significantly different from with that at 17.33%, 24.47% and 32.34% MC (d.b) in the horizontal loading orientation as well as the vertical loading orientation, bio−yield force at 10.25% and 24.47% MC (d.b) were not significant at 5% level of probability but significantly different at the moisture of 17.33% and 31.29%.
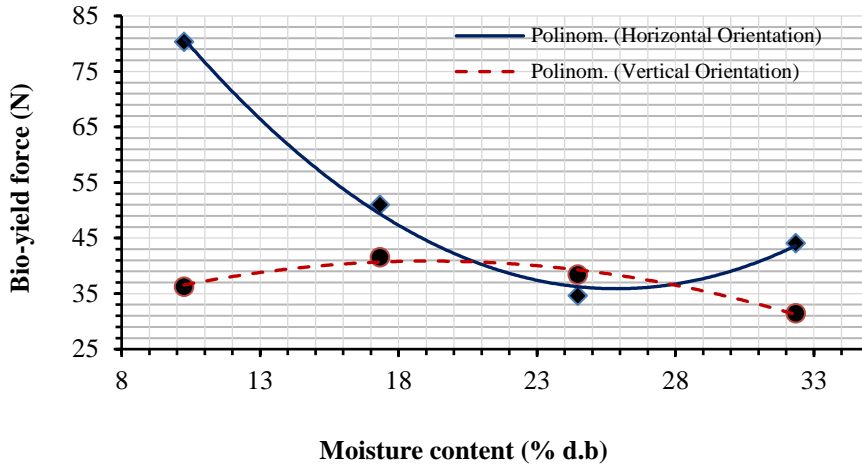
Figure 3. Effect of moisture content on bio-yield pressure of Moringa seed beneath compression test at the horizontal and vertical loading orientations.

When the moisture is above that at which the minimum values occur within the positions, the bio-yield force turned into a higher value at the vertical than on the horizontal position, but lower at moisture levels below that at which the minimum happened. The above result implies that the stress needed at the compressive cracking of unshelled Moringa oleifera seed to bring about the failure of the seed shell at the microscopic stage is moisture and loading orientation dependent. The minimal stress needed would be lower at the horizontal loading position but would require higher moisture than that, at the vertical position. The decrease in bio-yield force at the horizontal position with moisture may be due to the effect of moisture on the intercellular structure of the seed shell whereas its increase at the vertical position might be as a result of the seed shell structural arrangement of the three vertical edges running from one end of the nut to the other which constitutes reinforcement for the shell. The bio-yield force equation at varying sample moisture contents and loading orientations was described by 2nd order polynomial functions (Eqs. 14 and 15) with high R^2-values (0.994 and 0.968), which indicate that the mechanical property had a close correlation with sample moisture content.

$$Y_h = 159.3 - 9.544MC + 0.184MC^2 [\text{R}^2 = 0.994] \tag{14}$$

$$Y_v = 20.76 + 2.102MC - 0.055MC^2 [\text{R}^2 = 0.968] \tag{15}$$

Where: Y_h, Y_v = Bio-yield forces in the horizontal and vertical orientations (N), respectively, MC = moisture content (%d.b).

The varied rupture force of *Moringa oleifera* seed with moisture contents in compression under horizontal and vertical loading orientations is as shown in Fig. 4. At the horizontal orientation, the force at the rupture point dropped from 110 N to at least 52.4 N (25.79% d.b) as the moisture increased from 10.25 to 32.34% (d.b). Thereafter, it increased from 52.5 N with a similar boom in moisture level. Likewise, it surged from 57.2 N to an upmost value of 64.2 N (20.85% d.b) as moisture rose from 10.25 to 32.34% (d.b) and reduced with further growth in moisture content at the vertical loading orientation. The drop in the force at rupture with a rise in moisture become unexpected as the shell of the seed became anticipated to emerge as much less brittle as the moisture content increased.
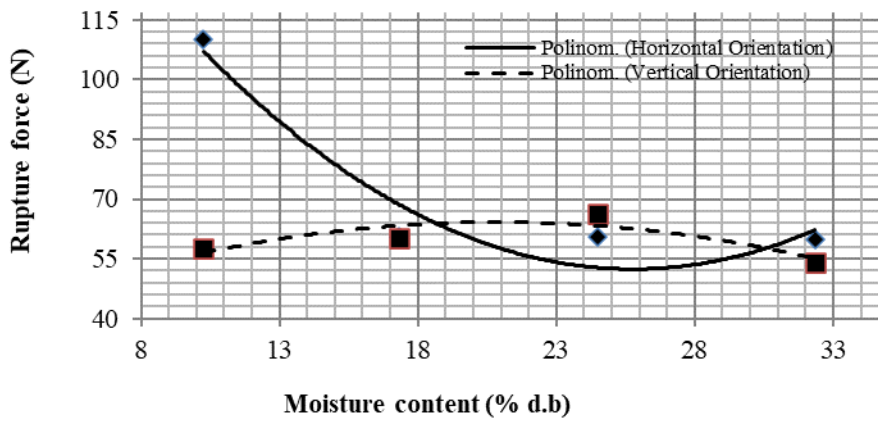
Figure 4. Effect of moisture content on force at rupture of Moringa seed underneath compression check on the horizontal and vertical loading positions.

The decrease in force at rupture of the seed at the horizontal position can be because of the moisture impact on the intercellular structure of the shell whereas the increase in rupture force at the vertical position might be as a result of the vertical bonds within the three edges running from one end of the nut to the other as seen on the shell. A similar trend was observed by Olaniyan and Oje (2002); Tavakoli *et al.* (2009); Aviara and Ajikashile (2011) for the rupture force of soybean, shea nut and conophor nut respectively concerning moisture levels. The minimum rupture force of *Moringa oleifera* seed was observed to be higher at the vertical position than at the horizontal position and this occurred at lower moisture. Moisture above that at which the minimum force at rupture occurred, rupture force was higher underneath vertical loading than on the horizontal position. The rupture force equation at varying sample moisture contents and loading orientations was described by 2nd order polynomial functions (Equations 16 and 17) with high R^2-values (0.925 and 0.751).

$$Y_h = 203.4 - 11.71MC + 0.227MC^2 \qquad [R^2 = 0.925] \qquad (16)$$

$$Y_v = 34.21 + 2.877MC - 0.069MC^2 \qquad [R^2 = 0.751] \qquad (17)$$

Where: *Y_h, Y_v* = Rupture forces in the horizontal and vertical orientations (N), respectively, *MC* = Moisture content (%d.b).

Subjecting the seed to compressive loading underneath horizontal and vertical position, deformation at rupture of seed with respect to moisture content is as shown in Figure 5. This depicts that the deformation at rupture of Moringa seed reduced from 2.3 mm to at the very least 1.1 mm as the moisture content elevated from 10.25 to 32.34% (d.b) and thereafter upsurge with a similar rise in moisture content under horizontal loading orientation. At the vertical loading position, it is observed that the deformation at rupture of seed reduced from 1.7 mm to a minimum of 0.9 mm as the moisture elevated from 10.25 to 32.34% (d.b) and thereafter upsurge with further rise in moisture. The deformation at rupture of seed at each moisture point was larger at the horizontal position than that on the vertical position. This means that the seed has a better capability to deform beneath compressive loading on its horizontal position than on vertical orientation. The deformation at rupture equation at varying sample moisture contents and loading orientations was also described by 2nd order polynomial functions (Eqs. 18 and 19) with high R^2-values (0.958 and 0.999).

$$Y_h = 4.598 - 0.266MC + 0.005MC^2 \quad [R^2 = 0.958] \tag{18}$$

$$Y_v = 2.831 - 0.144MC + 0.002MC^2 \quad [R^2 = 0.999] \tag{19}$$

Where: Y_h, Y_v = Deformation at rupture in the horizontal and vertical orientations (N), respectively, MC = moisture content (%d.b).
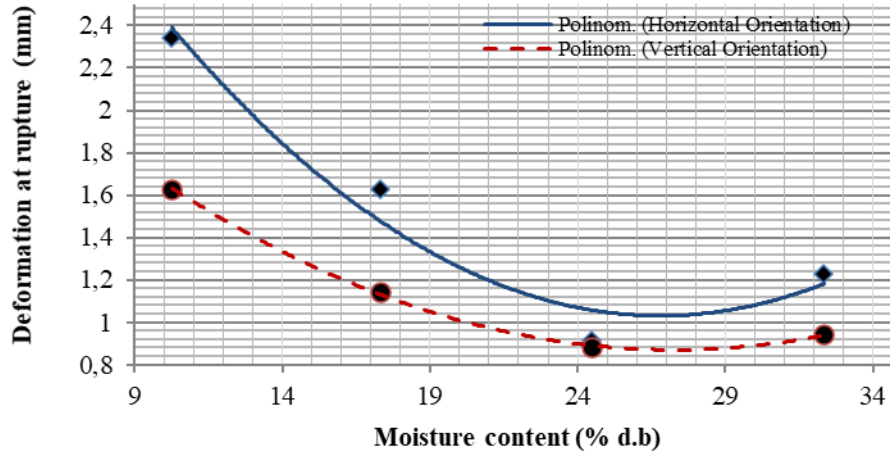
Figure 5. Influence of moisture on deformation at rupture of Moringa seed underneath compression test at the horizontal and vertical loading orientations.

The rupture energy of moringa seed with respect to moisture in a compression test underneath horizontal and vertical loading positions is shown in Fig. 6. It is observed that the work done for rupture of the seed decreased from 257.2 J to a minimum value of 54.4 J because the moisture content increase from 10.25 to 32.34% (d.b) and thereafter rose with more moisture at the horizontal loading orientation. It additionally shows that energy for rupture underneath vertical position decreased from 99.5 J to a minimal of 57.1 J as moisture increase from 10.25 to 32.34% (d.b) after which there is a surge with similar rise in moisture of the seed. Minimal work done for rupture of seed became higher at vertical loading than at horizontal loading position but dropped at higher moisture. The energy for rupture was higher at a horizontal position at moisture levels above 26% d.b than a vertical position. At a higher moisture content level, the turgidity of the sample seeds increased, which resulted in a diminutive amount of energy to completely break-up the seeds. Reduction in moisture content shrinks the intercellular shells, thus more energy required to break the shell. The energy for rupture equation at varying sample moisture contents and loading orientations was also described by 2nd order polynomial functions (Eqs. 20 and 21) with high R2-values (0.993 and 0.990).

$$Y_h = 613.1 - 43.48MC + 0.831MC^2 \quad [R^2 = 0.993] \tag{20}$$

$$Y_v = 144.6 - 5.875MC + 0.092MC^2 \quad [R^2 = 0.990] \tag{21}$$

Where: Y_h, Y_v = Energy for rupture in the horizontal and vertical orientations (N), respectively, MC = Moisture content (%d.b).
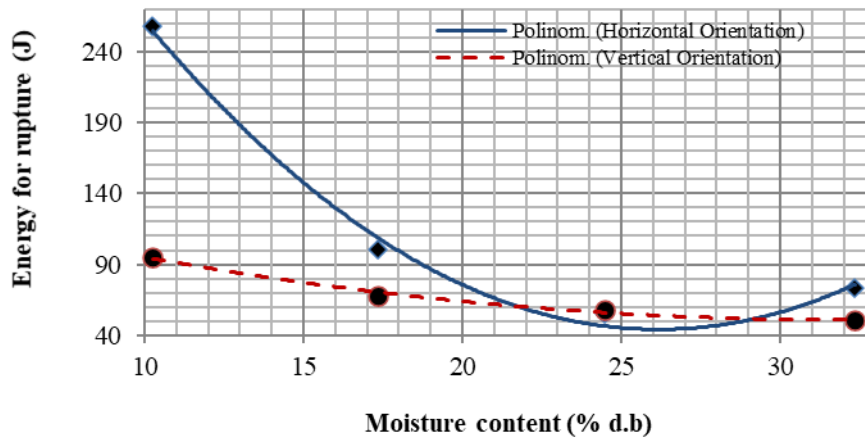
Figure 6. Influence of moisture content on rupture energy of Moringa seed beneath compression test at the horizontal and vertical loading positions.

The variation of Moringa oleifera seed compressive (crushing) strength with respect to moisture under the compression test in the horizontal and vertical positions is shown in Figure 7. The crushing strength of the seed was observed to reduce from 5.5 N mm^{-2} to a low value of 2.8 N mm^{-2} at 25.38% d.b as the moisture surged from 10.25 to 32.34% (d.b) as seen from the regression equation and thereafter increased with further moisture increment when the seed was in the horizontal position. But, in the vertical position, it increased from 2.5 N mm^{-2} to a maximum of 3.9 N mm^{-2} at 31.67% d.b and then reduced with higher moisture increment. The decreasing trend of compressive strength of the seed in the horizontal position might be due to the presence of moisture contained in the intercellular structure of the seed shell whereas its increase at the vertical position might be as a result of the seed shell structure of the three vertical edges running from one end of the nut to the other which constitutes reinforcement for the shell. The pattern exhibited less resistive strength to crushing in the horizontal position as the moisture content became higher; whereas in the vertical position, the cell's vertical edges provide some form of shield against external pressure which resulted in increased crushing resistance per contact area of the sample.

The compressive (crushing) strength equations at varying sample moisture contents and loading orientations were described by 2nd order polynomial functions (Equations. 22 and 23):

$$Y_h = 10.48 - 0.609MC + 0.012MC^2 \qquad [R^2 = 0.681] \qquad\qquad (22)$$

$$Y_v = 0.871 + 0.190MC - 0.003MC^2 \qquad [R^2 = 0.771] \qquad\qquad (23)$$

Where: Y_h, Y_v = Energy for rupture in the horizontal and vertical orientations (N), respectively, MC = moisture content (% d.b).
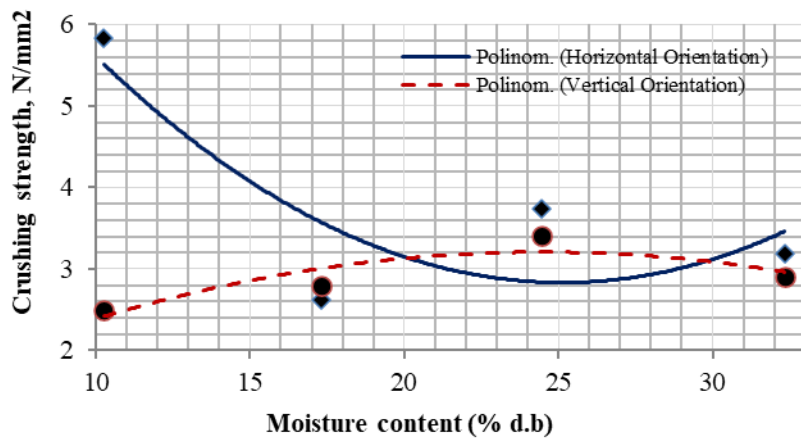
Figure 7. Impact of moisture content on crushing (compressive) energy of Moringa seed underneath compression at the horizontal and vertical loading orientations.

The elastic modulus of Moringa seed with respect to moisture beneath compressive loading at the two-loading orientations is provided in Figure 8. It shows from the graph that, the elastic modulus reduced from 125.8 N mm^{-2} to at least 78.7 N mm^{-2} at 26.96% d.b and thereafter became larger with more moisture increment under horizontal loading orientation. Additionally, for the vertical loading orientation, the elastic modulus surged from 66.38 N mm^{-2} to 140.5 N mm^{-2} (at 29.36% d.b). This depicts that the elastic modulus was larger at the vertical position than at the horizontal position and this indicates that the seed has a high affinity to go back to its natural form after compressive loading is removed from its vertical position compared to the horizontal position. The modulus of elasticity equation at varying sample moisture contents and loading orientations was described by 2nd order polynomial functions (Equations 24 and 25) with high R^2-values (0.642 and 0.959), which indicate that the mechanical property had a close correlation with sample moisture content.

$$Y_h = 264.1 - 13.75MC + 0.255MC^2 \qquad [R^2 = 0.642] \tag{24}$$

$$Y_v = -34.47 + 11.92MC - 0.203MC^2 \qquad [R^2 = 0.959] \tag{25}$$

Where: Y_h, Y_v = Energy for rupture in the horizontal and vertical positions (N), respectively, MC = Moisture content (%d.b).
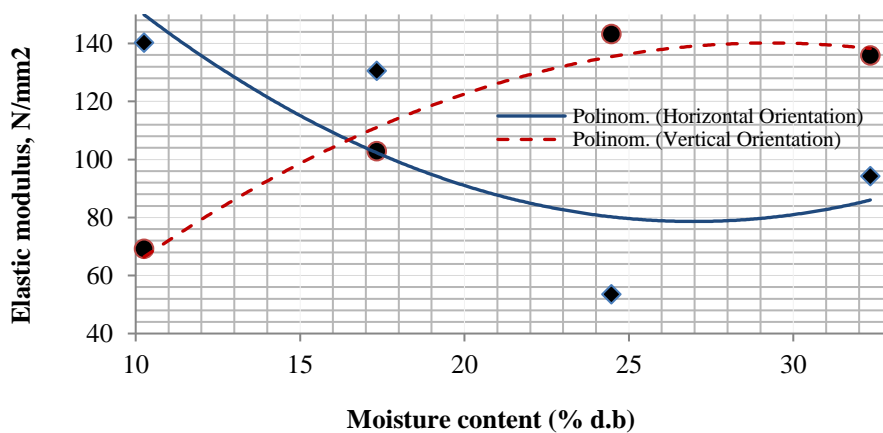
Figure 8. Effect of moisture on elastic modulus of Moringa seed underneath compression test on the horizontal and vertical loading orientations.

CONCLUSION

The subsequent conclusions were drawn from the results of the experimental study:

i. The bio-yield and rupture force of *Moringa oleifera* seed reduced with rise in moisture content to minimal values and increased with a further rise in moisture of the seed but the trend at the vertical position behaved differently. There were lower deformation and energy properties of the seed with a surge in moisture till certain values were reached before incremental changes occurred with further rise in moisture. The minimum values of these properties had been higher beneath vertical loading orientation than at horizontal loading orientation except for the deformation at rupture of the Moringa seed.

ii. The seed is easily cracked at a moisture content of approximately 25.38% d.b (at 2.8 N mm^{-2}). They did not readily crack at higher moistures above the optimum. When the moisture content was about 30% d.b, the *Moringa oleifera* seed did not crack but tended to crush when the force was applied.

iii. The elastic modulus of the seed was lower on the horizontal orientation (78.7 N mm^{-2} at 26.96% d.b) than that at the vertical loading (140.5 N mm^{-2} at 29.36% d.b). This implicates that with immediate removal of the applied compressive force; the seed gets to its original shape more at the vertical than the horizontal position. This decrease in the mechanical behaviour of the seeds with a surge in moisture suggests that energy is saved when seeds are cracked at high moisture but cracking at high moisture crushes the seeds into small pieces. For the fact that product quality is very important, it is agreed that the seeds be cracked horizontally (natural rest position) at low moisture contents so that kernels that are intact and whole could be obtained.

iv. Similarly, studies at the viscoelastic and aerodynamic residences of *Moringa oliefera* are of extraordinary importance for the ultimate layout and development of processing equipment.

DECLARATION OF COMPETING INTEREST

The author(s) have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Samson Ndukwe: Conceptualization, writing of original draft, methodology, data collation, formal analysis, and editing.

Nnaemeka Nwakuba: Methodology, review, editing, Investigation, methodology, formal analysis.

Nkechi Ngwangwa: Data collation, visualization, data collation, validation, formal analysis and review.

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Design, Fabrication and Performance Evaluation of Groundnut Dehulling and Separating Machine

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ABSTRACT

The process of oil extraction can be enhanced by dehulling, oil produced from groundnut seeds serve as a good source of protein, vitamin, fat, oil, and crude fibers. A groundnut dehulling machine was developed, having two dehulling rollers, rubber beaters, screen, blower unit, seed and chaff outlet. The separator unit has a centrifugal blower, screen and collecting tray. It's powered by 3 hp electric motor, which transmits constant speed of 3636 rpm to the blower and 1000 rpm to rubber beaters. Groundnut used was at 7.32% moisture content (w.b). Dehulling was achieved through the compression and shearing action of the rotating dehulling roller against the stationary dehulling roller. The effect of dehulling roller clearance (6.5 mm,7.0 mm, 7.35 mm and 7.5 mm) and speed (700 rpm and 750 rpm) was evaluated on dehulling efficiency, machine capacity, mechanical damage and separation efficiency. The result obtained after testing the machine shows that 7.35 mm clearance and 700 rpm of the dehulling roller gave optimum average dehulling efficiency 95.80%, separation efficiency 81.40% and the least mechanical damage 11.01%. Machine capacity of 97.98 kg h⁻¹. was obtained at 750 rpm and 7 mm dehulling roller clearance. The results obtained during evaluation was statistically analyzed, multiple linear model equations which are capable of predicting the effect of dehulling roller clearance and speed on dehulling efficiency, machine capacity, mechanical damage and separation efficiency was developed.

To cite: Adenigba AA, Sedara AM (2021). Design, Fabrication and Performance Evaluation of Groundnut Dehulling and Separating Machine. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2021, 2(1): 104-123.
https://doi.org/10.46592/turkager.2020.v02i01.008.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important grain legume that grows in wet conditions in semi-arid regions of the world (Rao, 1980). As major crop in most of the tropical and subtropical regions, groundnut ranks 12th in the world crop production. It is grown in all continents with a total area of 24.6 million hectares, and a production of 41.3 million tons in 2012 (FAO, 2013). It's cultivated on subsistence and commercial bases for food and industrial purposes (Thakur *et al.,* 2013; Mohammed *et al.,* 2018).

There are two main types of groundnut: The America groundnut (*Arachis hypogea*), and the Africa groundnut, the Bambara nut (*Voandzeia subterranean*). Both are grown in Western Africa as a protein source. The groundnut seed composed of approximately equal weight of fatty and non-fatty oil (Sedara *et al.,* 2020). Dehulling is a process employed to get rid of the outer pericarp and testa (hull) of most cereal grains, grain legumes, nuts and oilseeds using mechanical means, the removal of grains from their stalk, pod or cub can be achieved either by stripping, impact action and rubbing or any combination of these methods. The most popular method of shelling which is still widely used in the northern part of Nigeria is the method of crushing or pressing the pods between the thumb and the finger to break off the pods and release the seed. This method has low efficiency, it is time consuming, and has high demand of energy. In addition, the output per-man hour is as low as 1-2.5 kg of groundnut.

Figure 1. Groundnut fruit and its manual dehulling process.

Dehulling process for other legumes such as sorghum and millet is accomplished either traditionally by hand pounding of tempered grain using pestle and mortar or mechanically using abrasive de-hullers (Munck *et al.,* 1982). There have been several attempts to make machines that dehull legumes and other seeds such as sorghum, cowpeas, maize, etc. Most groundnut dehulling machines fabricated in Nigeria are either too expensive or not efficient, the persistent increase in the demand for groundnut and ground product renders the traditional method of dehulling and separation incompetent, laborious and time consuming. Since the local method of production could not match the demand there is a prompt need to develop a machine which will reduce drudgery, number of labour required and the time for dehulling and winnowing of kernel from the husk.

MATERIALS AND METHODS

Design Analysis
Determination of crops sizes
The variety of groundnut used for evaluating the machine is "SAMNUT 24". The length, thickness and width of the pods and seeds of each groundnut were determined by measurements using Vernier caliper. Twenty samples were randomly selected from the bulk of one hundred each of groundnut (Maduako and Hannan, 2004).

$$da = \frac{L+W+T}{3} \qquad\qquad (1)$$

$$dg = LWT^{1/3} \qquad\qquad (2)$$

Where: L is mean length of the seeds (mm)

W is mean width of the seeds (mm)

T is mean thickness of the seeds (mm)

Average size of groundnut pod (T) equals 7.9 mm

Average size of groundnut seed (T) equals 7.2 mm

The seed sizes were classified into three categories namely small, medium and large based on their length. The dimensional classification was based on the calculated average dimension (D) and the associated standard deviation ($çx$). Then, small, medium, and large size seeds were so defined that their specific (X) dimension satisfies the following three inequalities (Pradhan et al., 2013):

Small size group $D < X - çx$ \qquad\qquad (3)

Medium size group $D - çx < X < D + çx$ \qquad\qquad (4)

Large size group $X > D + çx$ \qquad\qquad (5)

Determination of crops shapes
The shapes of the crops were determined from the aforementioned measured dimensions. However, the shapes of the pods and seeds were expressed in terms of roundness (R) and sphericity (S) index by Karaj and Muller (2010);

Roundness, R (%):

$$R = (\frac{W}{L} + \frac{T}{L} + + \frac{T}{W} +)/3 \qquad\qquad (6)$$

Sphericity, S (%):

$$s = \frac{(L*W*T)^{\frac{1}{3}}}{L} \qquad\qquad (7)$$

The seeds of groundnut varieties were further classified according to Mazhar et al. (2013): when the ratio of length to width (L/W) fall within the range of 1.51 - 1.71 the variety was classified *Ellipticus* which is ellipsoid in shape, when the ratio falls within 1.85 - 2.31 the variety was classified *Oblongus* which is long cylindroids in shape and

when the product of length and the ratio of width to thickness *(W/T)*L* fall within the range of 1.29 - 2.08 the variety was classified *Subcompressus* which is sub – compressed and long in shape, while for 2.17-3.51 the variety was classified *Compressus* which is more compressed and broad in shape.

Determination of crushing strength

The crushing strength of the groundnut pod at different orientations of the pods was determined using hardness testing machine (Huber *et al.*, 1992);

$$Cs = \frac{W}{A} \tag{8}$$

Where:

Cs = Crushing strength (kg mm^{-2})

W is Weight required for cracking the seeds (kg)

A is Projected area of the seeds under load (mm^2)

Crushing strength (0.1180 kg mm^{-2})

Power required for dehulling

The power required for shelling groundnut/cowpea pods as reported by Abubakar and Abdulkadir (2012) is expressed as follows.

$$H = WK_k F_C Log\frac{L_1}{L_2} \tag{9}$$

   Where:

H is Power (kW) (0.385 kW) (0.523Hp)

F_C is Crushing strength of groundnut (N m^{-2})

K_k is Kick's constant (1.2)

W is Average weight of unshelled groundnut (kg)

L_1 is Average length of unshelled groundnut (m)

L_2 is Average length of shelled groundnut (m)

Determination of dehulling drum shaft torsional moment

Hall and Hallowenko, (1982) gave torsional moment (M_t) as;

$$M_t = \frac{60P}{2\pi N} \tag{10}$$

   Where:

 P is power required for dehulling (0.385 kW),

 S is speed of the dehulling drum (rpm) is 700 rpm and 750 rpm,

$$M_t = \frac{60(385)}{2\pi(750)} \tag{11}$$

M_t = 4.91 N m

Dehulling drum shaft diameter

The shaft size was selected using the relationship given by Khurmi and Gupta, (2005);

$$d_s = \frac{16}{\pi \tau_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

(12)

Where:

ds is shaft diameter (mm)

K_b is shock and fatigue factor applied to bending moment (1.5)

K_t is shock and fatigue factor applied to torsional moment (1.0)

M_t is torsional moments (4.91 N m)

τs is allowable stress of the galvanized steel shaft (40 N mm^{-2})

$d_s a$ is 34 mm

Blower shaft diameter

The shaft size (d_s) was selected using the relationship given by Khurmi and Gupta, (2005); From equation (12).

$$\frac{16}{\pi \tau_s} \sqrt{(1.5 \times 75.11)^2 + (1 \times 48.65)^2}$$

(13)

d_s is 25 mm

Power Transmission Parameters

Pulley diameters and speed ratio relationship

The pulleys diameter was determined using the expression outlined by Sanjay (2010) as;

$N_1 D_1 = N_2 D_2$ (14)

Where:

N_1 is speed of driving pulley (rpm),

N_2 is speed of driven pulley (rpm),

D_1 is diameter of driving pulley (cm),

D_2 is diameter of driven pulley (cm).

The sizes and speeds of 5 pulleys were determined; prime mover pulley (D_m is 8.7cm and Np is 1450 rpm), rubber beaters shaft pulleys (Drb is 12.6 cm and Nrb is 1000 rpm), dehulling roller unit pulleys (Ddr is 700/750 rpm and 18/16.8 cm) and the blower shaft pulley which is connected to the beaters shaft with a belt (Dbs is 5.5 cm and 3636 rpm).

Belt length
The effective belts length was selected using the relationship outlined by <u>Sanjay (2010)</u> as;

$$L_b = \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} + 2x \tag{15}$$

Where:

D_1 is diameter of driver pulley (cm)

D_2 is diameter of driven pulley (cm)

x is center distance between the driver and driven pulley (cm)

Centre distance
The center-to-center distance between the driver and driven pulleys were estimated using the expression given by <u>Khurmi and Gupta (2007)</u> as;

$$D_2 < x < 3(D_1 + D_2) \tag{16}$$

Belt tension
The following expressions were used to determine the belt tension (<u>Sharma and Kamlesh 2006</u>; <u>Sanjay 2010</u>);

$$M_t = (T_t - T_s)R \tag{17}$$

$$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta} \tag{18}$$

Where:

Tt and Ts is tension in tight and slack side of belt respectively (N)

R is radius of the shaft pulley (mm)

μ is coefficient of friction between the pulley and belt

θ is angle of contact between the pulley and belt (°)

β is half angle of groove of the pulley (°) when μ is 0.25, $2\beta = 34°$, and $\theta = 170°$

Therefore, the tensions in the tight and slack side of the fan belt were determined 877.45 N and 6.5×10^{-61} N respectively while those of cylinder belt were 1755 N and 1.6×10^{-60} N respectively.

Blower Design Parameters
Air discharge through the blower
The air discharge through the blower was determined from the expression below (<u>Joshua, 1981</u>);

$$Q = VD_aW_a \qquad (19)$$

Where: Q is air discharge rate (m³ s⁻¹)

V is velocity of air required for cleaning (19.48 m s⁻¹)

Da is depth of air stream (0.118 m)

Wa is width over which the air is required (0.512 m)

Q=19.48 x 0.118 x 0.512

Q = 1.177 m³ s⁻¹

Number of blades required

The terminal velocity of the seeds was determined from the expression given below

$$V_t = 3dg \left(\frac{\rho_s - \rho_f}{\rho_f}\right)^{1/2} \qquad (20)$$

Where:

Vt is theoretical terminal velocity (m s⁻¹)

g is gravitational acceleration = 9.81 m s⁻²

d is geometric mean of kernel physical dimensions = 0.0107 m

ρs is particle density = 746 kg m⁻³

ρf is fluid (air) density = 1.275 kg m⁻³

$$V_t = 3(0.0107 \; x \; 9.81)\left(\frac{746 - 1.275}{1.275}\right)^{1/2} \qquad (21)$$

Vt = 7.59 m s⁻²

The following relations were used to determine the number of blades required as reported by Mohammed, (2009).

$$D = 1.265 * \left(\frac{(AB)^2}{(A+B)}\right)^{1/5} \qquad (22)$$

Where:

D is chaff's outlet dimensional parameter

A is length of the chaff's outlet extended out of the main section (0.189 m)

B is width of the chaff's outlet extended out of the main section (0.512 m)

D is 0.534 m

Hence, number of blades (N_b) can be determined with the following relation

$$N_b = \frac{4WDV_t}{\pi L d^2} \qquad (23)$$

Where: *Nb* is number of blades required

d is diameter of air flow rate channel (0.620 m)

W is width over which air is required (0.512 m)

L is width of the inlet duct minus the clearance (0.723 m)

Vt is terminal velocity of the seed (7.59 m s^{-1})

Nb is (9 blades)

Figure 2 and Figure 3 shows the blower's blade design, front and side view
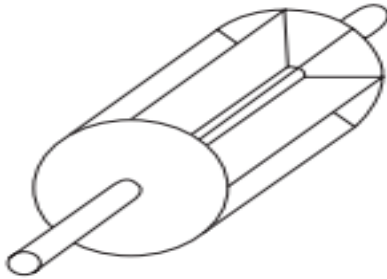
Figure 2. Isometric view of the blower's blade
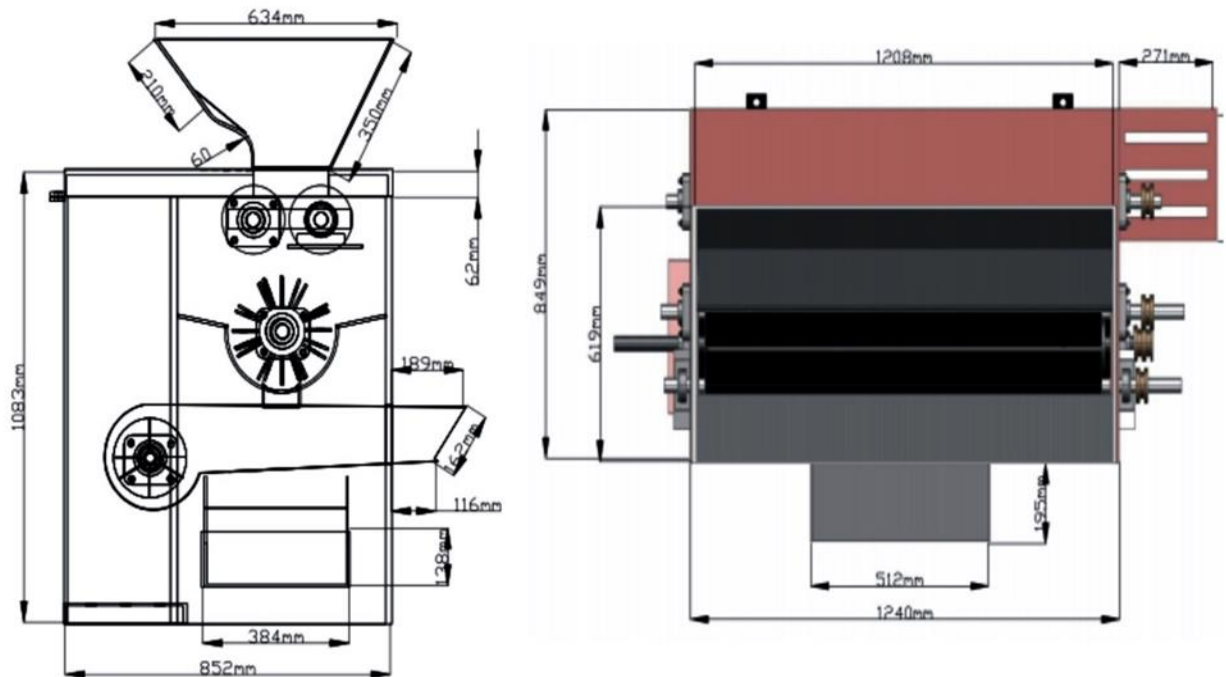
Figure 3. Groundnut dehuller side and plan (solid) view.

Machine's Performance Evaluation

The quantity of groundnut used was in three categories (1 kg, 2 kg, 3 kg), this variation in mass was examined and the effect of dehulling roller clearance (6.5 mm, 7.0 mm, 7.35 mm and 7.5 mm) and speed (700 rpm and 750 rpm) was evaluated on dehulling efficiency, machine capacity, mechanical damage and separation efficiency.

M_1 is initial weight

M_2 is mass of dehulled broken seeds

M_3 is mass of dehulled unbroken seeds

M_4 is total mass of chaff at chaff outlet

M_5 is mass of un-dehulled seed

M_6 is total mass of product at the (seed) outlet

M_7 is $(M_6 + M_4)$

M_8 is mass of chaff in M_6

Dehulling efficiency $(D_e) = \frac{M_3}{M_1} * 100\%$ (24)

Mechanical damage $(M_d) = \frac{M_2}{M_1} * 100\%$ (25)

Machine capacity $(M_c) = \frac{M_1 \ (kg)}{dehulling\ time\ (h)}$ (26)

Separation efficiency $(S_e) = \frac{1}{2} ([\frac{M_8}{M_8+M_4} + \frac{M_4}{M_8+M_4}] * 100)$ (27)

Data Analysis

The performance evaluation results were subjected to statistical analysis to determine the mean, standard deviation, coefficient of variation, linear and nonlinear regressions using MINITAB (12) software. One-way ANOVA was used to test for significance effects, interactions and to determine the most appropriate concave clearance, mass and speed on dehulling efficiency, machine capacity, mechanical damage and separation efficiency of the machine.

Linear regression equation: $y = b_0 + b_1 x$ (28)

Nonlinear regression equation: $y = b_0 + b_{1x2}$ (29)

Where x is independent variable, y is dependent variable and b_0 and b_1 are coefficients.

Figure 4. Effect of dehulling on the groundnut seed.

RESULTS AND DISCUSSION

Effect of Clearance and Mass Feed on the Machine Performance

Figure 5 and Figure 6 illustrates how machine performance is affected by dehulling clearance and mass fed at 700 rpm and 750 rpm. At 2 kg and 3 kg mass fed, dehulling efficiency increases as the dehulling clearance increases from 6.5 mm to 7.5 mm while 1 kg mass exhibit a different trend, the dehulling efficiency increased as the clearance increased from 6.5 mm to 7.35 mm, a subsequent drop in dehulling efficiency occurred as the clearance was increased from 7.35 mm to 7.5 mm (Figure 5). Moreover, it may be concluded that dehulling efficiency will decrease if the feeding rate continually increase during dehulling operation, this is in agreement with Maduako *et al.* (2006) that operation parameters which include feed rate, operating speed and clearance affects the overall performance of dehulling machine. Mass fed and clearance does not have a significant effect on machine capacity and separation efficiency while the speed of the dehulling drum (cylinder) and the blower has significant effect. There is a decrease in mechanical damage as dehulling clearance increase while increase in mass does not have significant effect on mechanical damage.
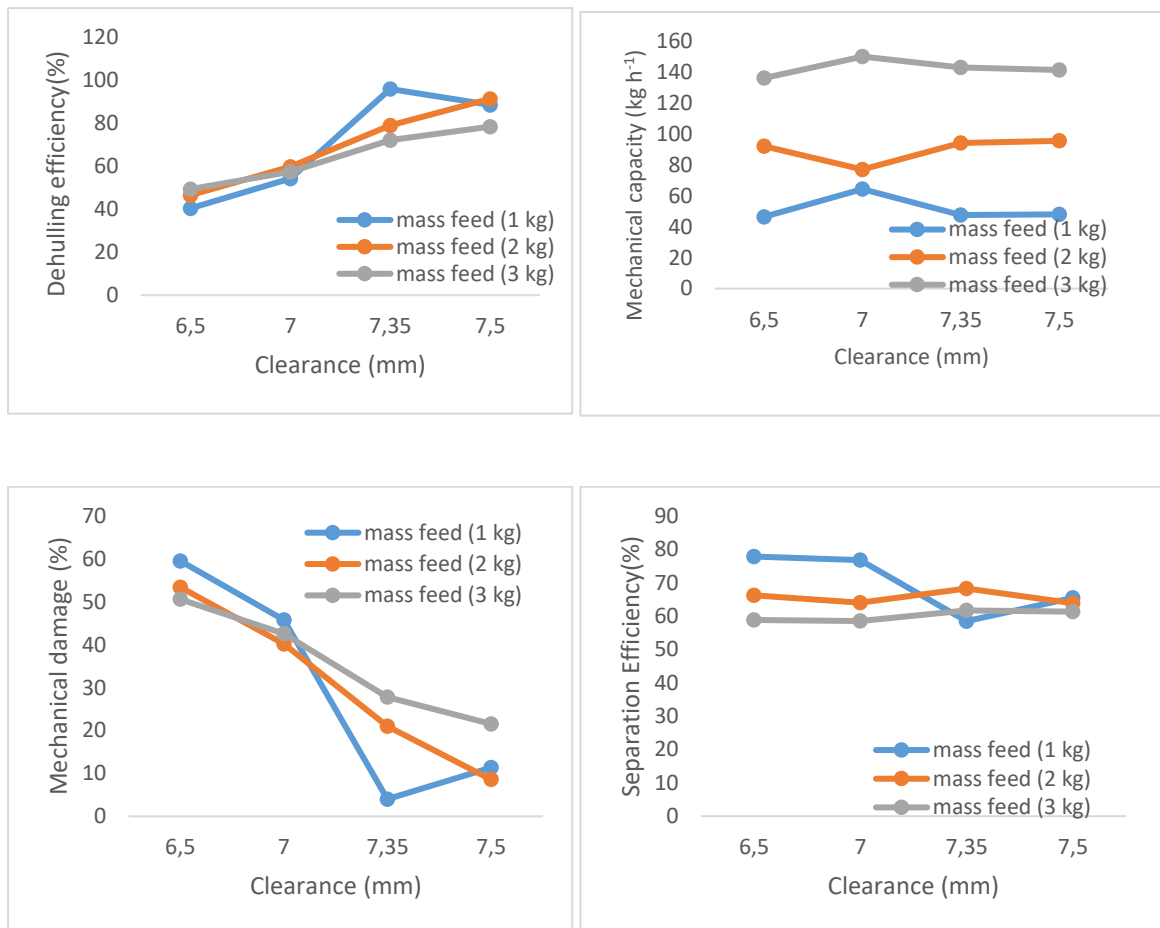
Figure 5. Machine performance vs clearance at three different mass feed and dehulling roller speed of 750 rpm.
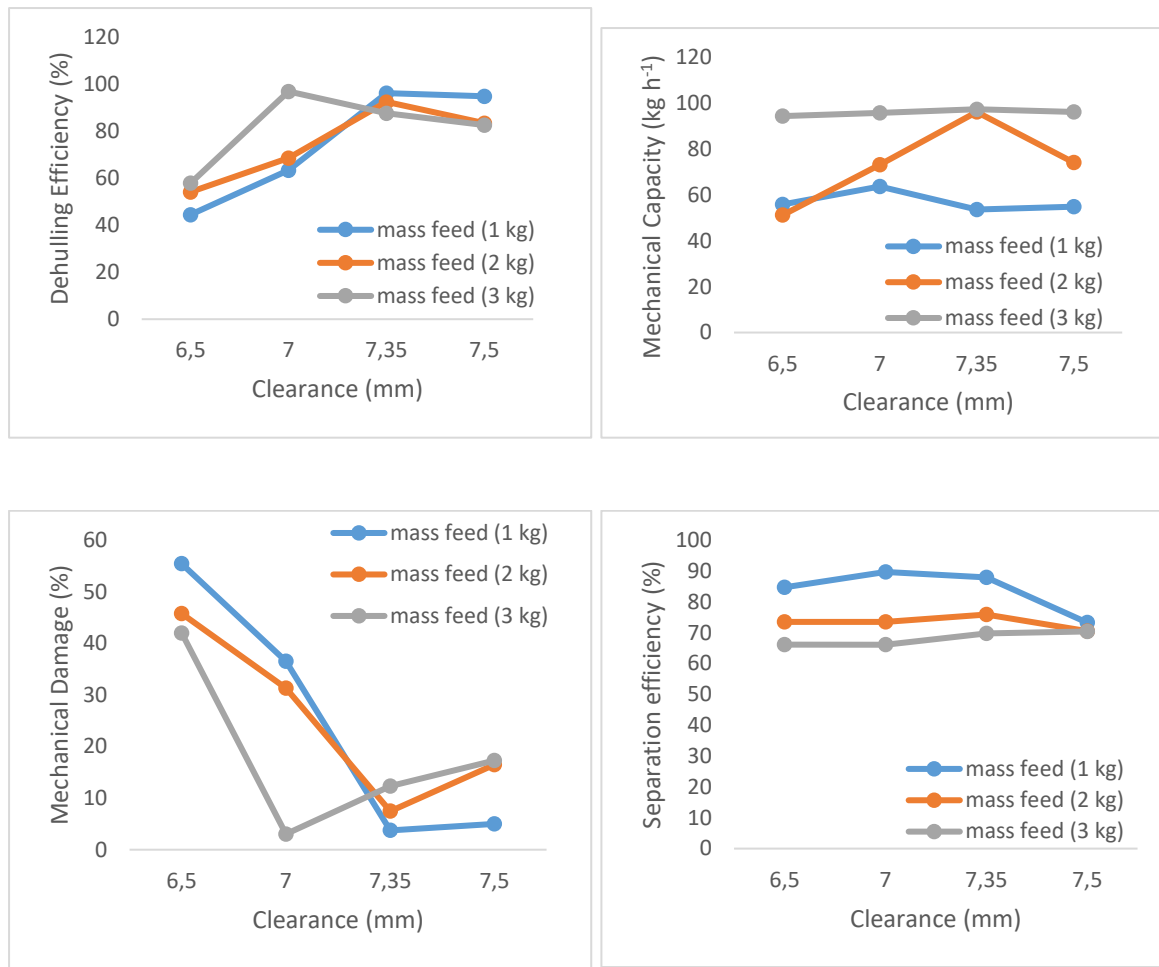
Figure 6. Machine performance vs clearance at three different mass feed and dehulling roller speed of 700 rpm.

Effect of Speed on the Machine Performance

Dehulling efficiency reduces as speed increases from 700 rpm to 750 rpm (Figure 7), due to the fact that groundnuts fed into the hopper have less retention time as they undergo compression and shearing action. Optimum mechanical damage of 62% and machine capacity was recorded at 750 rpm, Figure 8 shows that a decrease in mass fed and dehulling speed will lead to a decrease in machine capacity. However, mechanical damage does not only depend on mass fed and dehulling speed but also depends on the impact force exerted on the groundnuts by the rubber beaters as shown in Figure 9. This indicated that whole kernel recovery is dependent on seed sizes and speed Gupta and Das (1999).

Separation efficiency was optimum at 700 rpm of the dehulling roller (Figure 10). When the speed was reduced from 750 rpm to 700 rpm, groundnuts were able to pass through the clearance between the dehulling rollers at a reduced speed, this enables proper compression and cracking of the nuts which aids the separation process at the blower unit.
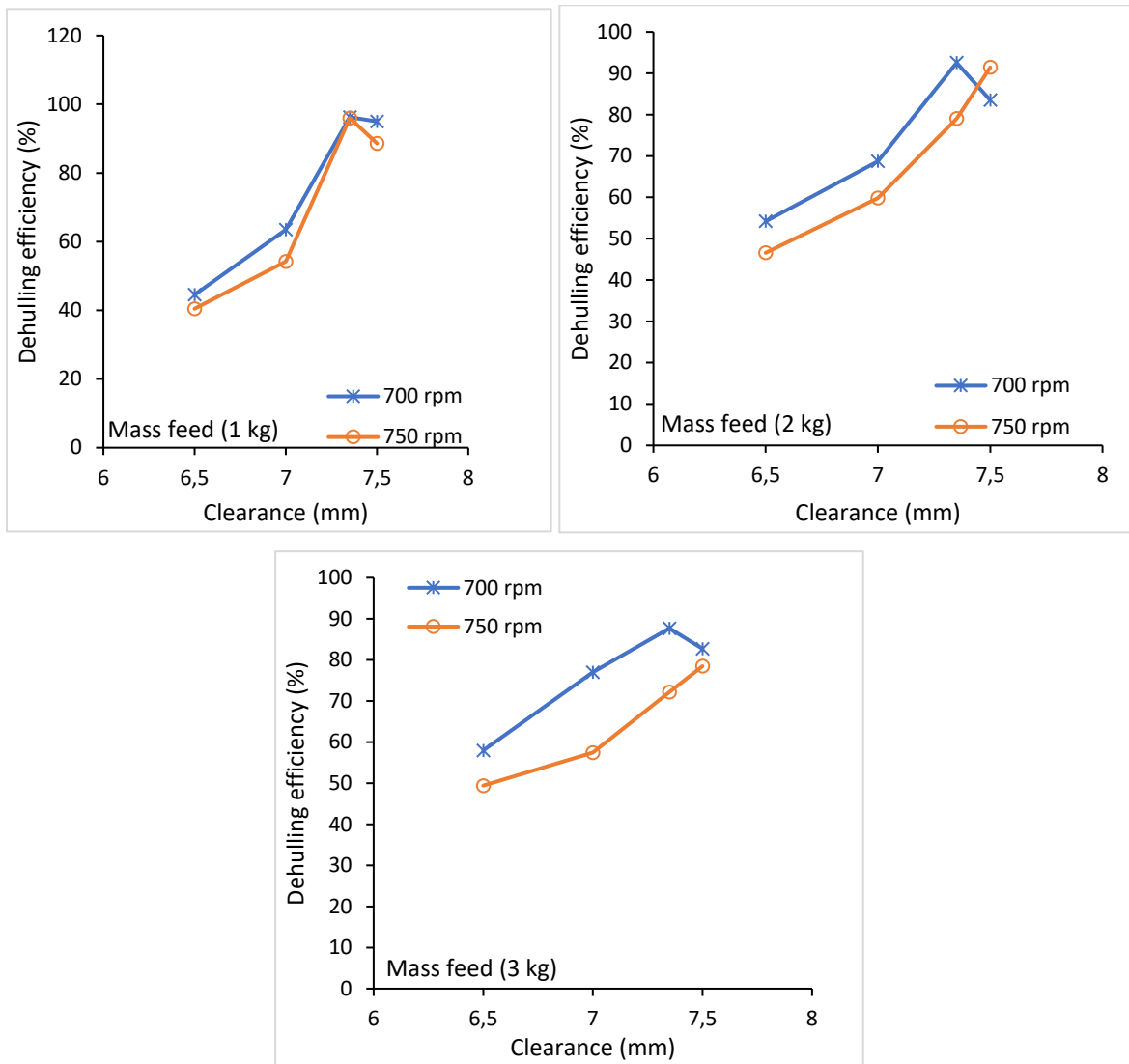
Figure 7. Effect of dehulling rollers clearance and speed at different mass feed on dehulling efficiency.
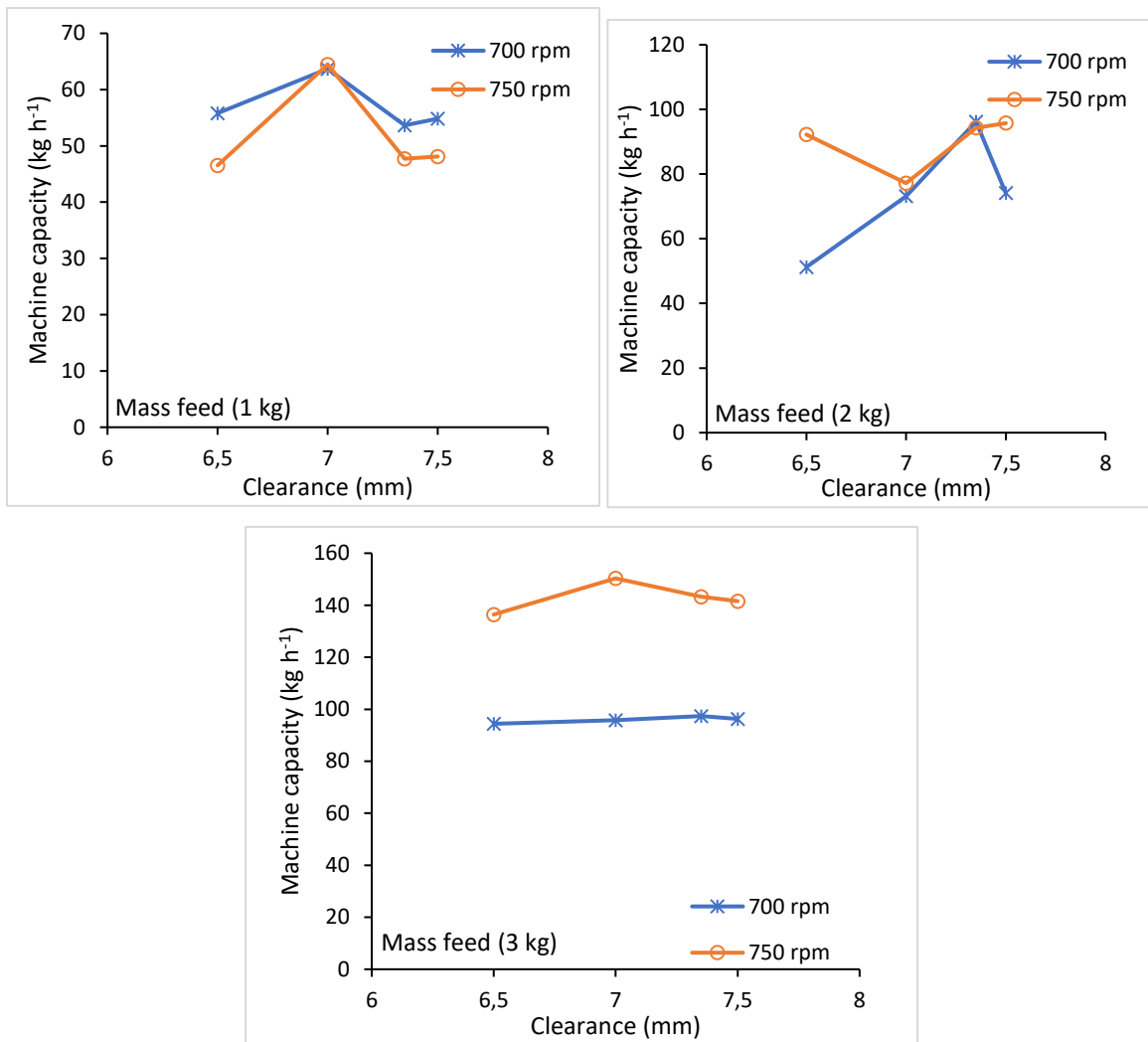
Figure 8. Effect of dehulling rollers clearance and speed at different mass feed on machine capacity.
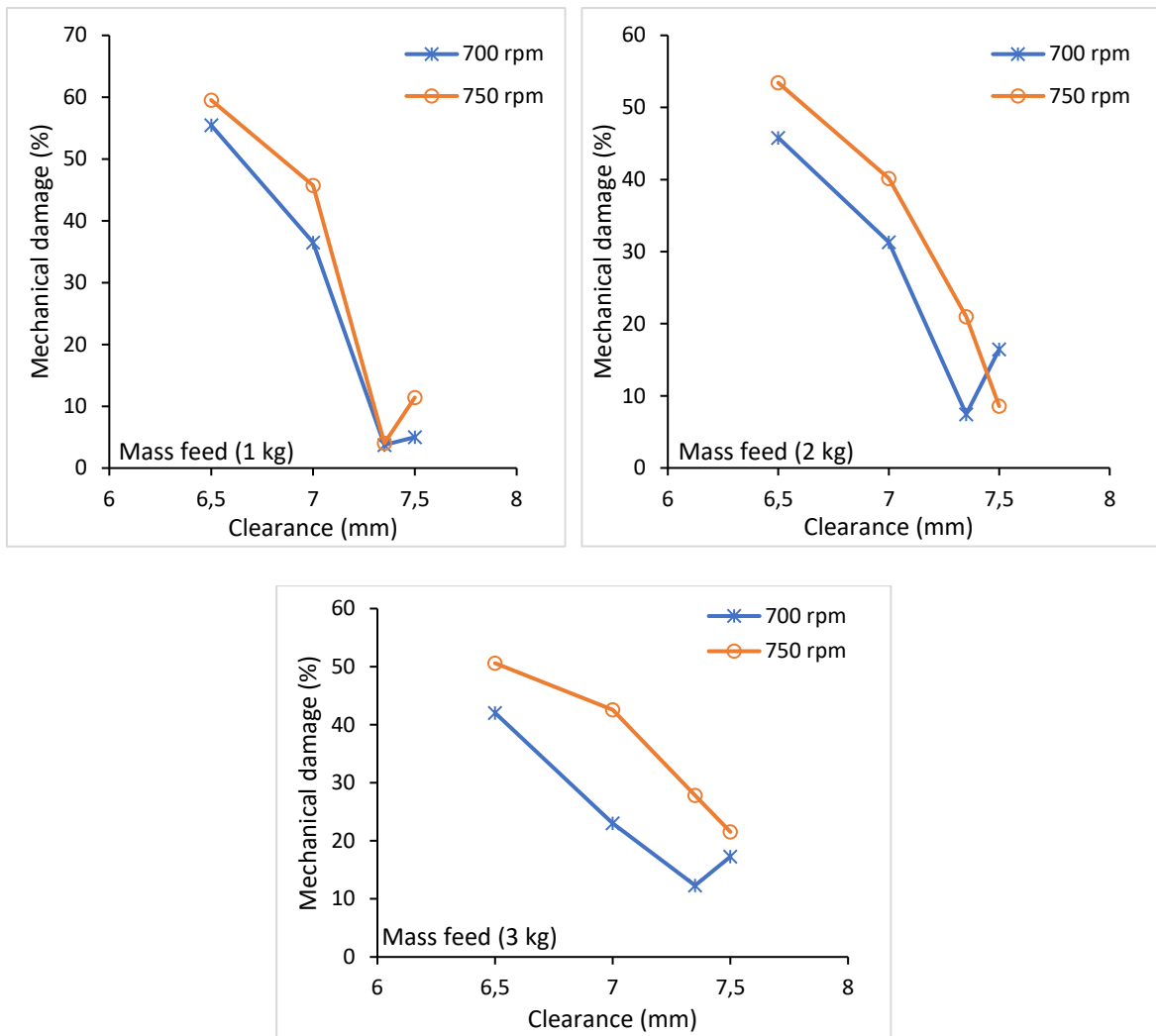
Figure 9. Effect of dehulling rollers clearance and speed at different mass feed on mechanical damage.
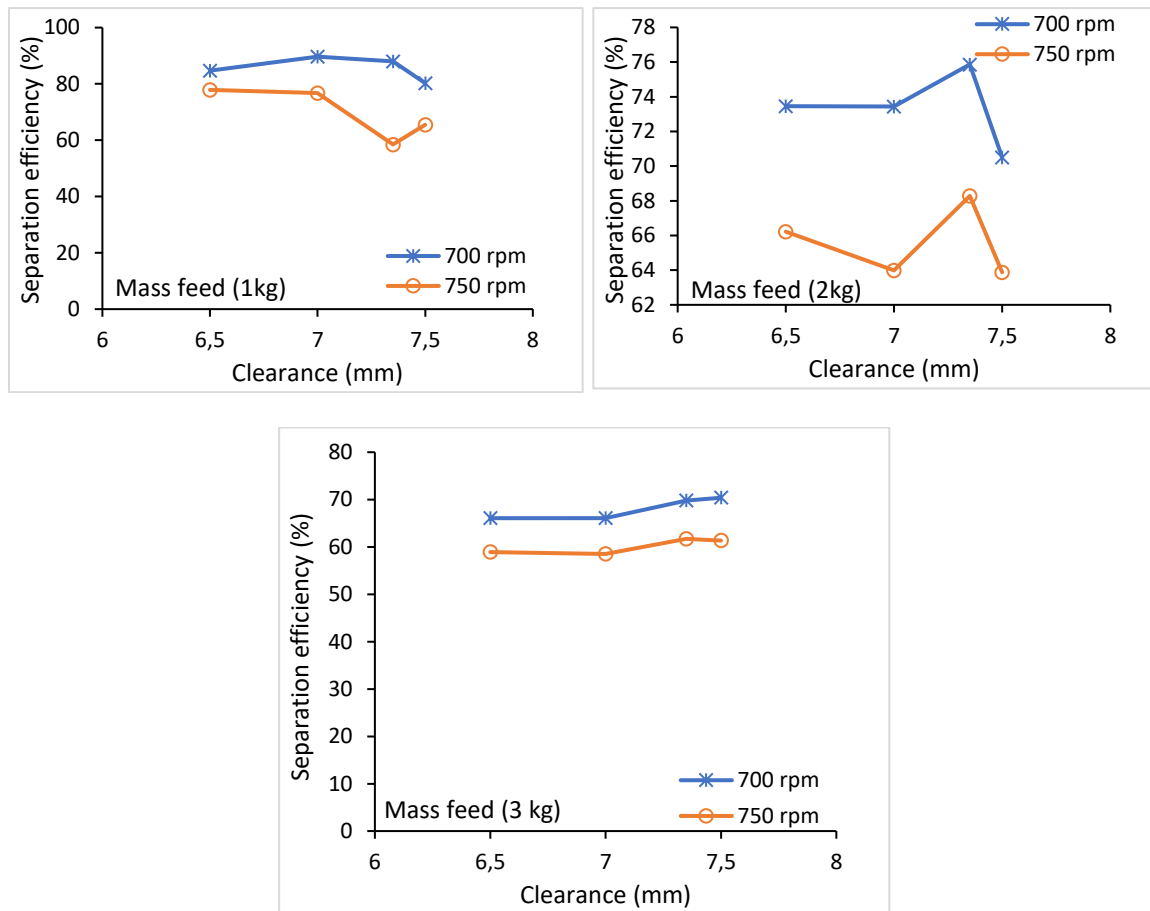
Figure 10. Effect of dehulling rollers clearance and speed at different mass feed on separation efficiency.

Statistical Test

The negative correlation between two variables shows that increase in one of the variables will lead to decrease in the other variable (e.g. increase in mass and speed will lead to decrease in dehulling efficiency and vice versa). Table 3 shows correlation value on the percentage of variation of output that can be accounted for by the input variable (e.g variation in mass feed to the machine can account for about 84.56% variation of the machine capacity while speed can only account for about 30.69%). Hence, the capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

Table 1. Summary of statistics at 700 rpm.

Clearance (mm)	Statistics parameter	1 kg (Mass feed)				2 kg (Mass feed)				3 kg (Mass feed)			
		DE (%)	MC (kg h⁻¹)	MD (%)	SE (%)	DE (%)	MC (kg h⁻¹)	MD (%)	SE (%)	DE (%)	MC (kg h⁻¹)	MD (%)	SE (%)
7.5	Max.	98.17	58.44	8.28	76.13	86.66	76.76	18.24	74.20	83.65	98.34	18.10	72.08
	Min.	91.72	53.57	1.83	70.48	81.76	72.01	13.34	68.67	81.90	94.44	16.36	69.14
	Mean	94.97	54.83	5.03	73.27	83.54	74.14	16.46	70.50	82.70	96.26	17.30	70.39
	SD	2.40	2.05	2.40	2.57	1.87	1.90	1.87	2.24	0.76	1.42	0.76	1.40
	CV	2.53	3.73	47.77	3.51	2.24	2.56	11.35	3.17	0.92	2.22	4.42	1.99
7.35	Max.	99.09	56.79	7.68	90.78	97.28	98.56	10.42	79.18	91.04	98.57	15.12	74.24
	Min.	92.33	49.26	0.91	86.26	89.58	92.14	2.72	71.05	84.88	93.51	8.96	66.12
	Mean	96.26	53.65	3.74	87.95	92.54	96.20	7.46	75.87	87.69	97.38	12.31	69.80
	SD	2.53	3.01	2.53	1.90	3.13	2.70	3.13	3.24	2.57	2.18	2.57	3.08
	CV	2.63	5.61	67.59	2.16	3.38	2.81	41.92	4.27	2.93	2.24	20.87	4.42
7	Max.	66.34	65.73	40.16	94.01	70.66	76.07	35.19	78.69	97.73	98.04	41.87	69.69
	Min.	59.84	61.63	33.66	85.54	64.81	69.56	29.34	70.94	95.13	92.98	2.27	61.30
	Mean	63.48	63.69	36.52	89.67	68.67	73.16	31.33	73.44	96.97	95.73	3.03	66.08
	SD	2.60	1.59	2.60	3.22	2.30	2.35	2.30	3.04	1.07	2.06	1.07	3.17
	CV	4.09	2.49	7.11	3.59	3.35	3.21	7.34	4.14	1.10	2.15	35.33	4.79
6.5	Max.	47.68	59.25	59.57	91.03	56.37	56.18	47.54	80.99	58.04	98.97	42.18	69.49
	Min.	40.43	52.92	52.32	77.57	52.46	47.90	43.63	65.85	57.82	86.76	41.96	58.97
	Mean	44.54	55.82	55.46	84.67	54.20	51.21	45.80	73.46	57.97	94.39	42.03	66.09
	SD	3.14	2.50	3.14	5.43	1.95	3.13	1.95	5.79	0.09	4.90	0.09	4.56
	CV	7.05	4.48	5.66	6.42	3.60	6.10	4.26	7.89	0.15	5.19	0.20	6.90

Table 2. Summary of statistics at 750 rpm.

Clearance (mm)	Statistical parameter	1 kg (Mass feed)				2 kg (Mass feed)				3 kg (Mass feed)			
		Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency	Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency	Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency
7.5	Max.	90.381	48.239	12.471	71.169	93.566	96.108	11.037	64.860	78.571	141.710	21.702	61.675
	Min.	87.529	47.893	9.619	61.597	88.963	95.283	6.434	63.503	78.298	141.376	21.429	61.028
	Mean	88.597	48.086	11.403	65.470	91.426	95.731	8.574	63.880	78.462	141.543	21.538	61.355
	SD	1.216	0.137	1.216	3.959	1.986	0.303	1.986	0.565	0.103	0.125	0.103	0.258
	CV	1.373	0.285	10.666	6.047	2.173	0.316	23.167	0.885	0.131	0.088	0.478	0.421
7	Max.	55.056	65.833	46.380	78.300	61.965	77.280	42.360	64.389	57.503	150.830	42.721	58.784
	Min.	53.620	63.171	44.944	75.468	57.640	77.042	38.035	63.619	57.279	149.551	42.497	58.167
	Mean	54.251	64.463	45.749	76.766	59.835	77.184	40.165	63.983	57.413	150.332	42.587	58.520
	SD	0.612	1.028	0.612	1.174	1.991	0.088	1.991	0.312	0.089	0.512	0.089	0.225
	CV	1.129	1.595	1.338	1.529	3.328	0.114	4.958	0.488	0.155	0.340	0.209	0.384
7.35	Max.	96.731	47.847	5.905	64.118	80.335	94.518	22.597	68.862	73.559	143.816	28.236	62.456
	Min.	94.095	47.596	3.269	52.505	77.403	94.073	19.665	67.418	71.764	142.586	26.441	60.161
	Mean	95.985	47.728	4.015	58.497	79.033	94.313	20.967	68.281	72.188	143.323	27.812	61.704
	SD	1.070	0.089	1.070	5.545	1.467	0.185	1.467	0.768	0.769	0.489	0.769	0.952
	CV	1.115	0.186	26.657	9.478	1.856	0.196	6.996	1.125	1.066	0.341	2.766	1.544
6.5	Max.	44.084	46.707	62.823	78.658	46.768	92.421	53.581	66.605	53.846	136.674	53.911	59.309
	Min.	37.177	46.318	55.916	75.935	46.419	91.954	53.232	65.846	46.089	136.302	46.154	58.535
	Mean	40.467	46.538	59.533	77.871	46.577	92.192	53.423	66.224	49.403	136.420	50.597	58.876
	SD	2.775	0.145	2.775	1.115	0.124	0.207	0.124	0.270	3.224	0.150	3.224	0.344
	CV	6.858	0.312	4.662	1.432	0.267	0.225	0.233	0.408	6.525	0.110	6.371	0.584

Table 3. Correlation between variables.

Variables	S (rpm)	M (kg)	C (mm)	Dehulling efficiency (%)	Machine capacity (kg h⁻¹)	Mechanical damage (%)	Separation efficiency (%)
S (rpm)	**1.0000**	0.0000	0.0000	-0.2112	0.3069	0.2112	-0.5990
M (kg)	0.0000	**1.0000**	0.0000	-0.0453	0.8456	0.0453	-0.6271
C (mm)	0.0000	0.0000	**1.0000**	0.8936	0.0846	-0.8936	-0.0955
Dehulling efficiency (%)	-0.2112	-0.0453	0.8936	**1.0000**	-0.0725	-1.0000	-0.0333
Machine capacity (kg h⁻¹)	0.3069	0.8456	0.0846	-0.0725	**1.0000**	0.0725	-0.6165
Mechanical damage (%)	0.2112	0.0453	-0.8936	-1.0000	0.0725	**1.0000**	0.0333
Separation efficiency (%)	-0.5990	-0.6271	-0.0955	-0.0333	-0.6165	0.0333	**1.0000**

The negative correlation between two variables shows that increase in one of the variables will lead to decrease in the other variable (e.g increase in mass and speed will lead to decrease in dehulling efficiency and vice versa). The correlation value also shows the percentage of variation of output that can be accounted for by the input variable (e.g variation in mass feed to the machine can account for about 84.56% variation of the machine capacity while speed can only account for about 30.69%). Hence, the capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

Multiple Linear Model equation

Where M is the mass feed into the machine (kg), S is the speed of the dehulling roller (rpm) and C is the clearance between the two dehulling rollers. The product of the input factors in the model expresses the interaction between the factors.

Separation efficiency (%) = 195.49-115.22*M+23.03*C+0.08*S*M-0.05*S*C +6.77*M*C

Mechanical damage (%) = 19.03+0.68*S-145.98*M+0.07*S*M-0.09*S*C+13.60*M*C

Dehulling efficiency (%) = 80.97-0.68*S+145.98*M-0.07*S*M+0.09*S*C-13.60*M*C

Machine capacity (kg/hr) = 9.63-368.29*M+69.83*C+0.53*S*M-0.09*S*C+2.72*M*C

CONCLUSION

This study was conducted to design, fabricate a groundnut dehuller and separator. The effect of dehulling speed and clearance between the dehulling rollers was evaluated on the machine performance. Based on the experimental findings, it can be concluded that:

i. The result obtained after testing the machine shows that 7.35 mm clearance and 700 rpm speed of the dehulling roller gave the best average dehulling efficiency (95.80 %), separation efficiency (81.40 %) and the least mechanical damage (11.01 %).

ii. The capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

iii. Variation in dehulling roller speed and mass fed can account for only 21.1% and 4.5% variation of the mechanical damage respectively.

iv. There is no positive correlation of the dehulling roller speed and mass fed on separation efficiency.

DECLARATION OF COMPETING INTEREST

The authors affirm that there is no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Ademola Adebukola Adenigba: Conceptualization, investigation, experimentation, writing original draft and review.

Adewale Moses Sedara: Editing of the original draft.

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Research Article

Design and Fabrication of Egg Quality Assessment System Based on Image Processing

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ABSTRACT

Eggs are a nutritious and important food in human daily diet, which is considered as a protein source of food. The most acceptable index for evaluating egg quality is Haugh unit with two factors, i.e. the weight of intact egg and the height of broken egg's albumin. Hauge unit has three classification: firm (higher than 72), reasonably firm (higher than 72), and weak (less than 60). Average results for Haugh unit on the first, fourth, eighth, twelfth, and sixteenth days (five eggs in each step) were 113.39, 91.47, 74.56, 72.04, and 64.14 respectively. On the first, fourth and eighth days, eggs were intact but the quality of the eggs decreases on the next days. This research aims to sort healthy eggs from others and swell the rate of sorting.

INTRODUCTION

Nowadays, the food industry is developing all over the world (Earle and Earle, 1997). It is necessary to implement efficient methods to calculate product quality factors and obtain acceptable results. Eggs are nutritious and important food in human daily diet, which are considered as source of protein, minerals, vitamin and fatty acid food (Anderson, 2011; Karsten *et al.,* 2010). Quality control is an important and impartible part of the food and agriculture industry (Bazyar *et al.,* 2019) which affects the quality of ultimate product (Mitra, 2016). The egg producing and processing, as a part of the country's food industry, needs to control and measure the input product with low costs (Moore and Sandground, 1956). There are two ways for testing the egg quality by image processing; destructive and nondestructive methods. Direct accessing to each index of

the albumin height (H) is an advantage of employing the destructive methods. Therefore, the method of this research is important for the global poultry industry to ensure the health, productivity and internal quality of eggs.

Two hundred egg samples were stored at a temperature of 30±7°C and 25±4% relative humidity. The results of albumin PH, Haugh unit (HU) and Yolk coefficient obtained from the destructive and nondestructive tests to determine the egg quality. The intelligent system used for egg classification over its quality was based on GA and PCA methods.

In another study, a system based on machine vision and artificial intelligent techniques used to grade egg samples. The researchers analyzed Hue-Saturation-Value (HSV) color space to detect the size, cracks and breakage of eggshell. They utilized Mamdani fuzzy logic method along with center average method for defuzzifier. The result of classification rate was 95% for size detection, 94.5% for crack detection and 98% for breakage detection (Omid *et al.*, 2013).

Ramírez-Gutiérrez *et al.* (2019) investigated the computer vision for deformation on curved surfaces of eggshell. In this study 75 sample eggs without deformation and 75 samples with deformations are analyzed. Vision system consists of a camera with a CCD sensor and a laser-structured light pattern with lighting conditions in concentrations lower than 1 lux to catch the images. Image processing implemented in 8 steps to obtain acceptable curvatures and calculate the number of pixels between real and interpolated curves. The most accurate result for classifying the defective samples with artificial neural network was 97.5%.

Zhang *et al.* (2015) applied a synthesis of hyperspectral image and multivariate analysis to assess egg internal quality. Hyperspectral imaging system consists of a CCD camera, an imaging spectrometer, a light unit, a motorized horizontal stage and Spectral Image System (v10E software). In this study, spectral analysis used to estimate Haugh unit (HU) and morphological analysis of images to detect bubble formation and scattered yolk. Eggs with internal bubbles and scattered yolk measured by support vector classification (SVC) model with 90.0% and 96.3% of were precision, respectively and Haugh unit (HU) was 84%.

Our proposed method is based on image processing techniques for assessment of the egg quality. The aim of the present study is to measure the albumen height, yolk height and yolk diameter. Based on the results, the Haugh unit (HU) results are criterion to grade the eggs into different groups.

MATERIALS AND METHODS

The manner of image analysis is shown in Figure 1, including image acquisition, image processing and extraction of features for measurement of internal quality.
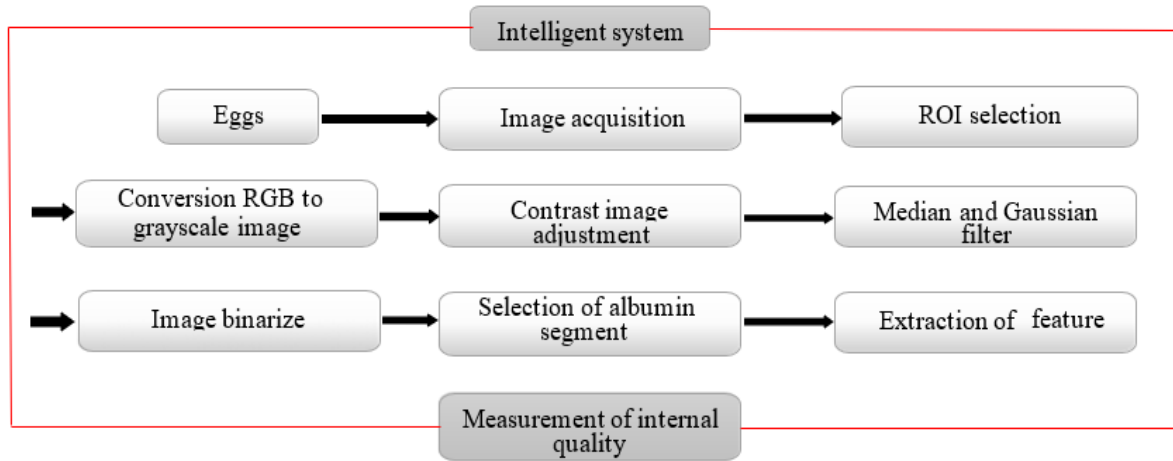
Figure 1. Experimental procedures.

Sample Collection

In this study, twenty-five intact and fresh egg samples were bought from store in Karaj, Iran. The intact eggs kept in the laboratory, out of refrigerator, at 26±2°C. The samples divided into 5 groups, each containing 5 eggs and the duration of the test was 20 days, once in four days.

Apparatus

Our proposed egg quality assessment system is shown in Figure 2.

Figure 2. Egg quality assessment system: (1) light box; (2) smart phone; (3) laptop.

This box was simulated in 3D sketch on SolidWorks software (2018) and made of wood to eliminate effects of environmental noises. Dimensions of box in length, width and height are 60, 60 and 50 cm, respectively. The light box dimensions in length, width and height are 15, 15 and 20 cm, respectively and it contains a 7W SMD bulb. One of the most important stages in egg morphological analysis is the uniform orientation of the light, surrounding the egg surface, to be designed in the dark environment. Luo *et al.* (2001) used imaging system (Digi Eye) includes digital camera, illumination box and computer to obtain the images.

Heredia *et al.*, 2006 used Digifood to obtain morphological parameters, which is better than CIELAB coordinates of image processing.

We used HTC TM one X9 smart phone to acquire sRGB (color) images. The camera of phone is 4160 × 2368 pixels in horizontal and vertical directions, respectively and Focus Length is 27 mm. Smart phone was fixed approximately 200 mm in horizontal distance from the center of the egg sample. Data information transferred through a USB cable to laptop for image processing operations. A Lenovo TM laptop with following specifications were employed for the experiments; windows 10 Enterprise, Intel® Core TM i5, NVIDIA Geforce GT740M and installed memory (RAM) is 4GB.

Egg Weight

The nutrient content of eggs depends on the weight of the egg that affects by many factors such as heredity, breed, strain, age of hen, body size, feed and water consumption, ambient temperature and diseases (Sekeroglu and Altuntaş, 2009). Egg weight is one of the important egg quality factors; the evaluation of samples egg weight obtained by using an electronic balance scale (Jadever scale model) with 0.01g accuracy.

Analysis Methods

The acquired images by the camera of phone were stored in .jpg format and processed by Matlab® (MathWorks, Inc., USA) with using an algorithm to identify the height of albumin which consists of 2 steps:

  a) Image pre-processing: evaluating the best process method, including filtering and segmentation.

  b) Image analysis: descriptive area of the light pattern is obtained from the image to extract feature of selective pixels.

Preprocessing

The goal of pre-processing is to modify any noises of image during the test period and to provide necessary information about the eggs.

Initially, we need to extract useful information from the RGB image, which is necessary to separate the important region of image from basic image. This region is called ROI (region of interest). Figure 3a shows the ROI of input image that is restricted to egg segment in 3493 × 943 pixels.

In the next step, we convert the image (Figure 3a) to grayscale mode to extract the morphological features. The level of grayscale intensity [0-255] shows color range between black and white for each pixel (Figure 3b).

Figure 3c shows an operation that increases the contrast of the 8-bit images to perform the image polarity. In this section, by applying a coefficient of intensity [0.01-0.99] to the image (Figure 3b), which is obtained in practical tests, intensity of bright and dark pixels value promoted in image.

One of the most important steps in pre-processing is utilizing the low-pass filter operation, applied on the images for exploring some important relationships between the spatial and frequency domains (Davies, 2012). We used Gaussian and median smooth filtering to eliminate signal components with high spatial frequencies. As indicated in Figure 3d, this filter employed with 3×3 mask to enhance the image with minimum noise and recognize the egg.

In our method, binary process employed to identify the objects on white color sample in black background. The Otsu thresholding method (Otsu, 1979) automatically calculates a threshold for a grey level image (image as shown in Figure 3d) by using I_{binary} function [Equation (Eq.) 1] minimizing the interclass variance of black and white pixels to obtain a binary image (Figure 3e).

$$I_{binary} = \begin{cases} 0 & \text{if } I_{image} \leq T_{otsu} \\ 255 & \text{otherwise} \end{cases} \tag{1}$$

Image Analysis

In this research, height of albumin was determined from morphology formulate operations based on image processing functions to segment yolk and albumin area on the image. In order to distinguish the yolk of egg, processing method was performed on the red channel (:,:,1) of RGB color image and followed the T_{yolk} for identify the yolk (Eq. 2). I_{yolk} (Figure 3f) shows the yolk on binary image.

$$I_{yolk} = \begin{cases} 0 & \text{if } I_{image} \leq T_{yolk} \\ 255 & \text{otherwise} \end{cases} \tag{2}$$

At this point, $I_{albumin}$ (Figure 3g) calculated by Subtracting I_{yolk} from I_{binary} (Equation 3). Subtract operation used to obtain image from the two same size images to extract the area of interest (Du *et al.*, 2004).

$$I_{albumin} = I_{binary} - I_{yolk} : [w \mid w \in I_{binary}, \ w \notin I_{yolk}] \tag{3}$$
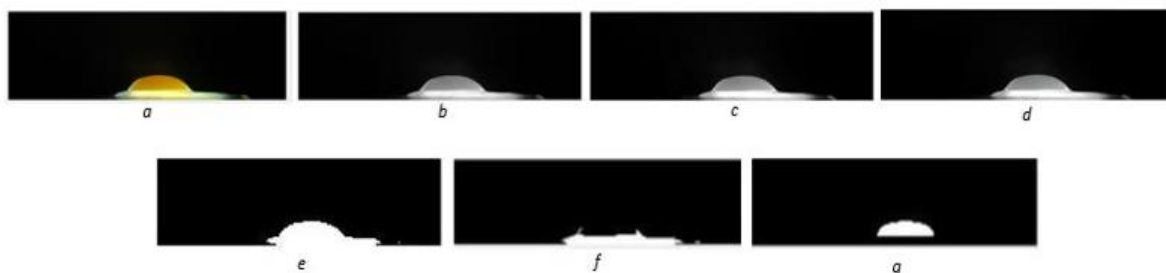
Figure 3. a. Input RGB image (ROI). b. Grayscale image. c. Enhancement image. d. Applied Gaussian and median filter. e. Binary image. f. Yolk section. g. Albumin section.

Image Calibration

To validate the extracted feature, calibration is essential. As shown in Figure 4, image calibration which taken by the camera in landscape mode, The ROI region image was 60 mm or 943.31 pixels wide and 220 mm or 3493.41 pixels length. So, with this method, image pixels count deforms by a proportion of millimeter unit; difference between the millimeter size on the real environment and image processing method result accuracy is less than 0.32 mm.

Haugh Unit

According to Haugh unit (Brant *et al.*, 1951) eggs can be divided into three states:
(AA)   grade, firmness, top quality (Haugh unit ≥ 72);
(A)   grade, reasonably firm, low quality (Haugh unit 60 – 71);
(B)   grade, weak, deteriorated (Haugh unit < 60);
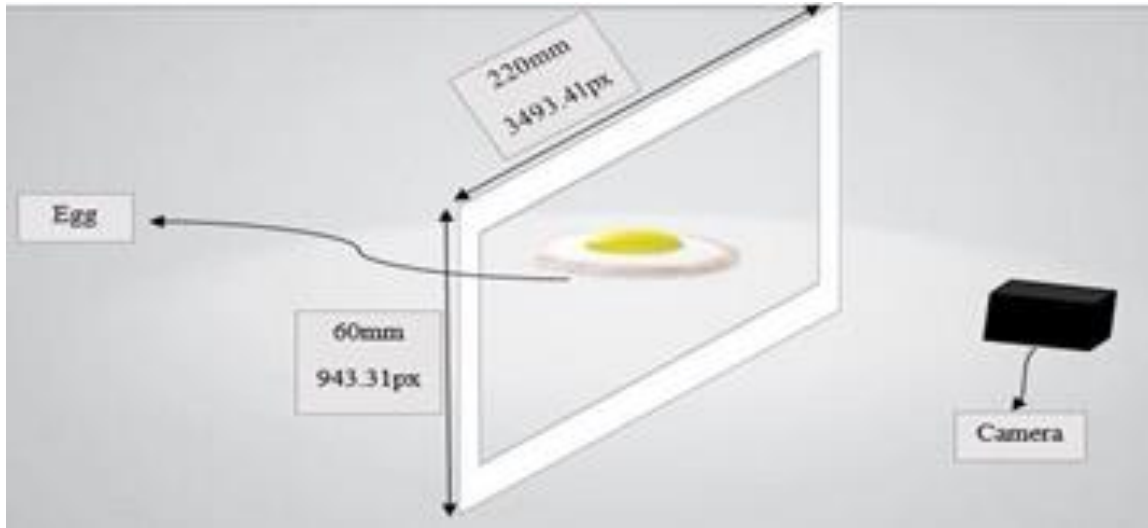
Figure 4. Schematic of the imaging system.

Haugh unit score is calculated by using egg weight and albumin height for each individual egg based on the following formula (Hough, 1937):

$$HU = 100 \log_{10}(H - 1.7W^{0.37} + 7.6) \qquad (4)$$

Where *HU* is observed Haugh unit, *H* is height of the albumin and *W* is weight of the egg.

RESULTS AND DISCUSSION

The obtained results indicate an image processing analysis method from I_{yolk} and $I_{albumin}$ images. Table 1 shows the analysis results from the various test days for albumin height and Haugh unit, that indicates the quality of eggs with AA, A or B grade. According to Table 1, the Haugh unit decreased over time, so the eggs on the first and fourth days were intact and well for consumption; On the eighth and twelfth days, some eggs were grade A, then on the sixteenth day, when mean of Haugh unit were less than 72, the eggs included A or B grades and needed assessment for quality.

Table 1. Results obtained from the available information.

Test days .... Unit Egg samples	Day 1			Day 4			Day 8			Day 12			Day 16		
	H	HU	Q	H	HU	Q	H	HU	Q	H	HU	Q	H	HU	Q
1	14.7	114.9	AA	8.7	91.6	AA	5.7	75.4	AA	5.9	75.1	AA	4.5	62.2	A
2	14.5	115.6	AA	9.4	96	AA	5.5	74.3	AA	5.5	69.8	A	4.1	58.4	B
3	12.6	108.9	AA	8.6	91.5	AA	5.5	71.9	A	5.0	65.6	A	5.2	70.7	A
4	13.8	112.7	AA	8.1	87.7	AA	6.2	79.2	AA	5.1	68.8	A	4.5	64.1	A
5	14.2	114.6	AA	8	90.3	AA	5.5	71.7	A	6.1	80.8	AA	4.7	65.1	A

Figure 5a shows the decrease of albumin and yolk height at each test day which represents the average of five repetitions per day. This decrease of albumin height was due to the reduction of moisture, viscosity and transparency of albumin. Within some days, the vitelline membrane of yolk becomes thinner and the water absorbs to the yolk, so the shape of the yolk becomes like a balloon and the color gets darker. Thus, the yolk height decreased over consecutive days, then the yolk diameter increased and it is more intense from the twelfth to the sixteenth day as mentioned in Figure 5b.

a

b

c
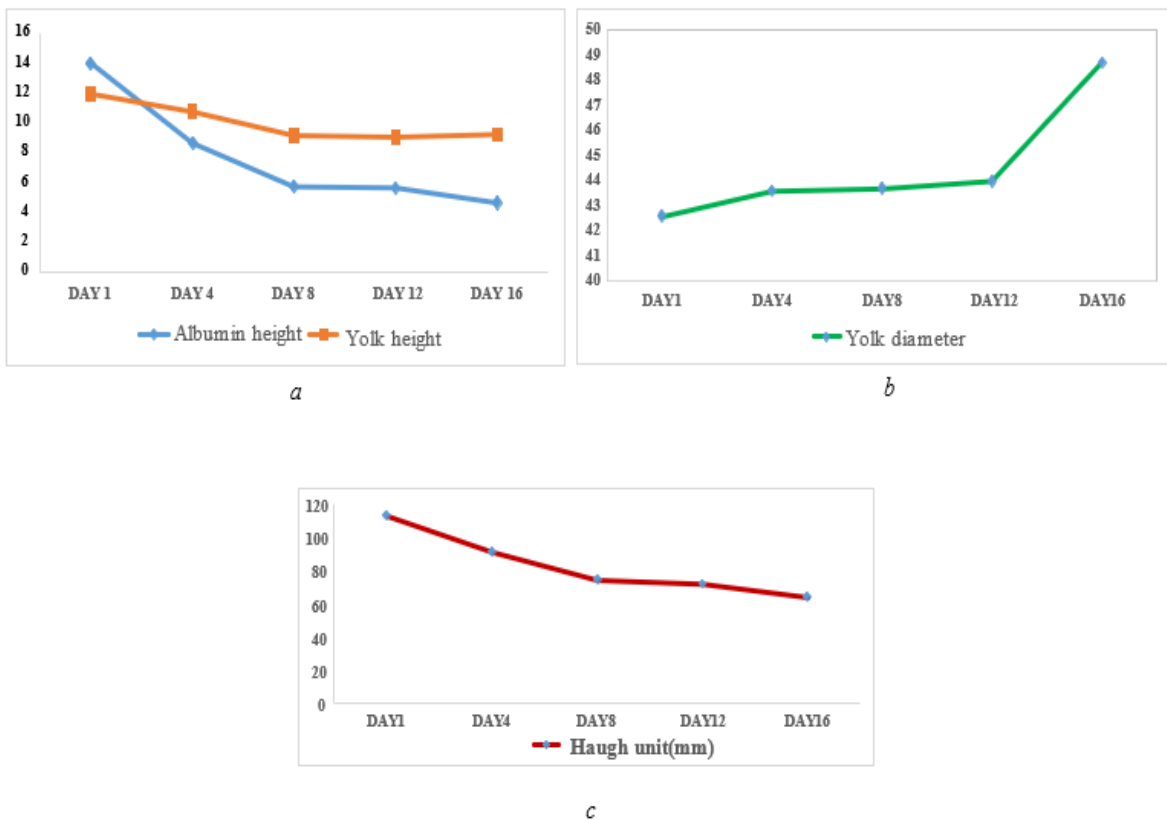
Figure 5. Plot of albumin and yolk height parameters (a), Plot of Yolk diameter (b), Plot of Haugh unit parameter (c).

The descending trend of Haugh unit were calculated once in every four days and is presented in Figure 5c. Albumin height and egg weight scale decreased over the test days, which affects the value of Haugh unit from day one to day sixteenth.

CONCLUSION

This research was based on information available on egg quality assessment by image processing method. Also, the relevant indices such as albumin height, yolk height, yolk diameter and Haugh unit is calculated. It was important to implement an image processing algorithm to reduce noise of image and separate albumin and yolk section from each other. The obtained results were used to classify the egg based on the internal quality assessment to the three value; AA, A and B grade. Therefore, the quality of the eggs has been declining for several consecutive days, which has been attributed to the decrease in albumin height and Haugh unit; A process that necessitates an examination of egg quality after eighth day. Considering the importance of egg quality assessment in the food industry, the method was an assured technique to achieve acceptable results.

DECLARATION OF COMPETING INTEREST

We declare that we have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Ehsan Sheidaee: Investigation, methodology, conceptualization, formal analysis, validation, writing.
Pourya Bazyar: Data curation, writing, review, editing, visualization.

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Impact of Improved Smoking Kiln Design on Hygiene and Timeliness of Drying of Smoked Fish

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ABSTRACT

The techniques used in processing cat fish in developing economies of the world are not without several drawbacks. The most prominent is traditional method and this has been known to generate high levels of polycyclic aromatic hydrocarbons (PAHs). In addressing the problems faced by processors in the industry, a fish smoker of 50 kg capacity that derives its power from dual heat sources (charcoal and gas) was designed, fabricated, and evaluated. The smoking time was evaluated on the heat sources with and without the use of a suction blower. The fish had a smoking (retention) time of 4 hours when it was processed without the suction blower while the retention time decreased from 4 hours to 3 hours when the suction blower was used. The suction blower also has a significant impact on the moisture content on dry basis (MC d.b.). The MC d.b. values of smoked fish when suction blower was used with charcoal and gas for 4 hours duration were 10.45% and 11.76%, respectively. Without blower, the values were 14.3% and 11.70%, respectively. The processed smoked fish produced was hygienic, not likely to exceed maximum limits of PAHs allowed by the United States Environmental Protection Agency since materials used are stainless steel and the heat sources used were indirectly introduced into the smoking chamber. Hygienic processing and practices of smoked fish and products can ensure food safety in our society.

INTRODUCTION

The origin of fish smoking dates back to the antiquity (Ames *et al.*, 1999; Silva *et al.*, 2011; Marzano, 2018). Over the years, various smoking techniques have been used including traditional ovens, drums, external hearth and fire (Marzano, 2018). Despite the comfort of use and low costs linked with the traditional smokestacks, they are not

energy efficient. The incessant use even raises the demand for already rare and unavailable firewood. Probable health hazards accompanying smoked fish from firewood are occasioned primarily by carcinogenic components of wood smoke – mostly polycyclic aromatic hydrocarbons (PAHs) and derivatives of PAH (Silva *et al.*, 2011). Therefore, smoking with firewood or other inefficient methods should be discouraged as much as possible. Because this method restricts the cross-border trade of processed fish due to the associated poor quality of the products, low capacity, high time rate of drying, poor energy efficiency and health effect.

Zwick *et al.* (2011) stressed the health effect of using open fire as indoor energy either for cooking or smoke-drying endeavors. The report reveals that twice as many people were reported dead each year from lung disease caused by indoor pollution as those died from AIDS, and open fire is the primary cause of that indoor pollution. Recent records from FAO (2018) and Khoshmanesh (2006) buttress that every year; over 3.3 million people die from illness attributed to indoor air pollution caused by these fire places. Health test conducted to measure smoke level in the lungs reveals 7.55 ppm for women and 6.48 ppm for children – these tally with the results from a person smoking 7 cigarettes in a day. Health effects of inhaling fine particles from wood smoke are Pneumonia, Lung inflammation, bronchitis, emphysema, etc. (Ajav *et_al.*, 2018). From the foregoing, smoke drying of fish through means other than mechanical dryer has deleterious impacts on processors' health and as well detracts from environmental sustainability efforts (Olayemi *et al.*, 2011).

A study conducted by Tongo *et_al.*, (2017) on hygiene of smoked fish processed in Nigeria discovered PAH4 levels varying from160 µg kg^{-1} to 470 µg kg^{-1} in traditionally smoked fish on informal markets while risks for cancer was discovered to be higher than allowed by the United States Environmental Protection Agency (USEPA). The study connected this discovery to the use of traditional kilns and therefore recommended the utilization of safer subsistence for smoking fish. The implication from this is that risk management action is needed on PAHs in fish smoked on traditional kilns (Bolaji, 2005).

According to Akinneye *et_al.*, (2007) and Davies and Davis (2009) the development of right fishing machinery and techniques that guarantee operational production, handling, processing and storage cannot be over stressed particularly now that aqua-cultural development is gaining popularity. Generally, there is copious fish catch in the dry season and at this period, lakes, streams, ponds and other water bodies experience reduction in water level. This creates opportunity for easy harvest and subsequent scarcity of fish during flood and raining seasons. It is vital to process and preserve quota of the fish caught in this season of abundance, so as to safeguard a sustainable supply of fish during off season and increase profit potentials of the fisher folks (Bolaji, 2005).

Major limitations to adoption of enhanced fish processing and preservation know-hows in the developing countries like Nigeria include shortage of upgraded kilns, high cost of kilns where available, the drying time, difficult technical features of the kilns and inadequate awareness due to lack of synergy between research institutions and the fishery industry where these kilns are needed (Olayemi *et_al.*, 2011).

Smoking according to Komolafe *et_al.*, (2011) can be performed in four ways namely: warm smoking, cold smoking, liquid smoking and hot smoking.

However, this research work is limited to hot smoking of cat fish. The design utilizes either charcoal or gas burner as smoke producer which then flows up as condensates either by free flow or forced aeration. The air flow pattern is laminar, vertical and

circulatory. When smoke producer heats up tick metal platform at the base, the suction blower sucks out the hot air and then redirects it back to the lagged chamber to bring about even heat distribution on the materials under process. Processing time in the kiln is normally in three stages which are: the preliminary dry period; anding period when the skin is toughened to prevent subsequent breakage; the smoking and partial cooking period, and the final cooking period.

Effort of this research endeavor is in essence geared toward designing and constructing an improved kiln in Agricultural and Bioenvironmental Engineering (ABE) department, Federal Polytechnic Ilaro, Ogun Nigeria. The incorporation of designed parameters such as suction blower, temperature sensor (micro controller) and dual heat source made this new design different from the conventional smoking kiln designs. The new design will help to achieve improved smoking timeliness, maximize kiln capacity and as well improve hygienic condition of processed fish.

MATERIALS AND METHODS

This section reveals the design philosophy, major component parts of the smoking kiln, design criteria, material selection, parameters to be measured during evaluation, design calculation, experimental procedure, materials used for evaluation and method of analysis of results.

Design Philosophy
Smoked fish is a product that has been cured by smoking. Smoking process involves flavouring, browning, cooking, or preserving food through exposure to smoke to avoid burning or smoldering material, most often wood, charcoal or other alternative sources. Fish smoking can be carried out in four ways. These include cold smoking, warm smoking, hot smoking, and through the employment of liquid smoke. Therefore, the design of smoking kiln can utilize either charcoal or gas burner as smoke producer which then flows up as condensates either by free flow or forced aeration. The air flow pattern is laminar, vertical and circulatory. When smoke producer heats up tick metal platform at the base, the suction blower sucks out the hot air and then redirects it back to the lagged chamber to bring about even heat distribution on the materials under process.

Major Component Parts of the Smoking Kiln
The smoking kiln was designed and constructed at the Engineering Workshop of the Department of Agricultural and Bio-Environmental Engineering, Federal Polytechnic, Ilaro, Ogun State, Nigeria. The kiln cabinet is made from stainless steel metal sheet of 1.5mm gauge. It was lagged with fibre glass as insulator. The smoking chamber consists of set trays with dimension 737 mm × 480 mm arranged into six layers in the chamber. Each layer is made of stainless-steel tray. The cabinet overall dimension is 830 mm × 400 mm × 1250 mm. Wire gauze also made from stainless steel were framed round in the dimension specified above to form each tray. The improved smoking kiln design has dual power, namely charcoal and gas. The heat chamber was separated from smoking chamber by 2 mm thick metal platform beneath the trays layers to prevent direct flow of naked flame from the burner to the tray section where the materials to be smoked will be laid in layers. Even distribution of heat around the chamber is made

possible via suction blower introduced at the top of the kiln near the chimney. The blower sucks heated air from the heat chamber and then directs it to the smoking chamber where fish under process are smoke dried. The suction blower capacity is 1.5 hp. The chimney conducts the mist to the surrounding air outside.

Component Parts of the Smoking Kiln

1. Heat Chamber: It is a type of oven that produces temperatures adequate to finish some process, such as hardening, drying, or chemical changes. The heat chamber in this technical report uses dual power, namely charcoal and gas burner. This section of the design is separated from the smoking chamber so as to prevent direct heat contact with the material to be smoked.

2. Smoking Trays: The trays are made with stainless steel materials and the length and breadth are 737.0 mm and 480.0 mm. This is the container into which the fish is loaded and smoked.

3. Tyres for Mobility: It helps in moving the smoking kiln from one place to the other. The smoking kiln therefore consists of four tyres for ease of mobility.

4. Suction Blower: The blower of 60 mm diameter and thickness of 1 mm was chosen. The blower was attached to the side view of the kiln and directly facing the charcoal pot and the gas burner. It also helps in blowing hot air into the smoking chamber so as to enable heat to spread in the smoking chamber. The capacity of the suction blower is 1.5 hp.

5. Chimney: The chimney was made of pipe of 2 mm thickness and diameter of 125 mm rapped under a protection cap. This component allows excess heat and mist in smoking chamber to pass out.

6. Stainless Steel Platform: It is used in transferring heat from the sources of power into the chamber and also helps in moisture drainage.

7. Cabinet framework: The frame supports the other component parts on it in order to make the entire assemble stable. It is made up of stainless steel of 830 mm × 400 mm × 1250 mm. The outer frame is made of mild steel so as to reduce production cost.

Design Consideration

Some relevant factors were considered in the design and fabrication of smoking kiln. Such factors are cost of maintenance, power requirement and ease of replacement of the various components, nature of material for construction and labor requirement. The machine is easy to maintain. Stainless steel of 1.5 mm thick plate was considered for the construction of parts to avoid contamination with the food materials to be processed.

Material Selection

Table 1. Table of material selection.

Machine component	Criteria for material selection	Machine selected	Dimension	Remark
Smoking tray	Must be strong and able to acquire more material	Stainless steel of 5 mm thickness	737 mm x 480 mm x 5 mm	It does not twist and each tray has ability to contain 8.5kg of fish
Heat chamber	Ability to withstand vibration and the heat that comes from heat source.	Stainless steel of 5mm thickness	752 mm x 300 mm x 1016 mm	Durable (fabricated)
Chimney	Must be strong	Galvanized Iron	296.0 mm long	It was constructed
Suction blower	Must be able to blow air into the chamber	Galvanized Iron	960.0 mm long and ɸ 60	Available (bought ready-made)
Stainless steel platform	Ability for ease of flow of heat from the source of power	Stainless steel of 3mm thickness	737 mm x 480 mm x 3 mm	Durable (fabricated)
Member frame	Must be strong and not flexible	Stainless steel	830 mm × 400 mm × 1250 mm.	Constructed

Figure 1 below shows the pictorial view of the kiln. The view shows the chimney of the smoking chamber, suction blower, tyres and handle. It was designed in such a way that the chamber can process 50 kg of fish per batch of drying. Figure 2 is the autographic projection of the entire assembly. The front view, side view and the plan are shown in the view. From the Figure, the layers of tray in the chamber, dual power section (charcoal and gas burner), oil and moisture spill platform and the draining trough can be seen. The working drawing is as shown in Figure 3 below.

S/N	COMPONENTS	SPECIFICATION
1	Exhaust Pipe	60 x 3mm thick Milld Steel Pipe
2	Suction Blower	Centrifual Fan
3	Thermometer	0-150 Cegree Centigrade
4	Heat Recirculation Pipe	55mmx 3mm Thick Pipe
5	Frame	40x 40 x 3mm Square Pipe
6	Smoking Chamber	-
7	Heat Source	-
8	Cylinder Rack	40 x40x4mm Angle Iron
9	Charcoal Pot	3mm Mild Steel Sheet
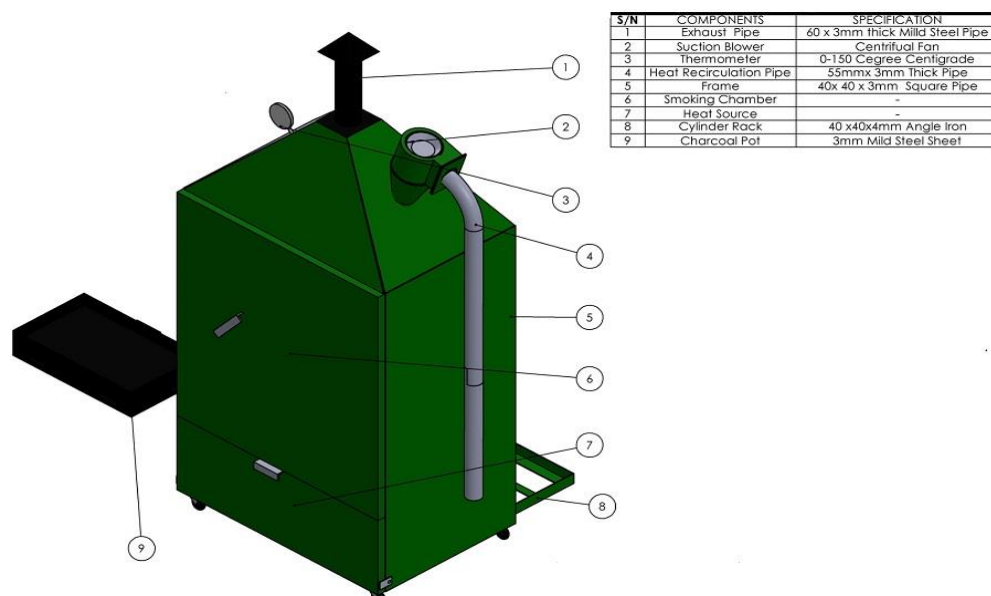
Figure 1. Pictorial view of the fish smoker.
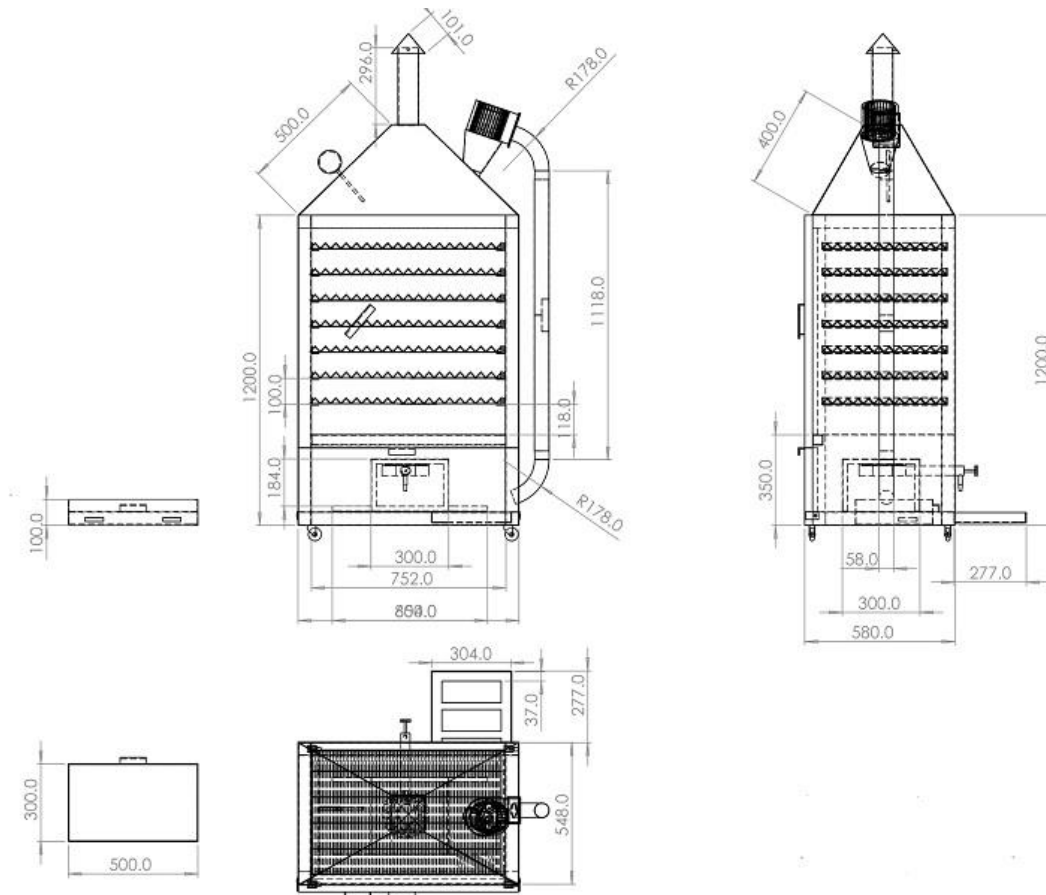
Figure 2. Autographic view of the fish smoker.
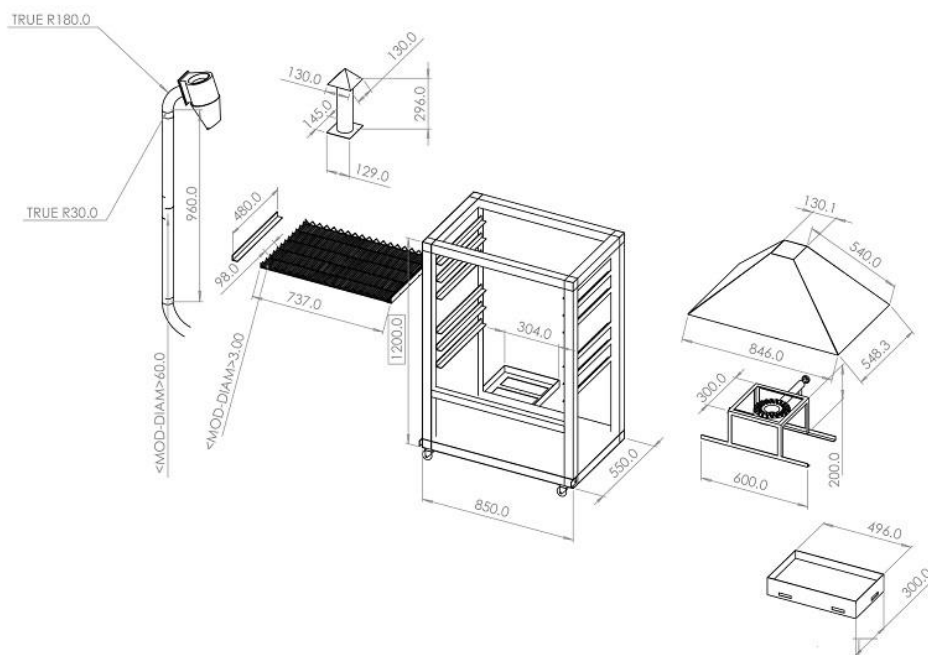
Figure 3. The working drawing of the fish smoker.

Materials and parameters for evaluation

Materials used for the smoking kiln evaluation are fresh cat fish at 70% MC, a microcontroller for temperature measurement, moisture meter for moisture content measurement, sensitive measuring scale, stop watch and recording materials. Variables

considered during evaluation are use of independent heat sources (charcoal and gas), smoking with and without suction blower, etc. Parameters measured are time rate of drying, weight at every hour of drying, temperature of each chamber and moisture content.

Fresh sample (28kg) of African catfish (*Clarias gariepinus*) was purchased from a fish farmer by a river site in Ilaro town of Ogun State, Nigeria in August 2019. The sample was brought into the Agricultural & Bio-Environmental Engineering Departmental workshop and 8kg was divided into four equal portions of about 2kg each. The first and second portions were smoke dried with the use of both charcoal and gas. The suction blower was powered for the first two experiments. In the third and fourth experiments conducted for both charcoal and gas, the suction blower was not powered. The quantity of fish processed was increased to 20 kg in the fifth experiment to confirm if quantity processed per batch will affect the time rate of drying. Figures 1 and 2 show some of the experiment runs carried out in this research work.

Design Calculation for the Improved Kiln
Fish tray design
The volumetric capacity of each fish tray was calculated in relation to the volume of fish it occupies. Each tray was designed to contain 8.5 kg of fish per unit operation on the average. The volume of any material was calculated as given by Khurmi and Gupta (2005):

$$V_1 = \frac{M}{\rho} \tag{1}$$

Where:
V_1 = volume of material in mm^3
M = mass of the material in kg = 8.5 kg
ρ = bulk density of fish (kg m^{-3}) = 1080 kg m^{-3} (Kamaldeen *et al.*, 2016)

$$V_1 = \frac{8}{1080}$$

V_1 = 0.00741 m^3

Compartment design
In the design of fish tray volumetric capacity, the shape of the compartment was designed to be rectangle. The dimension of the smoking tray is 737 mm x 480 mm x 5 mm and the skeletal view of the fish tray is as shown in Figure 4 below. The tray is made of stainless-steel wire net of 5 mm thickness.

V_2 = volumetric capacity of the compartment (Kamaldeen *et al.*, 2016)
= 1.5 × V$_1$ (Kamaldeen *et al.*, 2016)
= 1.5 × 0.00648
= 0.00972 m^3
Volume of the fish tray was multiplied by 1.5 to determine tray volumetric capacity in order to allow for enough clearance and space in the tray.
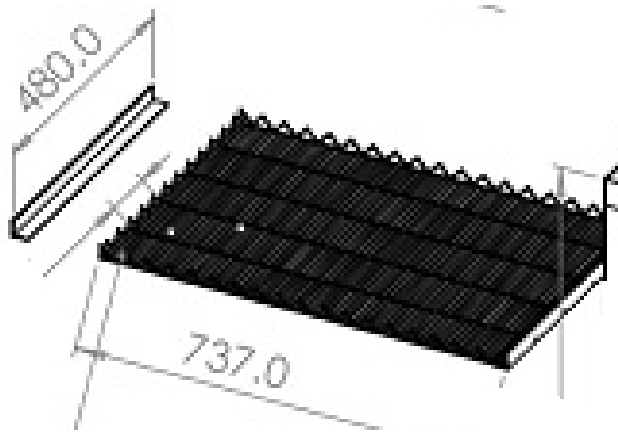
Figure 4. Skeletal view of the fish tray.

Rate of fish smoking by the machine

Since basic concept in smoking operation is to reduce moisture to save level for the purpose of longer storage, which is the same as drying, the drying rate formula can also be employed. Time taken for drying any commodity is given by Donald *et al.,* (1974) as:

$$\frac{C_{fm} \times 60}{V} C_a (T_a - T_e)t = h_{fg}DM(M_f) \tag{2a}$$

$$t = \frac{h_{fg}DM(M_f)}{\left[\frac{C_{fm} \times 60}{V}C_a\right](T_a - T_e)} \tag{2b}$$

(from equation 2a)

C_{fm} = Air flow from blower m³/s. This can be determined using expression given by Joshi (1978) as:

$$C_{fm} = AV \tag{3}$$

Where:
V = Velocity of air required for heat flow (m s⁻¹) = 9.8 m s⁻¹ (Ghanem and Shetawy, 2009),
A = Area of air duct or chute (m²); r = 0.028 cm (radius of the air duct)
$A = \pi r^2 = 3.14 \times 0.29^2$ m²
$C_{fm} = 3.14 \times 0.028^2 \times 9.8 = 0.024$ m³ s⁻¹ (volume flow rate of hot air through the piping)
V = Heated air specific volume = 13.26 m³ kg⁻¹ (Donald *et al.,* 1974)
C_a = Air specific heat = 240 kJ kg⁻¹ °C⁻¹ (Donald *et al.,* 1974)
T_a = Charcoal temperature (heated air temperature) = 450°C
T_e = External temperature of smoked fish 27°C ambient air. This can be determined from the equation of heat flow which can be given as:

$$q = KA\,(T_e - T_a) \tag{4a}$$

$$T_e = T_a - \frac{q}{KA} \tag{4b}$$

(From Equation 4a)

Where:
q = Heat produced by charcoal = 3.14×10^4 kJ
K = Fish thermal conductivity = 3.04×10^3 kJ °C^{-1} m^{-2}
A = Fish average surface area = 0.045 m^2 (Kamaldeen *et al.*, 2016)

$$T_e = 450 - \frac{3.14 \times 10^4}{3.04 \times 10^3 \times 0.045} \quad = 220° \text{ C}$$

h_{fg} = Latent heat of vaporization = 1200 kJ kg^{-1} (Donald *et al.*, 1974)

Dry matter calculation for charcoal heat source without suction blower
DM = Fish dry matter in the kiln which can be computed as given by (Donald *et at.,* 1974) as:

$$DM = W \, (1\text{-}MC) \tag{5}$$

Where: W = weight of fishes per unit tray = 2.0 kg
MC = Fish moisture content on wet basis which vary from 30 -75% but for this design, 70% fish moisture content on wet basis was selected
DM = 2.0 (1 − 0.70)
= 0.6 kg

Dry matter calculation for gas heat source without the use of suction blower
With reference to equation 5 above,
Where: W = weight of fishes per unit tray = 3 kg
MC = Fish moisture content on wet basis which vary from 30 -75% but for this design, 70% was selected
DM = 3 (1 − 0.70)
= 0.9 kg

Dry matter calculation for gas heat source with the use of suction blower
Where: W = Weight of fishes per unit tray = 4 kg
MC = Fish moisture content on wet basis which vary from 30 -75% (Kamaldeen *et al.,* 2016) but for this design, 70% was selected
DM = 4 (1 − 0.70)   = 1.2 kg

For moisture content M_2 of next level of drying,

$$M_2 = 100 - \frac{W1(100-M1)}{W2} \tag{6}$$

Where:
w_1 = Weight of un-dried fish,
w_2 = Weight of dried fish,
M_1 = Moisture content of un-dried fish
M_2 = Moisture content of dried fish

Smoking time calculation
From Equation 2b,
Where t = smoking time (min) which is given as:

$$t = \frac{h_{fg} \times DM \times M_f}{\left[\frac{C_{fm} \times 60 \times C_a}{V}\right](T_a - T_e)} \tag{7}$$

$$t = \frac{1200 \times 12.5 \, (2.33)}{\left[\frac{(0.049 \times 60) \, 0.0024}{13.26}\right] (450 - 220)}$$

$$= \frac{34\,950}{1.52} = 22\,993.42 \; s \cong 4h \; 40 \; min$$

Therefore, if all the six fish trays loaded with equal average size of a fish (0.5 kg) are expected to be completely smoked within 4 hours 40 minutes.
Note: Since uniform distribution of heat is expected in the cabinet using blower, all the trays loaded with fish are assumed to smoke at the same rate.

Smoking cabinet design
In designing the smoking cabinet, the sectioned view of the cabinet is shown in Figure 5 below. The volumetric capacity of smoking cabinet was computed in relation to the equation as given by John (2005) as:

$$V_3 = A \times W \tag{8}$$

Where:
V_3 = Volume of smoking cabinet in m^3
A = Surface area of smoking cabinet in m^2
Surface area (A) was obtained using equation given by John (2005) as:

$$A = \frac{L \, (3H + L)}{2} \tag{9}$$

Where:
L = Length of the smoking cabinet = 830 mm selected for convenient containment of 6 fish trays,1 charcoal pot, 1 oil collector within the chamber and 1 gas burner (for the smoking cabinet)
H = 1250 mm selected for convenient containment of 6 fish trays, 1 charcoal pot and 1 oil collector within the chamber and 1 gas burner
$A = 830 \, x \frac{3 \, x \, 1250 + 830}{2} = 1\,900\,700$ mm^2
w = Smoking cabinet width = 400 mm selected for convenient containment of 6 fish trays, 1 charcoal pot and 1 oil collector within the chamber and 1 gas burner V_3
= 1 900 700 ×400
= 760 280 000 mm^3
V_3 = 0.76 m^3
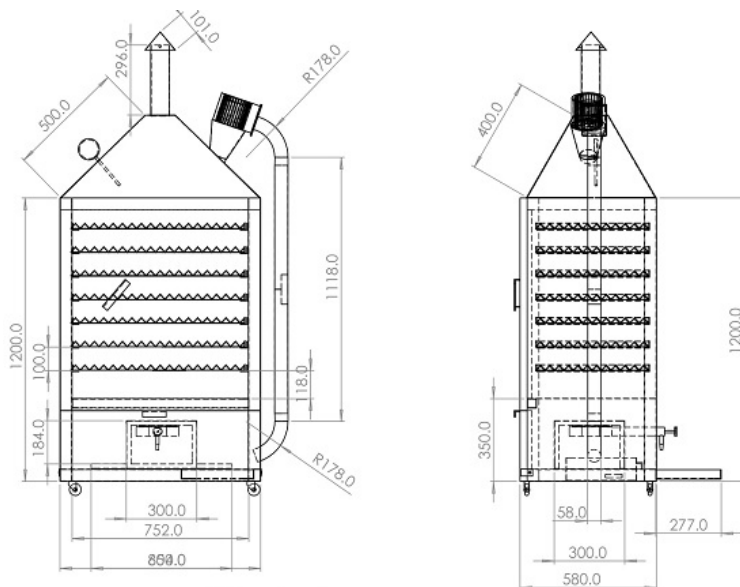
Figure 5. Sectioned view of the smoking cabinet.

The Smoking Kiln Working Principle

To operate the kiln, charcoal was arranged in the fire pot, ignited and kept opened for a while until the amber is uniform before fish are loaded on the tray. For the alternative heat source, industrial gas burner was used. The burner design is achieved by slotting arrangement provided at the base section of the chamber. It can be used in place of the charcoal pot. The ability the smoking kiln has for dual heat source gives it advantage over existing kilns around. Also, the gas burner is fast and supplies blue flews while in operation. On closing the door, the hot air supply either from charcoal pot or gas burner flows upward to obey the principle of heat flow from region of higher concentration to lower concentration.

The smoke chamber is firmly shut and opened at intervals of 1 hour for observation and necessary readings like weight, moisture content, time taken, temperature and other relevant parameters for analysis. The heat transfer was aided mechanically by the use of suction blower incorporated in the design at the top. The suction blower has prime mover of 1.5 hp electric motor attached and is powered by electricity. The heat flow is aided by the blower through heat flow by conduction, convection and radiation. The charcoal pot is positioned by slotting arrangement too. The design is done in a way to prevent dripping of oil and moisture on the hearth so as to reduce smokiness of the chamber or eventual fire outburst. The burner has a 2 mm thick plate on it in the chamber to prevent fire outburst. The plate was designed to be sloppy downward so that it can easily convey both oil and water drips to the draining trough at the peripheral of the chamber.

During smoking endeavor, the trapped hot air goes through the suction blower and then returns back to the kiln chamber through the galvanized iron pipe fitted to the member frame - see Figures 1, 2, 4 and 5 above for details. The lagging ensures that the drying chamber remains hot for a long period after the charcoal is burnt or burner fired. The temperature of the system was measured with the aid of a digital microcontroller sensor inserted in the perforated sides of the chambers. With the aid of materials and other insulators used in the construction, it denotes a partial hermetic heating and smoking process.

Experimental Procedure

Two different sources of power (gas and charcoal) were used to smoke the fish sample (cat fish). The samples were washed thoroughly and salted with 10gm of salt, then permitted to dry before they are laid on the fish tray for smoking endeavor. The charcoal in the pot charcoal was first kindled with the help of kerosene, the kindled charcoal was allowed to burn for 10 to 15 min to allow the kerosene odour to be exhausted. Additional charcoal was supplied to the burning charcoal and put underneath the thick plate platform. Similar operation was carried out for the alternative source (gas). From the experiment, it was deduced that the time to smoke with gas was shorter as compared to charcoal. More also, smoking with gas retained the golden brown colour of the smoked fish compared to charcoal.

For another experiment, suction blower was introduced for the two sources of power (charcoal and gas), the suction blower was driven to injet a fairly hot constant heat. During the smoking, the sides of the fish facing the burning flame are changed routinely by pulling out the burning tray and then turning the fish's upside down. The trays are then pushed back afterwards.

Similarly, the weight of the fish is computed intermittently at an hour interval anytime the arrangement of the fish is to be altered and the corresponding moisture content calculated (Ashaolu, 2014). This situation continued until the final weight and hence the final moisture content is obtained. The final moisture content that is, safe moisture content (10 to 15%) (Olayemi et al., 2011) is computed using equations 5 and 6 above when there is virtually no further reduction in the moisture content. The time taken for the smoking was the total time taken including the time for the intermittent computation of moisture content and that of altering the position of the fish.

The result is given in Tables 2 to 6 below. After smoking and determination of final moisture content, the fish is permitted to cool and kept in plastic bucket, well covered carton and polythene bag to compute its storage life. These containers were carefully chosen because they are among the mutual storage materials used for handling fish in Ogun State. The determination of the storage life was carried out in the months of August to November 2019. Figure 6 below shows the flow chart of the smoking process.
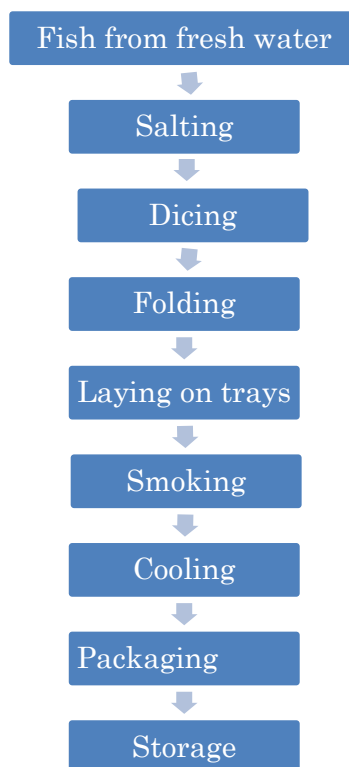
Figure 6. Flow chart of fish smoking process.

Cost Estimation of the Kiln

Cost of engineering products like the newly developed smoking kiln can broadly be grouped under direct or indirect cost. Direct cost is the cost of factors which are directly credited to the manufacture of a precise product (i.e. materials and labor costs). Indirect cost on the other hand is that indirectly credited to the manufacture of a specific product, such as overhead cost (usually expressed in percentage of direct labor cost) (Ajav et al., 2018). The costing of the newly designed and fabricated smoking kiln was based on the detailed factorial estimate method (John, 2005). This is because fabrication of the machine is complete and detailed breakdown and estimation of component parts is possible. The cost analysis of the machine is shown in table 2 below.

Table 2. Bill of Engineering Measurement and Evaluation (BEME) of the improved smoking kiln - mechanical components (Direct Material Cost).

Qty.	Material Specifications	Rate (₦)	Amount (₦)	Amount (USD)
1	Angle Iron One Length, 25 mm x 25 mm x 3 mm	1.500	1.500	4.5
2	Cutting Stones	500	1.000	3.0
3	Grinding Stone	500	1.500	4.5
1	Stainless steel plate 1 mm thickness	22.000	22.000	66.0
2	Mild steel plate 1 mm thickness	11.000	22.000	66.0
6	Stainless mesh	4.000	24.000	72.0
1	Hollow pipe 90 mm diameter	5.000	5.000	15.0
1	Blower	15.000	15.000	45.0
4	Tire	1.250	5.000	15.0
50	Fiber glass per kg	300	15.000	45.0
1	Pkt. Mild Steel Electrode Gauge 12	4.000	4.000	12.0
50	Stainless steel electrode (pieces)	100	5.000	13.0
	Transport	5.000	5.000	15.0
Sub Total			**₦ 126.000**	**376.0**

Direct labor cost
Fabrication (Bending, Rolling, Shearing, welding, painting) 7 000
Sub Total = ₦7 000 (USD 21.0)

Indirect / Overhead Cost
1. Over head of direct material cost = 20% of ₦7 000 = ₦1 400
2. Over head of direct labor cost = 20% of ₦126 000 = ₦25 200

Sub Total = ₦26 600 (USD 79.8)
Total = ₦126 000 + ₦7 000 + ₦26 600 = ₦159 600 (USD 478.8)

Statistical Method and Result Analysis

Correlation (product moment method) and Regression (least square method) were used as statistical instrument for result analysis. Correlation coefficient, r is as given in equation 10 below. Null hypothesis is Ho: $\pm 0.5 \leq r \leq \pm 1$; while alternative hypothesis is H₁: $r < 0.5$. For Ho in the range of values stated above, it means there is a strong relationship between the dependent variable and independent variable. If the correlation coefficient is not within acceptable region, alternative hypothesis is accepted. The implication of this is that the relationship between them is weak or unacceptable.

$$r = \frac{\sum xy - n\ddot{x}\ddot{y}}{\sqrt{\{\sum x^2 - n(\ddot{x})^2\}\{\sum y^2 - n(\ddot{y})^2\}}} \tag{10}$$

$$b = \frac{n\sum xy}{n\sum xy - \frac{\sum x \sum y}{n\sum x^2 - (\sum x)^2}} - \frac{\sum x \sum y}{n\sum x^2 - (\sum x)^2} \tag{11}$$

$$a = \bar{y} - b\ddot{x} \tag{12}$$

$$\bar{y} = \sum y / n \tag{13}$$

$$\ddot{x} = \sum x / n \tag{14}$$

$$y = bx + a \tag{15}$$

Using equations 10 to 13, regression line "*y = bx + a*" (equation 15) can be determined. Relationship between the dependent variables and the independent variables was established through the statistical instrument and table 8 for summary of the relationship between moisture content and drying time.

RESULTS and DISCUSSION

Tables 3, 4, 5, 6 and 7 below show the result of smoking exercise of cat fish at moisture content of 70%. The weights of fish processed for the five experiments are 2 kg, 2 kg, 2 kg, 2 kg, and 20 kg respectively. The final weights for the first four experiments are respectively 0.67 kg, 0.68 kg, 0.68 kg and 0.70 kg. For the fifth experiment, the final weight is 6.72 kg.

In the first experiment, charcoal was used as source of heat with the exception of suction blower. The second experiment involves use of gas burner as source of power for fish smoking without the use of suction blower. The first two experiments were repeated

in the third and fourth experiment with the use of suction blower. The last experiment (fifth) was a repeat of second experiment. But this time, the quantity of fish processed was increased to 20 kg as against 2 kg to confirm if quantity of fish processed per batch has impact on drying time. See Figures 7, 8, 9 and 10 for detailed information on the mechanical dryer.

It took four (4) hours to run the first two experiments to safe moisture content of 10.45% and 11.76% respectively. In attaining safe moisture content for prolonged shelf life like the one in the first two experiments, the third and fourth were repeated but this time with suction blower. Their moisture content of 11.7% and 14.3% were attained in three hours. The fifth experiment took less than five hours (4 hours, 30 minutes) to attain moisture content of 10.7%. All the five experiments took less than five hours to attain moisture content recommended in the literature for fish preservation. Figures 11, 12, 13, 14 and 5 are the plots for the five experiments. These results are discussed in the next subsection.

Figure 7. Smoking exercise with the mechanical dryer.

Figure 8. Exercise on weight measurement after smoking endeavour.

Figure 9. Mechanical dryer showing dual heat sources used for the experiment.

Figure 10. Instruments used for measurement of weight, temperature and moisture content.

Table 3. The result of evaluation using charcoal without suction blower.

Time	Weight of tray	Weight of tray with fish	Weight of fish	DM	MC
(h)	W_1 (kg)	W_2 (kg)	W_3 (kg)	(kg)	(%)
0	2.20	4.20	2.00	0.60	70.00
1	2.20	3.70	1.50	0.60	60.00
2	2.20	3.40	1.20	0.60	50.00
3	2.20	2.98	0.78	0.60	23.08
4	2.20	2.87	0.67	0.60	10.45

Table 4. The result of evaluation using gas without suction blower.

Time	Weight of tray	Weight of tray with fish	Weight of fish	DM	MC
(h)	W_1 (kg)	W_2 (kg)	W_3 (kg)	(kg)	(%)
0	2.20	4.00	2.00	0.60	70.00
1	2.20	3.76	1.56	0.60	61.54
2	2.20	3.45	1.25	0.60	52.00
3	2.20	3.00	0.80	0.60	25.00
4	2.20	2.88	0.68	0.60	11.76

Table 5. The result of evaluation using charcoal with suction blower.

Time	Weight of tray	Weight of tray with fish	Weight of fish	DM	MC
(h)	W_1 (kg)	W_2 (kg)	W_3 (kg)	(kg)	(%)
0	2.20	4.20	2.00	0.60	70.00
1	2.20	3.60	1.40	0.60	57.00
2	2.20	3.00	0,80	0.60	25.00
3	2.20	2.88	0.68	0.60	11.70

Table 6. The result of evaluation using gas with suction blower.

Time	Weight of tray	Weight of tray with fish	Weight of fish	DM	MC
(h)	W_1 (kg)	W_2 (kg)	W_3 (kg)	(kg)	(%)
0	2.20	4.20	2.00	0.60	70.00
1	2.20	3.60	1.40	0.60	57.00
2	2.20	3.00	1,00	0.60	40.00
3	2.20	2.90	0.70	0.60	14.30

Table 7. Result of evaluation using gas with suction blower with large quantity processed.

Time	θ	W_1	W_2	W_3	W_t	DM	MC
(h)	(°C)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)
0	40.51	7.00	7.00	6.00	20.00	6.00	70.00
1	109.30	5.88	6.13	5.14	17.15	6.00	65.02
2	112.50	5.05	5.23	4.41	14.6	6.00	59.16
3	115.66	3.90	3.98	3.38	11.25	6.00	46.67
4	147.80	3.19	3.37	2.81	9.37	6.00	35.97
4.30 min.	156.20	2.30	2.40	2.02	6.72	6.00	10.71

Table 8. Summary of the relationship between moisture content and drying time at various conditions.

S/N	Dependent Variable	Independent Variable	Resulting Equation (Regression Line)	Null Hypothesis, r (correlation coefficient)	Inference
1	Moisture Content	Drying Time	$y = -15.6x + 73.91$ $R^2 = 0.9649$	$r = \frac{271.04-427.1}{\sqrt{\{10 \ x \ 2521.18\}}}$ $= -0.983$ $r \approx -0.98$ *Note: result from using charcoal without suction blower*	Strong negative correlation, Ho is therefore accepted
2	Moisture Content	Drying Time	$y = -15.3x + 74.664$ $R^2 = 0.9565$	$r = -\frac{153.02}{\sqrt{24568.92}}$ $r = \approx -0.976$ *Note: result from using gas without suction blower*	Strong negative correlation, Ho is therefore accepted
3	Moisture Content	Drying Time	$y = -20.69x + 71.96$ $R^2 = 0.9679$	$r = -\frac{103.48}{\sqrt{11049.2}} = -0.985$ $r \approx -0.99$ *Note: result from using charcoal with suction blower*	Strong negative correlation, Ho is therefore accepted
4	Moisture Content	Drying Time	$y = -18.41x + 72.94$ $R^2 = 0.9761$	$r = -\frac{91.9}{\sqrt{8725.7}} = -0.984$ $r \approx -0.98$ *Note: result from using gas with suction blower*	Strong negative correlation, Ho is therefore accepted
5	Moisture Content	Drying Time	$y = -12.078x + 77.6$ $R^2 = 0.8717$	$r = -\frac{718.02}{\sqrt{42616.7}}$ $= -0.959$ $r \approx 0.96$ *Note: result from Gas with suction blower with large quantity processed*	Strong negative correlation, Ho is therefore accepted

Results from Table 8 show that there is relationship between the moisture content of the fish and the retention time. Since r value is within the range of null hypothesis, null hypothesis was therefore accepted. The deduction from the evaluation is that strong negative correlation existed between moisture content and drying time irrespective of drying condition or parameter varied. Fish moisture reduces as retention time increases. The colour also kept changing until stable golden-brown colour was attained. Beyond this level (retention time), it was observed that the colour changed to burnt brown.

The rate of moisture removal measures quantity of moisture being removed by the smoking kiln per unit time. The moisture removal was measured hourly using the average value of mass of fish weighed at interval of an hour in each case. From the graph in Figure 11, it can be deduced that it took 4 hours for the smoking kiln to dry 2 kg of cat fish to moisture content of 10.45% when the suction blower is not powered. 10 -14 % is the recommended MC in the literature (FAO, 2018) to prolong the shelf life of the fish to about 3 months or more.

The graph in Figure 12 shows the relationship between moisture content and time rate as well. But this time, the heat source is gas and suction blower was not also used. The weight of fish processed is 2 kg and the final moisture content got is 11.76% at the end of fourth hour of smoke drying. While comparing the first graph with the second, it was discovered that at fourth hour of drying the second sample (11.76%) has less prolonged shelf life than the first (10.45%). But, what the second lacked in shelf life is compensated for in the cost of fuel (gas) used. The hygiene of the fish is even retained using gas since it produces blue flame than using charcoal. There is possibility of

carbon (II) oxide forming the coatings for the sample processed using charcoal and this may be dangerous to health.

The graph in Figure 13 shows the relationship between moisture content and time rate as well. This time, suction blower was used, and the heat source is charcoal. The weight of fish processed is 2 kg and the final moisture content got is 11.70% at the end of third hour of the experiment for the sample. The graph shows that the moisture content (MC) peaked at third hour. The implication is that the use of suction blower has positive impact on drying time when compared with the first and second experiment.

The graph in Figure 14 shows the relationship between moisture content and the drying time when suction blower was used with gas burner. At third hour, the moisture content was observed to be 14.30% unlike the first and second that took four (4) hours to bring them to moisture content of 10.45% and 11.76% respectively. Another inference from the third experiment is that introduction of suction blower for even heat distribution brought the time of drying below usual drying hours by one (1) hour. More also, the moisture content at the third hour is in the range of moisture content (10-14%) recommended in the literature for preservation of dried fish (Ashaolu, 2014). It should be noted that oil was part of what sipped out from the cat fish during the smoking process and this was collected through draining trough at the peripheral of the smoking kiln. Fish with very high oil content will affect accuracy of result as oil will be part of weight measured at interval (Ashaolu, 2014).

Lastly, other evaluation method was carried out using gas burner as source of power with large quantity. This time, suction blower was powered. The weight of fish processed is 20 kg and the final moisture content got is 10.71% at the end of four hours thirty minutes (4½ hours). From the evaluation observed, the smoking kiln can process 50 kg of fish and more. Synoptically, the quantity of fish to be processed has moderate impact on drying time when suction blower is used.
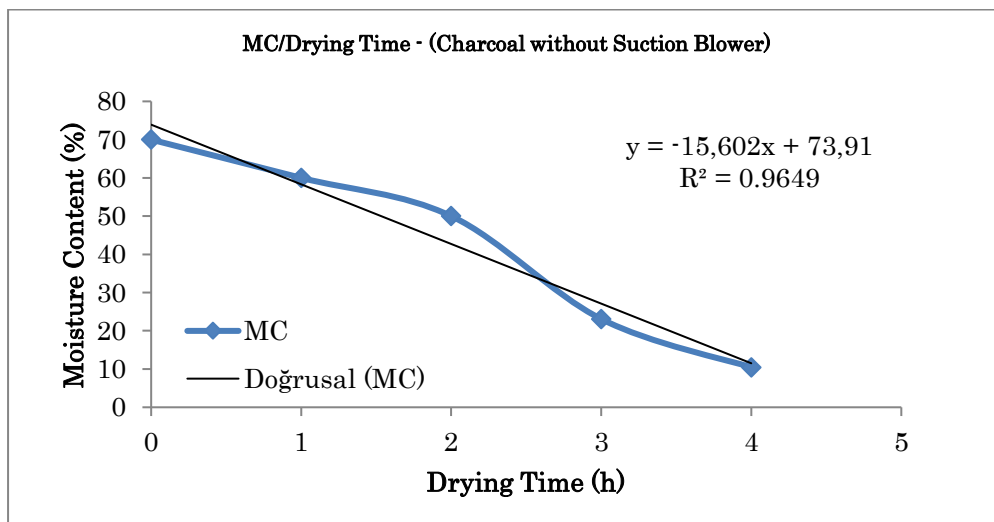
Figure 11. Graph of MC against drying time (charcoal without suction blower).
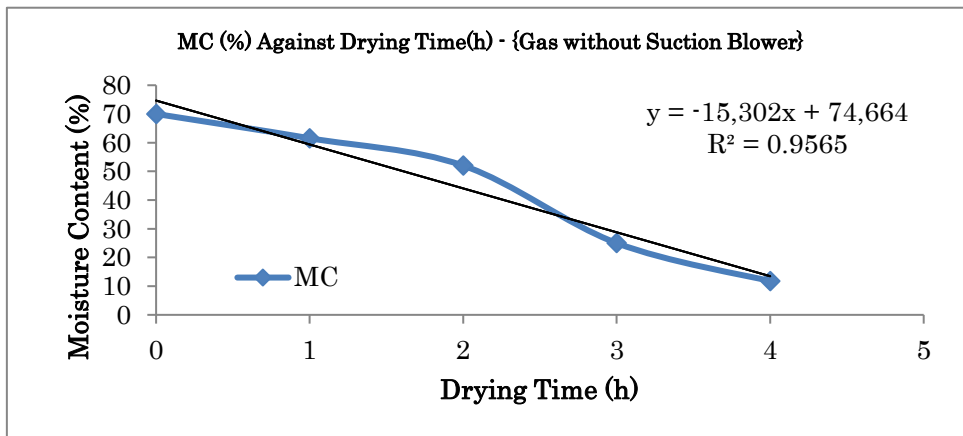
Figure 12. Graph of MC against drying time (Gas without suction blower).
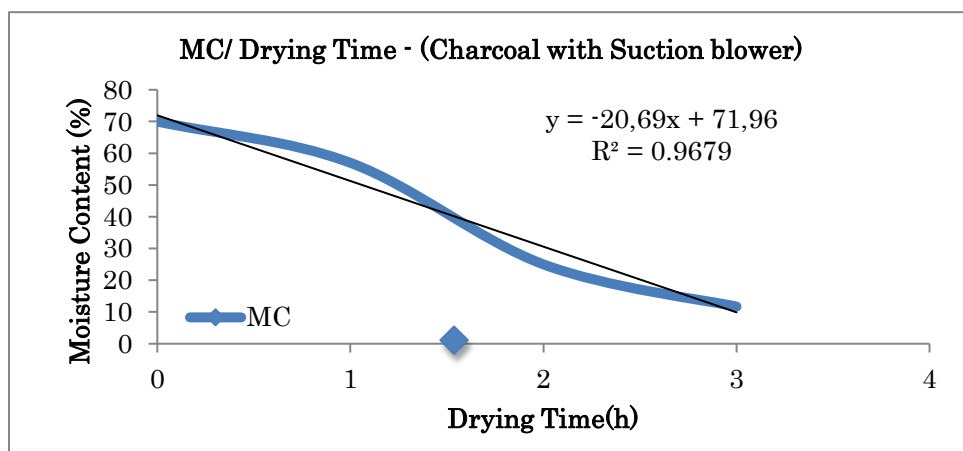
Figure 13. Graph of MC against drying time (charcoal with Suction Blower).
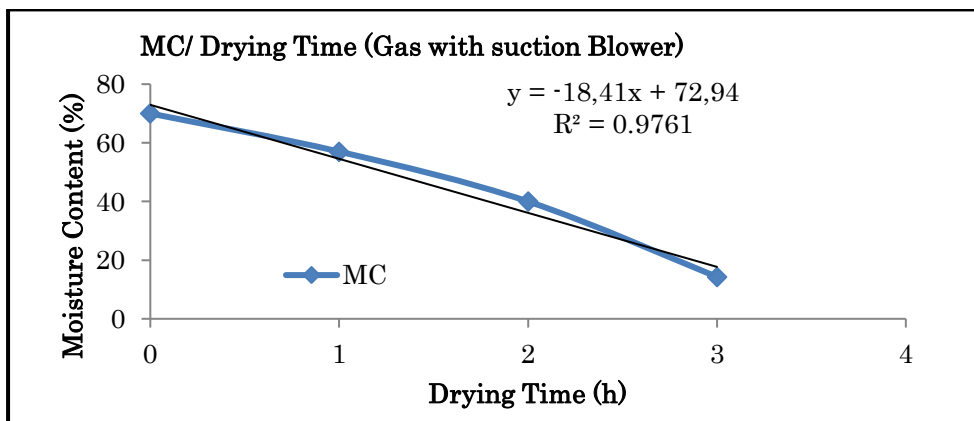
Figure 14. Graph of MC against Drying Time (Gas with Suction Blower).
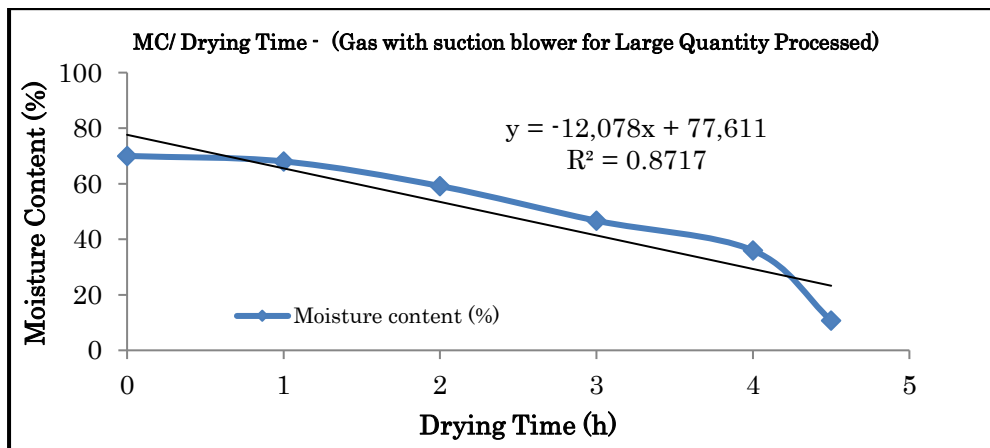
Figure 15. Graph of MC against drying time (Gas with suction blower with large quantity processed).

CONCLUSION

In this study, smoking kiln of 50 kg in the department of Agricultural and Bioenvironmental Engineering, Federal Polytechnic Ilaro, Ogun State was designed and fabricated. Findings from the existing design show that the kiln capacity was not maximized. Also, the time it took to achieve drying effect recommended in the literature was rather too long. It was equally observed that the convenience it takes to draw fish tray in and out of the smoking chamber was not there. Likewise, the tires were not strong enough to bear the weight of the entire kiln and as a result, did not encourage ease of mobility of the entire assembly.

In designing and fabricating an improved kiln so as to take care of the limitations with the existing design, the kiln was designed to kitchen size and for easy of mobility, the tires provided can withstand the entire assembly. The trays were framed round with angle iron and as well cross braised to support the weight of the fish loaded on it. The framing also makes it convenient to draw the tray in and out easily. A 2 mm thick plate was introduced at the base to collect and drain off oil and water spill by gravity to the draining trough which then directs it outwards. Suction blower was introduced at the top section of the kiln to uniformly distribute air round the chamber. The blower is powered by 1.5 hp electric motor directed to electricity source. A gas burner was incorporated into the design as alternative heat source to the chamber. It was designed in such a way that the charcoal pot and gas burner are detachable.

The designed work has impact in the area of smoking kiln capacity, drying time, ease of mobility and heat distribution. The designed kiln can process 50 kg of fish or more at once. Findings from the designed work show that it will only take 3 hours to bring the fish to moisture content recommended in the literature (10-14 %). With introduction of suction blower, the time it took reduced by 1 hour (from 4h to 3h). It is an indication that introduction of suction blower to every smoking kiln will help to achieve shorter time to bring the fish or other similar product to moisture level that will prolong their shelf life. Smoked fish from the designed kiln were easily identified from the fact that it was firmer when chewed and had a characteristic golden-brown colour. The high heat intensity produced by the gas was responsible for the smoky flavour and sweet fragrance of the fish. The dirt like the gills and other unwanted parts were removed before smoking and the weight was measured before and after smoking exercise.

The designed smoking kiln can be used to achieve both hot wet smoking and hot dry smoking. Therefore, the designed smoking kiln can be used by both farmers and elites because of the hygiene and aseptic way of handling the smoked products.

Preservation is very important in aquaculture because it extends the shelf-life of fish. It equally changes the texture and adds more value to the products. Another observation is that smoked fish from the designed smoking kiln have longer shelf life than those from common drum ovens. It takes over three months for mold to appear, but the texture still remains intact. This led to the fact that the water content has reduced greatly, inhibiting the bacteria which often can cause spoilage. The smoking exercise was properly handled so that the protein content is not denatured and the golden-brown colour is retained. Also, the heat chamber design is open to improvement. From the evaluation observed, the smoking kiln can process 50 kg of fish or more. From the experiment, each layer of tray takes 8 kg of fish at an average weight of about 0.5kg. In all the six trays, 48 kg (78 kg x 6) of fish or a bit more can be smoked at once. From the analysis, it is obvious that the improved smoking kiln constructed was maximized in terms of capacity. Also, it takes shorter time to bring the fish to recommended moisture content.

The recommendations on the mechanical dryer are as given below:

i.   It is recommended that fish should be processed in the designed kiln between 3 and 4 hours when either of the heat sources is to be used with or without suction blower. Beyond this time range the golden brown colour will turn black.

ii.   The suction blower should be used when smoke drying fish since it improves timeliness of drying.

iii.   The experiment should be carried out when the kiln is fully loaded to capacity to establish if the time rate of drying if will be affected.

Lastly, it is more economical to use gas as heat source than charcoal but the limitation with gas is that one must be around till the smoking endeavour is completed. Otherwise, there can be fire outburst/outbreak or a situation whereby the material under process will roast to ashes.

DECLARATION OF COMPETING INTEREST
The authors declare that there are no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT
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Oluwagbayide Samuel Dare: Writing of the original draft and data analysis.
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Quality Valuation of Direct Harvested Rainwater Near Nekede Landfill in Owerri West Local Government Area, Imo State, Nigeria

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ABSTRACT

Quality assessment of direct harvested rainwater at Nekede landfill in Owerri west Local Government, Imo State, Nigeria was examined. Some physicochemical and bacteriological parameters were analyzed. The WHO (2006) domestic, irrigation and rules for consumption standards was used to assess if the harvested rainwater is impure or infected. The water samples were collected from four sampling locations at a distance of 20 m away from each other. EP samples (March-April 2019) shows, turbidity ranged 5.0-5.20 NTU, Cl (3.40-3.90), Mn (0.05-0.09), NO_3-N (8.40-9.90), PO_4^{3-} (0.03-0.05) mg l^{-1} falls within the limit, Cu 1.0-1.10 mg l^{-1}, Zn 3.00-3.10 mg l^{-1} falls within WHO standards only. Cd, Al and Co_2 were above the standards, SAR and Na was Not detected (ND). PP (June - July 2019) shows turbidity, Cu, Cl, Mn, Ca, NO_3-N, Na, and PO_4^{3-} falls within the recommended standards. Cd (0.02), Al (0.02-0.06), CO_2 (5.00-5.10) mg l^{-1} was above the standards, while SAR and Zn has (4.63-47.27) (3.00-3.20) mg l^{-1} falls within WHO standard and Mg (0.43-0.60) mg l^{-1} falls within FAO. E-Coli results on EP 20-32, PP 10-35 and Coliform count EP (ND), peak precipitation (1-10) falls within FAO standards, Salmonella EP and PP was above WHO and FAO standards. The bacteriological parameters indicates that the water is not fit for drinking, thus the water has been seriously contaminated with dangerous pollutants.

INTRODUCTION

Rainwater is the core source of water to feed the demands that is either for ground recharge or satisfying the surface water bodies. Where surface water is not readily sufficient, rainwater becomes the alternative source for domestic uses. According to Adriano *et al.,* (2011) It has become the key water source in most regions with significant rainfall but lacks modern and unified supply system. It is a good choice in regions where quality fresh surface water or groundwater is deficient. The application of appropriate rainwater harvesting technology becomes important for the utilization of rainwater as a water source. Rainwater categorized as distilled water, collects impurities such as dust particles, gases, bacteria etc., during its passage through the atmosphere. The portion of rainwater which flows over the surface near landfill known as runoff picks up organic matter, whereas the portion percolating through the ground has got mineralogical composition with organic and inorganic matter which gathers while making movement through the subsurface strata before it reaches the water table. The accumulated quality of water in rainwater harvesting (RWH) systems are affected by several issues, these includes:

a. Ecological circumstances which is closeness to massive industries, major roads and the existence of birds (Fo¨rster, 1998; Taylor *et al.,* 2000).

b. Weather-related conditions for instance temperature, drought hours and precipitation patterns (Evans *et al.,* 2006).

c. Connection with catchment materials and the dirt and debris that are dumped upon it amid rainfall events (Simmons *et al.,* 2001; Van Metre and Mahler, 2003).

d. Management by pre-cistern treatment devices such as filtration or first-flush alteration (Yaziz *et al.,* 1989; Martinson and Thomas, 2005).

e. Natural management processes which take place within the rainwater cistern (Scott and Waller, 1987; Spinks *et al.,* 2003).

f. Handling by post-cistern treatment instrument such as particle filtration, ultraviolet disinfection, chlorination, slow sand filtration or hot water systems (Coombes *et al.,* 2000).

According to Abdul *et al.* (2009), freshwater harvesting is a simple-low-cost water supply method, that includes to collect and store rainwater directly from roof surfaces, open field and ground catchments for rural, agricultural, industrial and environmental purpose. Harvested freshwater maybe the only source of water supply for rural and remote households where no other water supply is available. Rainwater harvesting for domestic usage is becoming increasingly popular as the availability of good quality water is declining. This is further exacerbated by the adverse impacts of climate change on water supply sources. The most noteworthy issue in relation to using unprocessed harvested rainwater for drinking or other potable uses, however, is the potential public health risk associated with microbial pathogens.

Harvested rainwater (HRW) has been considered an efficient choice water source for drinking and diverse non-potable uses in a number of nations throughout the world, the most important issue in relation to using untreated HRW for drinking or varying potable uses, nevertheless, is the potential public health risks related with microbial pathogens (Muhammad and Mooyoung, 2008). In the past, the provision of piped water directly to the household has been related with better hygiene and reduction in disease (Christine, 2006).

The basis of water quality investigation is to generate information which will become useful in the management of water resources in any nation or community. It would

prove useful in administration, control and investigation of pollution challenges, classification of water resources, baseline data collection, water quality surveillance and water quality prediction (Ekiye and Luo, 2010). According to Igwo-Ezikpe and Awodele (2010) some physico-chemical and microbiological parameters of rainwater collected from Industrial areas of Lagos State Nigeria, showed that the anthropogenic activities, the rainwater samples were to a great extent contaminated and would be hazardous to human consumption without proper treatment.

Consumption of this water sources by human beings has proved dangerous because of the associated health hazards. The determination of degree of pollution of rainwater harvested from catchment near dumpsite requires painstaking investigation, careful application of expert knowledge and huge financial resources, frequent monitoring of water quality. A research of rainwater quality found that there is correlation between water quality and rainfall intensity. Values of pollutants (COD, BOD, N, and P) were found to be higher in case of moderate rain, whereas; samples taken during a heavy rainstorm; the components have low concentrated, as the rain washed the contaminants (Teemusk *et al.*, 2007).

There is no landfill regulation and standard that provides a basic for compliance and monitoring. Burning of waste introduces harmful substances into the air which raindrops pick up as they fall through the atmosphere. In most cases, rainwater near dumpsite becomes contaminated and poses health risk to humans who depend on it as a drinking water source. The physio-chemical, biological levels of pureness define the exact quality valuated with respect to the demand for the supposed usage (Chapman, 1997). Some of the natural factors which affect the water quality regularly include, rocks, soils and the earth surface of which it flows, activities from Industries, agriculturist and mining effluent which emanates from organic evolution (WHO, 1996). The major focus of this article is to analyse the physio-chemical and bacteriological quantity of direct harvested rainwater with respect to WHO (2006) domestic, irrigation and rules for consumption standards and to assess if the harvested rainwater is impure or infected, make suggestions on the improvement of the quality of harvested freshwater near landfill.

MATERIALS AND METHODS

The study was conducted near a landfill located along the old Nekede road in Owerri West L.G.A of Imo State. It lies between longitude 5° 25' 3" N and latitude 6° 55' 06" E. The study area was about 3 km from Owerri main town. It was characterized by a main annual precipitation ranging from 2000 mm-25000 mm, a mean temperature ranging from 26°C-28°C and humidity ranging from 70%-80% (Google Earth, 2016).

Four samples of rainwater were harvested from old Nekede landfill in Owerri West L.G.A Imo State. Two samples were harvested during the early precipitation (first rainfall of the year) of the year, one sample per month in March and April 2019 respectively. From these two samples, one sample was harvested at the landfill and the other sample was harvested at a distance of 20 m away from the landfill which serves as a control point. The remaining two samples were harvested during the peak precipitation (when precipation is intense) of the same year one sample each in June and July 2019; one sample was harvested at the landfill and the other sample was

harvested at a distance of 20 m away from the landfill which also serves as the control point.

The early precipitation samples was carried out between 10:00 am and 1.00 pm in March and April 2019 whereas the peak precipitation samples collection was done between 8.00 and 10.00 am in the morning of June and July 2019, using sterilized sampling Can installed at a fixed point. The sampling Cans were affixed 1 m above the earth surface to prevent rain splash. The sampling Cans labeled were immediately transported after collection to the "De Apples" laboratory Egbaeda in Imo State for examination and analysis.
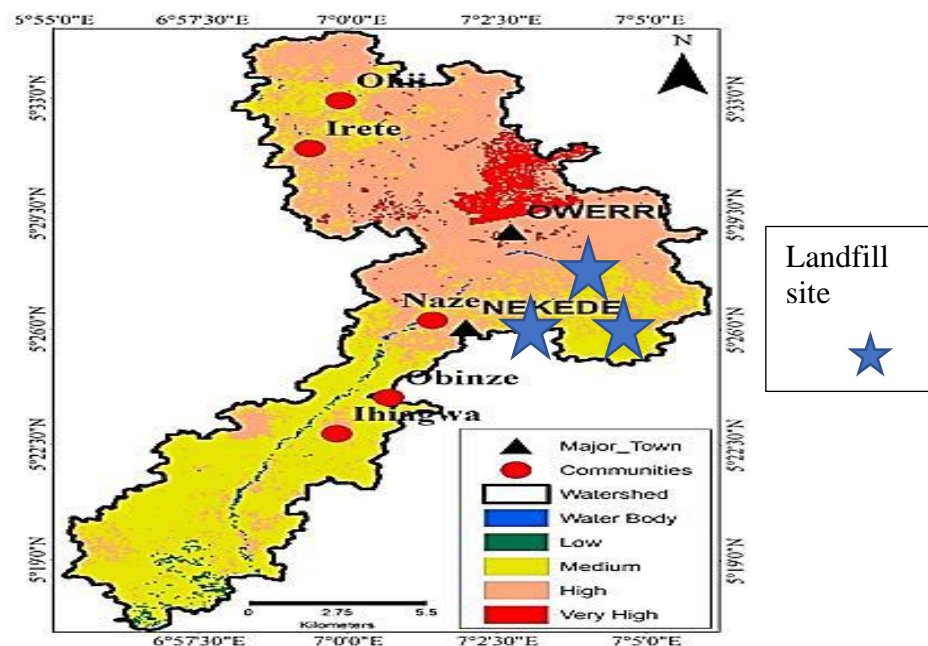
Figure 1. Map location of the study area Obineche *et al.* (2020).

Laboratory Analysis of Water Parameters

Twenty one (21) freshwater constituent was determined in each sample. Standard techniques were used to analyse the other parameters. The physic-chemical and bacteriological properties of the harvested water was analyzed. The visual aspect was carried out using a portable automated calorimeter. Other properties like colour, turbidity and odour were obtained through organoleptic process.

Temperature: The fluctuation in water temperature usually depends on the season, geographical locations, Sampling time and temperature of effluence entering the source of water. The temperature was determined at the point of sampling using a mercury-in glass thermometer with calibration 0-100°C.

pH: This is defined as the measurement of the hydrogen ions content and also the composition of the acidity and alkalinity levels. The pH was determined using standardized digital JENNY 3540 pH meter in the laboratory.

Total Dissolved Solids: A given volume of samples were filtered and weighed into a known, mass of evaporating dish. It was then evaporated to dryness and then weighed

again. The difference in weight between the first and the final reading gives the total dissolves solid in mg l^{-1}.

The phenolphthalein alkalinity, methyl orange alkalinity gives the total alkalinity, traced elements were analyzed using the spectrophotometer.The amount of SAR was determined using the formulas

$$SAR = \frac{NA^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \qquad (1)$$

The determination of heavy metals, like zinc (Zn) cadmium (Cd), copper (Cu), aluminium (Al), manganese (Mg), sodium (Na) was carried out using atomic absorption spectrometer, while calcium (Ca), carbon (iv) oxide (CO_2), chloride (Cl^-), was determined using the titration method and titration with EDTA was used to determine the hardness. Colorimetric after distillation was used to obtain fluoride (F^-). The odour and pH was by dilution factor and pH electrode.

The media for bacteriology investigation includes: Plate count agar for aerobic mesophilic bacteria, while for Coliform count lactose broth media incubation at 35±0.5°C was used (APHA, 1985); the total heterotrophic bacteria and fungi count was by surface spreading method (Okafor, 1985). The reagents used were graded with instruments pre- calibrated preceding the analyses. Membrane filtration technique were used for E- coli and salmonella determination.

Turbidity: This illustrates how particles suspended in water affects its limpidity. It serves as a crucial indicator of suspended sediments level. This was measured in the laboratory using turbidimeter model 2100 A.

After the data have been collected, the raw data compiled from field observations and measurements were summarized using the IBM SPSS version 2012 statistical software package was used in the determination of the mean and standard deviation, while the graphical plots was generated using microsoft excel version 2010 The result of the laboratory analysis was represented with tables and graphs to obtain clear means of comparison and conclusions.

RESULTS and DISCUSSION

The result in Table 1 and 2 shows all the physiochemical and bacteriological values analyzed. The two tables shows the variation in the four different sample locations with their physiochemical and bacteriological parameters investigated in the rainwater samples and the comparison between the early and peak rainfall of the year at old Nekede landfill. The result of the physiochemical and bacteriology analysis of direct rainwater sampled with summary of individual description during the research study is as presented in the tables. The comparison of values of the different parameters with the World Health Organization and Food and Agriculture Organization.

Table 1. Physiochemical parameters of direct harvested rainwater at Old Nekede landfill.

Parameters	EP Samples 1	EP Samples 2	PP Samples 1	PP Samples 2	SR	MV	SD	WHO Limit	FAO Limit
Odour	Odourless	Odourless	Odourless	Odourless	-	-	-		
Turbidity NTU	5.20	5.00	5.00	4.80	4.8-5.20	5.00	0.100	5.00	35.0
pH	6.90	6.30	6.50	5.90	5.9-6.90	6.40	0.360	6.5-8.5	6.5-8.5
Cu (mg l^{-1})	1.00	1.10	1.20	0.09	0.09-1.2	0.84	0.442	2.00	0.20
Cl^- (mg l^{-1})	3.90	3.40	3.98	3.90	3.40-3.98	3.79	0.228	250	1065
Cd (mg l^{-1})	0.02	0.01	0.02	0.02	0.01-0.02	0.02	0.000	-	-
Al (mg l^{-1})	0.04	0.02	0.06	0.02	0.02-0.06	0.03	0.000	-	-
CO_2 (mg l^{-1})	5.60	5.50	5.40	5.00	5.0-5.60	5.37	0.236	-	-
F^- (mg l^{-1})	2.10	2.50	1.06	1.03	1.03-2.5	1.67	0.667	1.00	1.00
Mg (mg l^{-1})	0.50	0.60	0.60	0.43	0.43-0.6	0.53	0.089	0.30	5.00
Mn (mg l^{-1})	0.09	0.05	0.09	0.06	0.05-0.09	0.07	0.000	0.10	0.20
NO_3-N (mg l^{-1})	9.90	8.40	10.0	8.90	8.4-10.0	9.30	0.674	50.0	30.0
P (mg l^{-1})	0.02	0.01	0.01	0.01	0.011-0.02	0.012	0.000	-	-
Zn (mg l^{-1})	3.10	3.00	3.20	3.00	3.0-3.20	2.325	0.779	3.00	2.0
Hardness (mg l^{-1})	29.0	27.0	34.0	32.0	27-34.0	30.50	2.692	2.00	No limit
Ca (mg l^{-1})	14.0	13.4	14.5	13.0	13.0-14.5	13.725	0.572	75.0	800.0
PO_4^{3-} (mg l^{-1})	0.05	0.03	0.05	0.03	0.03-0.05	0.04	0.000	200	480
SAR	-	-	47.27	4.63	4.63-47.27	25.95	21.32	No limit	15.0
Na (mg l^{-1})	ND	ND	13.00	12.0	12-13.0	12.50	1.375	200	480

NTU: Nephelometric Turbidity Unit, ND: Not Dectected, ppm: Part per million mg^{-1} l^{-1}, Cu: Copper, Cl: Chloride, Cd: Cadmium, Al: Aluminium, CO_2: Carbon dioxide, F^-: Fluoride, Mg: Magnesium, Mn: Manganese, NO_3-N: Nitrate Nitrogen, P: Phosphorus, Zn: Zinc, Ca: Calcium, PO_4^{3-}: phosphate, SAR: Sodium Absorption Ratio, Na: Sodium, ER: Early precipitation sample, PR: Peak precipitation, SR: Sample range, MV: Mean value, SD: Standard deviation

Table 2. Bacteriological parameters of direct harvested rainwater at Old Nekede landfill.

Parameters	EP samples 1	EP samples 2	PP samples 1	PP samples 2	SR	MV	SD	WHO Limit	FAO Limit
E-coli	25-30	20-25	30-35	10-20	-	-	-	0.00	500.0
Salmonella	40-44	30-35	25-35	25-30	-	-	-	-	-
Coliform	ND	ND	0-10	1-5	-	-	-	0.00	1000.0

ND: Not Detected.   All bacteriological parameters have this unit cfu: Colonie forming unit.

Turbidity: Turbidity (cloudiness) which is measured in Nephelometric Turbidity Unit (NTU), measures the extent to which suspended substance in the water is absorbed or scattered when beaming light energy incident on it. It is easier to detect the turbidity of a glass of water when it is greater than 5 NTU. Obviously, water at point of supply with turbidity above 5 NTU is likely objectionable for the health reasons and most importantly aesthetic reasons. The above rain water turbidity was 5.2, 5.0, 5.0 and 4.8 NTU respectively. The sample 1 under early rainfall has higher turbidity unit of 5 NTU other samples have maximum unit of 5 NTU (Nigeria) as shown in table 1. Thus, in terms of turbidity, the rain water passed the test.

The pH of water measures the taste property of the water. The pH values of the four samples of the direct rainwater were measured and found to be 6.9, 6.3, 6.5 and 5.9 respectively. The range shows 5.9-6.9 which is slightly above the WHO and FAO limits, while the mean values of 6.40 falls within WHO and FAO recommended standards.

Odour: Odour is said to be perceptual experience recorded by the sensory system mental state. Odour is highly objectionable and is highly unacceptable in any water meant for drinking especially at the point of use. The production of volatile substances by algae, hydrogen sulphide and other substances contribute to odour in water. Thus, in terms of odour, the rainfall has no odour.

Chloride: Highly salinity content is inarguable an inherent characteristic of Streams, rivers, wells and other small water bodies which often have little salt content. In this research, both the mean value and range of chloride 3.79 mg l^{-1} and 3.40 – 3.98 mg l^{-1} falls within WHO and FAO acceptable limit.

Calcium: The values of calcium obtained in sample 1 under the early and peak precipitation has the highest value of 14.0-14.5 mg l^{-1} followed by sample 2 under early and peak precipitation which has 13.4 and 13.0 mg l^{-1} which was to be the lowest obtained. It was observed that the mean values of calcium concentrations falls within the WHO and FAO standards of 75.00 and 800 mg l^{-1}, this show that the water is fit for irrigation and possibly drinking purposes.

Manganese: Manganese contents shows range 0.05-0.09 mg l^{-1} and mean values of 0.07 mg l^{-1} which indicates that it falls within the WHO and FAO recommended standards. Although iron found in freshwater has not been said to be the cause of any known health problem, however, manganese in drinking water is reported to cause neurological disorder (Nigerian Industrial Standard for Drinking Water, 2007).

Nitrate: Nitrate is not desirable in drinking water because it occurrences in water, has been medically proven to cause various kinds of health problems including methemoglobinemia (infant cyanosis or blue babies). The maximum contaminant level for Nitrate in various water quality standards around the world is 50 mg l^{-1} (NIS, 2007). Therefore, from the table1 it will be observed that the harvested rainwater range 8.40- 10.0 mg l^{-1} and mean values 9.30 mg l^{-1} falls within WHO and FAO limits.

Sodium Adsorption Ratio (SAR): Table salt which is often used to add flavour to food to desired taste contains sodium, a highly electropositive substance, as its only positive element. Intake of too much salt into the body is associated to increase in heart pressure of susceptible individuals, worsening of cases of people suffering from heart, kidney or circulatory problems. The direct rain water value in this research for early rainfall was not detected but varies for peak rainfalls were found to be 47.27 and 4.63 mg l^{-1}. The range and mean values are 4.63-47.27 mg l^{-1} and 25.95 mg l^{-1} which falls within WHO recommended limits,

Sodium: The mean value of sodium falls within the acceptable limits 12 500 mg l^{-1} of the WHO and FAO. their range are 13.0-14.5 mg l^{-1}. Therefore, the rainwater is free from sodium containations.

Magnesium: The mean value as obtained in the table 1, shows that magnesium 0.53 mg l^{-1} falls within the FAO limit only, and ranges between 0.43-0.6 mg l^{-1} respectively. This indicates that the water is not 100% fit for drinking.

Cadmium: The result of the range and mean value of cadium obtained shows 0.01-0.02 mg l^{-1} and 0.02 mg l^{-1} respectively, which is above WHO and FAO the recomended limits for drinking and domestic uses.

Hardness: The hardness values for samples 1 and 2 under early precipitation were 34 mg l^{-1} and 32 mg l^{-1} respectively, hence the values obtained were not up to the WHO 200 mg l^{-1} and FAO standards when compared. This shows that the water obtained would lather easily and is safe.

Phosphate: The mean values and the range of phosphate obtained 0.04 mgl^{-1}, 0.03 – 0.05 mg l^{-1} shows that the sample falls within the recommended limit by WHO and FAO. Hence drinking water is not supposed to contain phosphate.

Zinc and Copper: The mean value results of Zn and Cu, 2.325 and 0.84 mg l^{-1} shows that it falls within WHO limits only. While their ranges are 3.0-3.20 mg l^{-1} and 0.09-1.20 mg l^{-1}.
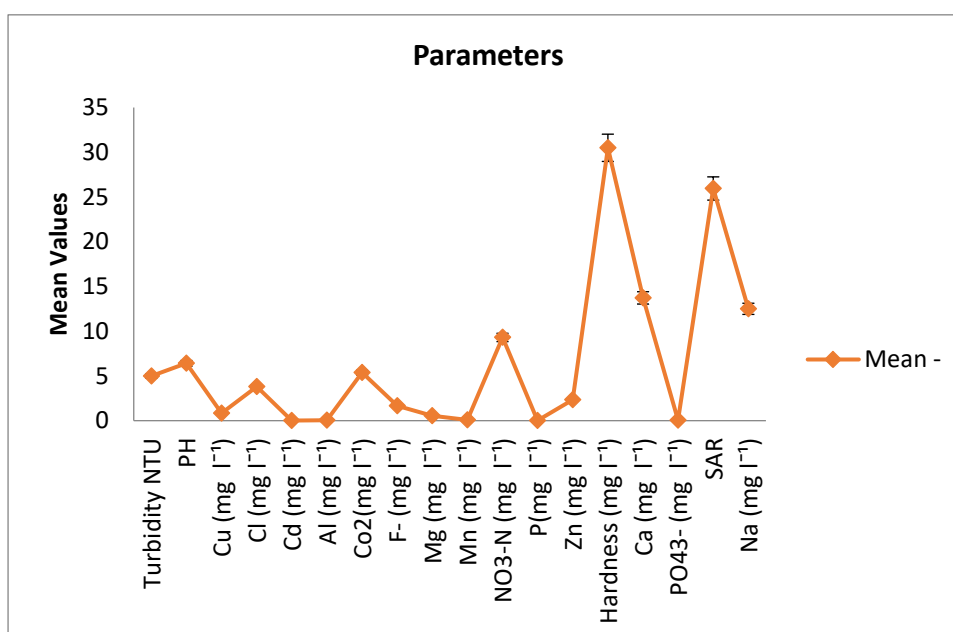
Figure 2. Graphical representation of mean values against parameters.

Bacteriological: E-coli and other harmful bacteria were seen. The E-coli of the water samples collected have slight differences. The results from table 2 shows that, E-coli early and peak precipitations samples falls within FAO limit, while the salmonella composition in the rainwater for early and peak precipitation was above the WHO and FAO recommended limits. Coliform count was not detected in the early precipitation (EP) but was detected in the peak precipiation (PP) which falls within the FAO recommended limit.

Early Precipitation   Peak precipitation (rainfall intervals)
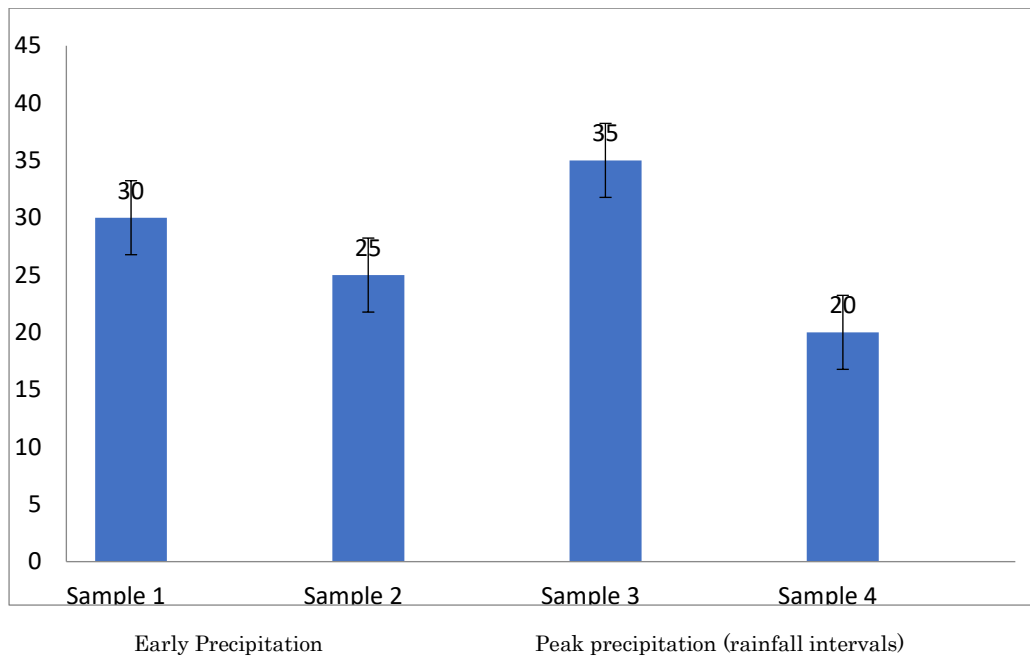
Figure 3. Graphical representation of E-coli in all the samples analyzed.

CONCLUSION

The results of the water quality analysis indicate that direct harvested rainwater near dumpsite is not fit for consumption due to domestic and industrial effluents discharged into the surroundings. The various human activities and the emission of CO_2 gas into the atmosphere which help to build up water contaminants is very dangerous and hazardous to health. The results of the physiochemical and bacteriological parameters of the direct rainwater samples from four sampling locations on the direct rainwater based on the FAO and WHO standards, leads to the following conclusions; the total coliform and salmonella thyphi contents were very high and thus the water is not fit for drinking. The acceptable pH limit for drinking water ranges between 6.5-8.5; any water with pH which is not within the recommended limits causes instability in diet and hence it hold in toxic ion. In these samples, the pH values vary from 5.9-6.9 which is in line with the permissive range for drinking water. Finally, the quality assessment of direct harvested rainwater near Nekede landfill in Owerri West L.G.A Imo State, Nigeria was evaluated and result shows moderate variations among some samples of the parameters. Some of the water samples could be said to be appropriate for domestic uses, but not for human consumption due to contamination especially by gaseous emission of CO_2 into the atmosphere.

There is need of a conservation and management plan to reduce the sewage impact on water. It was quite evident from the findings that the site is receiving lots of domestic and industrial waste effluents. The solution of this problem lies in the treatment of sewage and disposable of fully treated sewage disposal. We should go for alternative methods for the sewage disposal like the dry sanitation.

Public participation is needed for waste bin awareness, water pollution caused by sewage, agricultural and industrial impacts can be controlled by considering the following;

1. A natural focus on water sector reform should be encouraged and water-related institutions should be reorganized, water conservation should be accelerated and system efficiency should be increased.

2. A sewage system should be provided for the collection and treatment of the sewage system.

3. Illegal incineration of waste in landfills should be prevented so that the careless and illegal dumping of solid waste should be minimized, as the introduction of harmful substances that predispose people who live nearby to a high risk of cancer will lead to the problem of polluting the air and soil as well as nearby water bodies.

4. To determine the degree of pollution of rainwater harvested directly near the very large dumpsite, careful research should be carried out, practice based on expert knowledge, and water quality should be frequently monitored.

5. Villagers should be informed about the dangers of using untreated water as a source of drinking water.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Christopher Ikechi Obineche: Writing original draft, methodology and investigation.
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Donatus Okwudiri Igbojionu: Validation and review.
Chinedu Obani: Compilation and statistical review.

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Functional Properties of Extruded Corn Flour

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ABSTRACT

Effect of extrusion cooking on hydration properties (water absorption index (WAI), water solubility index (WSI)), and viscosity (peak viscosity (PV), final viscosity (FV)) of corn flour was studied. The preconditioned corn flour was processed using different extrusion cooking conditions at the variable moisture content (MC), temperature (T), and screw speed (SS). Statistical analysis showed that irrespective of variable processing parameters the hydration properties were improved after extrusion cooking. WAI and WSI were increased by 70% to 268% and 5 to 198%, respectively over unextruded flour. The viscosity of extruded corn flour showed a significant ($p < 0.05$) decrease, indicating high paste stability of corn flour after extrusion cooking. Overall, there was 72 to 86% decrease in PV and 89 to 95% decrease in FV. The mild processing conditions (high MC, low SS, and low T) imparted better hydration properties, whereas severe processing conditions (low MC, high SS, and high T) imparted better paste stability to corn flour. Extruded corn flour with modified functional properties has the potential to be exploited in the development of various gluten-free ready-to-eat products, composite flours, bakery products, etc.

INTRODUCTION

Corn, also known as maize (*Zea mays* L.) is called as 'Queen of Cereals'. At the global level, it is the second important cereal crop with a production of 1 040 million MT in 2016-17 (FICCI Maize vision-2022, 2018). Corn is not only an important staple cereal for food security but also a potential whole cereal for nutritional foods. Corn is a gluten free grain with unique profiles of nutrients and bioactive compounds. It contains about 62% starch, 4% fat, and 8.7% protein. It is an essential source of micronutrients, dietary fiber, and bioactive such as carotenoids, phytosterols, phenolics, flavonoids, anthocyanins, and (Hassan *et al.,* 2019). The consumption of corn and other whole grain products has been linked to the lowering risk of cardiovascular disease, type-2 diabetes, obesity, cancer etc. (Siyuan *et al.,* 2018). According to Shah *et al.* (2016), the resistant starch from corn is known for prevention against cecal cancer, atherosclerosis, and obesity-related complications.

Recently, the bioactive compounds derived from corn and other whole grains have gained the attention of the food industry for the development of functional foods. It is increasingly being processed into a variety of food products such as corn starch, cornmeal, grits, composite flours, tortillas, ready-to-eat snacks, and breakfast cereals, etc. Corn flour also has vast potential in the bakery industry for the development of gluten-free baked products like composite bread (Sun *et al.,* 2019). However, the poor functionality of raw corn flour with regard to water absorption capacity, water solubility, and dough viscosity renders it unsuitable for bakery products. Being gluten-free, the incorporation of unprocessed corn flour in bread can deteriorate the technological and textural properties of bread. It lowers the gluten content, disrupts the gluten network of composite dough, and retains a low amount of gas, resulting in rapid staling and poor crumb texture (Jafari *et al.,* 2018). Gluten, hydrocolloids, modified starches and enzymes in the form of additives have been used to make up for the poor functionality of composite flours (Martinez *et al.,* 2013; Schoenlechner *et al.,* 2013).

Thermal treatment is another way to enhance the functional properties of corn flour and thereby the quality of the final product. Extrusion cooking is an important hydrothermal treatment, in which material with relatively low moisture content is processed at high temperature and high shearing rate. Extrusion modifies the functional properties of flours by the way of starch gelatinization, fiber dissolution, and protein aggregation (Hagenimana *et al.,* 2006). Extruded flours can replace hydrocolloids being used to mimic the viscoelasticity properties of wheat in low gluten or gluten-free food products. The earlier studies showed that the incorporation of extruded flours of sorghum (Jafari *et al.,* 2018), finger millet (Patil *et al.,* 2016) and wheat flour (Martinez *et al.,* 2014) had positive effects on crumb texture, dough rheology, and organoleptic properties of breads. Extruded corn flour can also be a gluten-free healthy ingredient for bakery industries. Thus, this experiment was undertaken to envisage the consequence of extrusion cooking on the functional properties of corn flour so that its potential applications in food formulations can be explored.

MATERIALS AND METHODS

Preconditioning of Corn Flour

Corn grains of Pusa Composite-3variety were purchased from local commercial suppliers (New Delhi, India) and were subjected for milling in the hammer mill and screened subsequently (BS 30 mesh) to obtain uniform flour. Before subjecting to extrusion cooking, the flour was conditioned to attain desired moisture content by adding a known quantity of distilled water. The flour was stirred continuously while adding water to ensure uniform hydration. The flour was then transferred to zip-lock polyethylene pouches and kept overnight for equilibration of moisture. The quantity of added water was determined as per the methodology reported by Chakraverty, (1988).

Extrusion Cooking of Corn Flour

Extrusion cooking was performed using a twin 40/20 screw extruder (M/s Brabender Lab-Compounder KETSE, Germany). The preconditioned flour was extruded at eight cooking conditions having three variable parameters: moisture content (10 and 20% wb), screw speed (200 and 400 rpm), and die temperature (120 and 180°C) as given in Table 1. The feeding and barrel zone temperatures were fixed as 80°C and 100°C, respectively, and the feeder speed was fixed as 20 rpm during all experiments. The extruded corn was dried, milled, and screened to obtain fine flour (BS 30 mesh) which was stored at the dry and cool place before analysis. Unextruded corn flour was taken as a control sample.

Table 1. Details of extrusion cooking parameters

Treatments	Feeder speed (rpm)	Moisture content (% wb)	Screw speed (rpm)	Temperature (°C)
T1	20	10	200	120
T2	20	10	400	120
T3	20	10	200	180
T4	20	10	400	180
T5	20	20	200	120
T6	20	20	400	120
T7	20	20	200	180
T8	20	20	400	180

Analysis of Corn Flour

Physicochemical analysis

Proximate analysis of corn was done using a standard procedure (AACC, 2000). Total starch (TS) was estimated by measuring glucose level (Goni *et al.,* 1997) and the amylose content of flour was determined by the colorimetric method (Juliano 1971).

Hydration properties

Hydration properties of extruded and unextruded corn flour were determined by the method suggested by Gujral and Singh (2002). WAI corresponds to the quantity of water immobilized or absorbed by the starch, also reflects the degree of starch gelatinization (Rweyemamu *et al.,* 2015), WSI is the leaching of molecular compounds out of the starch also denotes the level of conversion and degradation of molecules (Siddiq *et al.,* 2013).

Viscosity of corn flour

The pasting properties with respect to extruded and unextruded corn flour were measured by Rapid Visco Analyser (M/s MCR 52, Anton paar, Austria) using AACC standard method: 76-21.01 (AACC, 2000). Thermocline Version 2.2 software (M/s Newport Scientific, Warriewood, NSW, and Australia) was used to obtain pasting curve, from which the values of PV and FV were identified.

Statistical Analysis

The significant differences between the effects of various treatments were analysed by Analysis of Variance (ANOVA) using SAS (9.4) software. Tukey's HSD test was performed for pair-wise comparison of effects of each treatment at 5% significance level.

RESULTS and DISCUSSION

Physicochemical Characterization

The physicochemical composition of corn was performed and the respective values of moisture (8.60%), carbohydrate (72.07%), fat (4.95%), protein (11.06%), crude fibre (1.97%), ash (1.35%), total starch (45.81%) and amylose content (19.45%) were reported.

Hydration Properties of Extruded Corn Flour

Extrusion cooking involves several phenomena such as starch gelatinization and degradation, fiber solubilization, protein denaturation, enzyme inactivation etc. These reactions modify the functionality of flours by changing their hydration properties and pasting properties (Martinez *et al.*, 2014). Hydration properties display its behavior during processing and are presented in Table 2.

Extrusion cooking significantly (p<0.05) increased the WAI of corn flour. Unextruded (control) corn flour had a WAI value of 2.45 g g^{-1}. WAI of extruded corn flours varied from 4.16 to 9.02 g g^{-1}, showing about 69.8% to 268.2% rise over the control sample. The highest and lowest increment was noted for T5 and T4 treatment, respectively. Results indicated that the higher improvement in WAI was observed at mild processing conditions i.e. high moisture content, low screw speed, and low temperature. WSI of control corn flour was found to be 10.46%. Like WAI, significant (p<0.05) increase in WSI values (10.99 to 31.18%) was observed for corn flours extruded under variable extrusion conditions; depicting about 5 to 198% rise over control sample. The highest and lowest increase was registered in T4 and T5 treatment, respectively. Results depicted high severity of extrusion process at moisture (low), screw speed (high) and temperature (high), causing higher degradation and conversion of molecules.

An increase in WAI and WSI of extruded corn flour was anticipated on account of gelatinization of starch and degradation of other molecules after extrusion. Gelatinized starch possess high water absorption potential than raw starch at room temperature (Jongsutjarittam and Charoenrein, 2014). Increase in water absorption capacity was due to the uncovering and loosening of molecular chains, resulting in higher availability of hydrophilic structures and easier penetration of water molecules (Marzec and Lewicki, 2006). The degradation and dextrinization of material during extrusion results in low molecular weight compounds, on account of which the water solubilityincreases. (Mesquita *et al.,* 2013). However, the limit of increase varies with the molecular bonding between degraded starch, proteins, and lipids (Patil and Kaur, 2018).

Table 2: Hydration properties of corn flour.

Treatments	WAI (g g^{-1})	WSI (%)
Control	2.45[f]	10.46[d]
T1	6.46[bc]	12.01[d]
T2	4.41[e]	29.17[a]
T3	4.94[de]	27.06[ab]
T4	4.16[e]	31.18[a]
T5	9.02[a]	10.99[d]
T6	7.18[b]	11.68[d]
T7	5.83[cd]	12.73[cd]
T8	5.05[de]	20.24[bc]
Standard error	0.247	1.594

Means with different superscript letter within same column are significantly different (p<0.05)

Viscosity of Extruded Corn Flour

The viscosity curves, also known as pasting profile are the efficient assay for rapid determination of cooking attributes of flours (Jan *et al.*, 2016). Viscosity primarily depends on the swelling potential and rigidity of the starch granules, and the leaching of amylose in the solution (Kaushal *et al.*, 2012). The viscous behavior is generally decided by the starch, protein, and the ratio of amylose and amylopectin present in the flours. (Sun *et al.*, 2015).

Peak viscosity (PV) is the highest viscosity attained while pasting/heating due to the net effect of starch swelling and disruption of the granules (Balet *et al.*, 2019). PV indicates the degree of gelatinization and water-holding potential of the starch granules before physical breakdown (Cozzolino, 2016). Final viscosity (FV) is a thickening or gelling capacity of the material, also denotes the viscous paste forming ability of the material after cooking and cooling (Jan *et al.*, 2016). The extent of modification of starch molecules during the processing of flours can be estimated by its viscosity values. These changes are pronounced in extrusion processing, due to the high shearing rate. (Desouza *et al.*, 2011). PV and FV values of unextruded and extruded corn flours are presented in Table 3.

Table 3. Viscosity of corn flour as affected by extrusion cooking

Treatments	Peak viscosity (cP)	Final viscosity (cP)
Control	1237.0[a]	3260.0[a]
T1	321.6[bc]	342.0[b]
T2	192.0[d]	192.6[f]
T3	269.3[c]	257.5[e]
T4	178.7[d]	172.7[f]
T5	347.8[b]	357.2[b]
T6	338.5[bc]	327.0[dbc]
T7	311.6[bc]	305.4[dec]
T8	281.4[bc]	288.4[de]
Standard error	14.990	9.787

Means with different superscript letter within same column are significantly different (p < 0.05)

Extruded corn flour exhibited significantly (p < 0.05) low PV values than unextruded corn flour, values ranged from 178.7 to 338.5 cP (Table 3). The PV value of control corn flour was 1237 cP. Overall, there was about 72.6 to 85.6% decrease in PV of corn flour

after extrusion cooking. The highest and lowest decrease was found for treatment T4 and T5, respectively. A similar trend was observed for FV values of corn flour. Extruded corn flour showed low FV values (172.7 to 357.2 cP) than unextruded flour (3260 cP), depicting about 89 to 94.7% decrease.

Results confirmed that decrease in moisture and increase in screw speed, as well as temperature during extrusion, caused a marked decrease in viscosity values. This has a direct relation with the severity of extrusion conditions. In case of low severe processing conditions, a part of starch molecules may retain their structure while in a fully swollen state, which in turn increases the paste viscosity (Siddiq *et al.,* 2013). Reduction in viscosity values of extruded flours is because of the higher starch gelatinization and degradation on account of the combined effect of moisture, heat, and mechanical shearing generated during extrusion cooking (Repo-Carrasco-Valencia *et al.,* 2009). These results were corroborated with the findings of Guha *et al.* (1998) in extruded rice and Sarawong *et al.* (2014) in extruded banana flour. Siddiq *et al.* (2013) also observed reduced pasting profile thus low peak and final viscosities of extruded bean flours. Overall, extrusion altered the viscoelasticity of corn flour; forming relatively stable pastes having low final viscosity and retrogradation tendency (Patil and Kaur, 2018).

CONCLUSION

Extrusion cooking significantly improved the functionality of corn flour in terms of water absorption capacity, water solubility, and dough viscosity, thus can be effectively used to make up for the poor functionality of raw corn flour. Extruded corn flour exhibited better hydration properties in terms of high water absorption and high water solubility than that of unextruded corn flour. Extruded resulted in corn flour showed a unique pasting profile with low peak and final viscosities and low retrogradation tendency. Results demonstrated that the changes in hydration and pasting properties of corn can be controlled by regulating the extrusion parameters. The modified functionality of corn flour may be effectively exploited in food formulations such as instant corn starches, composite flours, baby foods, gluten-free bakery products, ready-to-eat snacks, etc.

DECLARATION OF COMPETING INTEREST

The authors must declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Sharmila Patil: Conceptualization, methodology, investigation, writing-original draft, review and editing.
Charanjit Kaur: Project administration, funding acquisition, writing-original draft, formal analysis, discussed the results and contributed to the final manuscript.
Manoj Kumar Puniya: Data curation, validation, review and editing, discussed the results and contributed to the final manuscript.
Archana Mahapatra: Data curation, review and editing, visualization, discussed the results and contributed to the final manuscript.
Jyoti Dhakane: Data validation, review and editing, discussed the results and contributed to the final manuscript.

Kirti Jalgaonkar: Writing-review & editing, formal analysis, software.
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ACKNOWLEDGMENTS

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Nematicidal Effects of Various Fractions of *Curcuma longa* against *Meloidogyne incognita* (root knot nematodes)

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ABSTRACT

Parasitism is an important limiting factor responsible to cause damage to agricultural production. Plant parasitic root knot nematodes attack several economic crops in Pakistan. Plant-parasitic nematodes considerably add huge losses to economies in the top tomatoes crop producing countries throughout the world, instead of controlling the main pathogenic nematode species as usual; one of the innovative strategies to control plant-parasitic nematodes would be to manage diversity in communities in order to lead them to be less pathogenic. The plants and their materials are one of the potential remedies for nematodes management. Turmeric (*Curcuma longa*) along with its several biological applications may serve as a biopesticide against Meloidogyne incognita, a nematode species. A bioassay guided isolation of various fractions of turmeric was subjected to nematicidal activity in comparison with *Azadirachta indica* against *Meloidogyne incognita* larvae at the concentration of 0.25, 0.5, and 1% for 48 hours. Alongside, Larvae and eggs of nematodes were inoculated around the tomato seedlings in experiments with turmeric in a growth chamber. The control contains water instead of turmeric. Root gall severity and final nematode population were suppressed significantly. It was observed that the use of turmeric is very important for selected plant parasitic nematodes management.

INTRODUCTION

The nematodes (Root Knot Nematodes) are known worldwide as a plant parasitic. These are the roundworms, aquatic and small in size. Nematodes are found in plant roots and water occupied soil areas. Root and plant tissues are source of feeding for nematodes. They are major reason of decrease in crop production. Nematodes can destroy all fruits and vegetable crops. Nematodes are the utmost ample animals in the world (Van den

Hoogen *et al.,* 2019) as well as leading constituents in soil (Bardgett and Van der Putten, 2014). *Meloidogyne* spp. were first reported on tomato in 1957 in the Eastern region of Saudi Arabia. Since then, many other plant parasitic nematodes have been reported causing serious losses to many economically important agricultural crops (Al-Yahya, 2018). In form of low crop production, almost 358 $ billion loss per year as per available data of 2010-13, of the farmer's community by plant-parastic nematodes in 37 different crops (Abd-Elgawad and Askary, 2015). Nematicides is a very effective strategy for the control over root knot nematodes (Hajihassani *et al.,* 2009; Medina Canales *et al.,* 2019); while since last few years, due to health and environmental degradation as well as contamination/toxicity of resources, many toxic chemicals were removed from world markets such as methyl bromide, etc. (Kim *et al.,* 2018; Xiang *et al.,* 2018). Due to severely attack by root knot nematodes, ultimately cause of huge loss quantity of crop production (Stephen, 2020). The capacity of exactly illustrate and classify *Meloidogyne* varieties is a critical step if the menace by *Meloidogyne* varieties for the production of crop in affected fields.

Around 80% loss of crop yield due to hit by root knot nematodes (Kaşkavalcı, 2007). To control over crop loss by root-knot nematodes some chemicals were replaced and successfully captured the markets with effective results (Desaeger *et al.,* 2017); still new chemicals are regularly getting their share against root knot nematodes management. Xiao *et al.* (2018), during research used *B. cereus* strain Jdm1 to control over *Meloidogyne incognita* in tomato. Good efficiency was seen in the field study and control efficiency up to 50% for gall index 30 DPI. The rhizosphere was immediately recovered after some impact during the treatment. The effect of root-knot nematodes is almost negative on all types of crops throughout the world. Present approach to overcome on root knot nematodes is not impressive and adequate for the entirely tide over (Forghani and Hajihassani, 2020). Almost three important techniques are common and effective against the plant parasitic nematodes, such as biological control, cultural control, and chemical control (Lamber and Bekal, 2002). All of these; the biological control against nematodes has potential and very effective in controlled environment (Lamber and Bekal, 2002). Crop rotation is a useful technique for bound the growth of nematode's growing population and can lessen nematode stages under damage threshold throughout the year (Lamber and Bekal, 2002). The 11 vegetable crops yield losses by nematodes were observed in one province of Pakistan; dramatically the losses ratio was very high and observed around 25.6% average, and 40% in tomato, as compared to same crops 6.6 average and only 0.2% of tomato in the United States of America (McSorley *et al.,* 1987; Safdar and Mckenry, 2012). Among the commonly found root-knot species, *Meloidogyne incognita* is pre-dominant. *Curcuma longa* (turmeric) belongs to Zingiberaceae (ginger family) is a small fleshy rhizomatous perennial herb of bright yellow to orange color in its root system. It is originated from southeastern Asia. India is the main cultivator of this spice (Damalas, 2011). It is an incredible natural antiseptic, disinfectant, anti-inflammatory, and analgesic. Turmeric, also known as the queen of spices, has received very little input in terms of nematological research. The study was aimed to investigate nematoxic impacts of turmeric on hatching and survival of RKN (*M. incognita).*

MATERIALS AND METHODS

Plant Material
Turmeric is cultivated for its underground rhizome. Fresh *Curcuma longa* was collected from local markets in Karachi. The plenty of water was used for cleaning the samples, dried (only rhizomes dried for one month at room temperature) by air and then homogenized to good powder and airtight jars were used for store.

General Experimental Procedures
Nematode inoculums and plant material
Artificial inoculums experiment of healthy plants with *M. incognita* were performed to study the effect on nematode population. As root knot nematodes commonly infect tomato plants; Starting from a single egg of nematode, the inocula were increased on tomato plants (Nico *et al.,* 2004; Wesemael *et al.,* 2011). Inoculum consisted of second-stage juveniles (J2s) and eggs, which were extracted from tomato roots by the NaOCl procedure (Hussey and Barker 1973). The population density of *M. incognita* was determined by 10 replications of 1-ml aliquots of the inoculum's suspension. In initial stage 90 nematodes were taken and 90 larvae have been studied.

Nematode population analysis
After incubation period of two months, the roots of individual plants were washed make them free from soil. The root galling severity in the *Meloidogyne* infected tomato plants was assessed on a 0–5 rating scale according to the percentage of galled tissue, in which 0=0–10% of galled roots; 1=11–20%; 2=21–50%; 3=51–80%; 4=81–90%; and 5=91–100% (Neher and Campbell 1994; Hoeksema *et al.,* 2000). Nematodes from 100 cm^3 samples of infested potting mixtures and from 5 g samples of roots were extracted by centrifugation (Palomares Rius *et al.,* 2012), as described for inoculum preparation. Final population densities of nematode were estimated by using extracted nematodes. (Nematodes were considered dead when there is no movement upon checking with a fine needle physically).

Growth chamber experiment
The research work was carried out in the growth chamber with controlled environment at 30°C ± 5°C, 50-60% humidity in summer season.

Extraction and isolation
Roots of turmeric (5 kg dry weight) were air dried and extracted with ethanol (100 L) which was then concentrated to a gum (710 g). The gum was dissolved in distilled water and extracted thoroughly with petroleum ether (40 L) and then with hexane (60 L). After that hexane, soluble portion was dried (46.8 g). The remaining aqueous layer was acidified with acetic acid to pH 3 and then, extracted with CHCl3. The CHCl3 soluble portion was dried (158.0 g). Extraction of aqueous extract with ethyl acetate (5 L) yielded an impure mixture of ethyl acetate extract.

Nematicidal activity
The research work was carried out in a controlled environment at 28±2°C. For maintaining of stock culture, fresh eggs were used in root tissues of tomato for the hatching of egg. After 48 hours the larvae were seen from the sample of egg masses at

30°C incubation for larvae mortality studies. (We did experiments in sterilized petri dishes. 10 ml of each extract was used and 1 ml of larwae suspension was poured into the labeled dish. (1 ml volume was found to have ± 90 larwae). Assay was performed in triplicate. Water with nematodes larwae was taken as a control). Standard nematicide *Azadirachta indica* (0.05%) was taken for comparison and tap water taken as control.

RESULTS and DISCUSSION

Turmeric has a wide spectrum of biological activities. The nematicidal activity of extracts of *C. longa* was performed and the results of various fractions have been shown in Table 1. It was observed that antinematal activity of turmeric is almost insignificant against *M. incognita* as maximum mortality was achieved up to 20%.

The maximum antinematal activity was observed when 1% concentration of extract was used and the % mortality was found in the range of 15-24%. Similarly, the range of 8-14% was found with 0.5% extract solution, while 2-11% with 0.25% solution of all fractions. According to Figure 1, the comparison of all fractions shows that chloroform fraction has greater mortality followed by ethyl acetate and methanol fraction has the least mortality among the tested fractions. The order of antinematal activity of tested turmeric fractions was observed as follows.

Table 1. Nematicidal activity of different fractions of rhizome extract isolated from. *Curcuma longa* on the larval mortality of *M. incognita* (R). Percent mortality/concentration after 24 h.

| Fractions (%) | 24 h | 48 h | 24 h | 48 h | 24 h | 48 h |
	1	1	0.5	0.5	0.25	0.25
Crude extract	15	20	10	12	7	9
Methanol	10	18	8	9	4	6
Chloroform	20	24	14	10	10	11
Ethyle acetate	16	20	12	8	8	9
n-Hexane	15	18	8	12	2	2
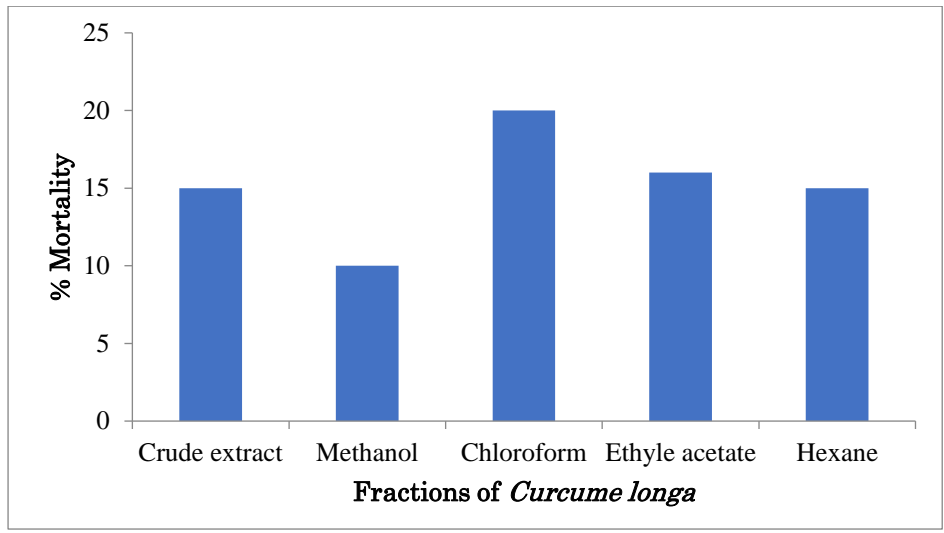
Figure 1. Comparative mortalities of different fractions of *C. longa* against *M. incognita* (mean ± S.E., n = 3) in 24 hours.

Chloroform> Ethyl acetate> Crude extract > n- Hexane > Methanol
Figure 2 shows the comparative viability of all fractions with respect to time and concentration against the selected nematode.1% concentration of all fractions showed significant mortality results. The chloroform extract showed maximum mortality in all concentrations i.e., for 1%, 0.5% and 0.25% concentration, the mortality rate is 20%, 14% and 10% for 24 hours and 25%, 10% and 11% for 48 hours respectively. Ethyl acetate fraction showed 16% and 20% mortality rate with 1% concentration and the lower concentrations showed moderate mortality. n-Hexane fraction showed moderate mortality results but methanol fraction has the least activity against nematodes.
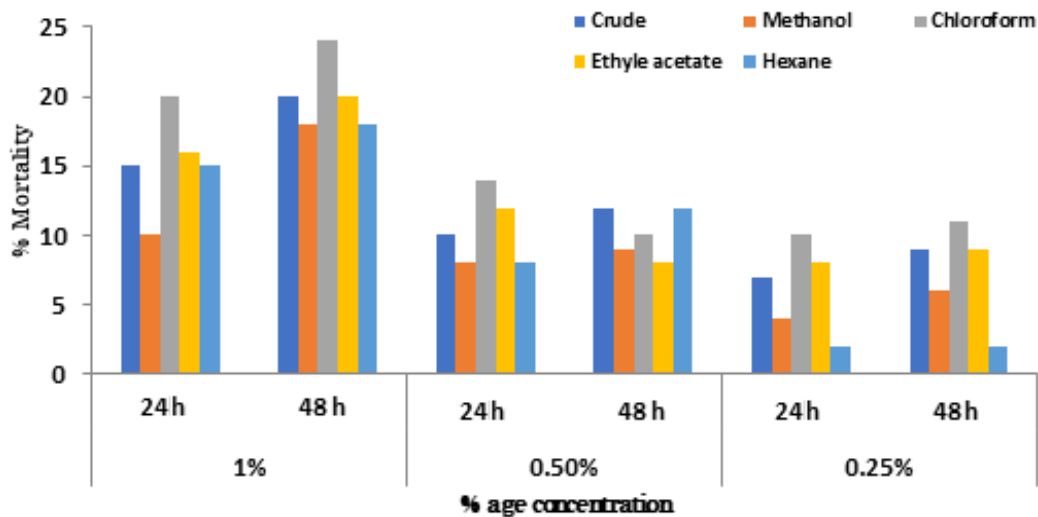
Figure 2.   Comparison nematicidal activity of various fractions of turmeric on the larval mortality of *Meloidogyne incognita* (root knot nematodes) with respect to time. (mean ± S.E., n = 3).

The results reveal that the chloroform extract has more potent and active components against root knot nematodes. It may be deduced that the mortalities of all fractions at 24 hours have considerably increased at the concentration of 1%. Moreover, the effect of time on mortality was observed almost insignificant at the concentrations of 0.5 and 0.25%. Many essential oils and phytochemicals like monoterpenes and leaf extracts of *Lantana camara* for their nematicidal activity have been reported (Ahmad *et al.* 2010; Echeverrigaray *et al.* 2010). The active components would be isolated and analyzed in future which may be used as eco-friendly biopesticides against root knot nematodes. Being the important components in our diet, the turmeric components will not dangerous for man and environment. They will be helpful in controlling the harmful effects of nematodes in future.

CONCLUSION

The antinematicidal effect of turmeric against root knot nematodes was studied. Chloroform extract showed significant antinematicidal activity in all concentration range, which leads to the conclusion that the study may be helpful after isolation and analysis of active constituents from turmeric, these bioactive components, may be used as eco-friendly biopesticides against root knot nematodes from chloroform extract. It is suggested that nematode suppression in this research may rely on nematoxic compounds released from the composted material. Turmeric agro-industrial waste is sufficient for nematode management. Additionally, this approach may be suitable to integrate with other management tactics to lessen the production reduce in vegetable and woody crops caused by *Meloidogyne* spp.

DECLARATION OF COMPETING INTEREST
The authors declare that there are no conflict of interest

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Design, Development and Evaluation of a Bucket Drip Irrigation System for Dry Season Vegetable Production in South-Eastern Nigeria

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ABSTRACT

In South-Eastern Nigeria, during the dry season from November to April, vegetables are always in short supply and consequently expensive. Hence, there is a need to design, develop an affordable and simple bucket drip irrigation system that can be used to grow vegetables under limited water supply conditions. Using the estimated consumptive use of the proposed crop okra and the area occupied by the crop stands, the capacity of the bucket as a source of water was computed. The bucket filled with water was placed at a head of 1 m. The water was allowed to flow through emitters located at 30 cm intervals along the lateral lines laid at the land slope of 2%. Two lengths of PVC tubes 11 m long, 1 mm thick and internal diameters 16 mm, Micro-tubes 5 cm long and internal diameter 1.2 mm, were used. The discharge from each emitter was determined through volumetric measurements. The system was then evaluated using the Christiansen's method and the Merriam and Keller's method and assessed using ASAE standards 1996(a) and 1996(b) performance rating. 22 sampled emitters evaluated from the lateral line showed total energy drop of 2.5 x 10^{-5} m, flow variation (FV) of 8%, coefficient of variation (CV) of emitter discharge of 0.02, uniformity coefficient (UC) of 97% and emission uniformity (EU) of 73%. The results show that the system is efficient and can be used by farmers to meet the demands for vegetables in the dry season.

INTRODUCTION

Water used for crop production is becoming scarce at a faster rate in most of the agro-ecological zones globally. In Nigeria, crop production is the largest user of water in agriculture. Agriculture is growing fast around all main cities in Africa with the upsurge of city population and consequent growing demand for vegetables. There is need to increase Irrigated agriculture quickly in the future in order to cope with this increasing demands. However, water resources are inadequate and irrigation is labor demanding because in many inner-city and cities farming, irrigation water is carried by hand from the well, reservoir or river to the field (Van Leeuwen, 2001). In south-eastern Nigeria, crops are grown mostly during the rainy season when soil moisture is adequate to support crop production. Farmers produce food crops in large quantities during this period but due to lack of storage facilities and short storage life of the crops, they become scarce during the dry season when demand for them usually is very high. The nutritional gap created by the scarcity of vegetables among households during this period can be addressed by developing an affordable and simple irrigation system that farmers can use to grow vegetables and other crops under limited water availability.

Bucket-fed drip irrigation system has the potential to address the problem of water deficit that hampers the cultivation of vegetables by smallholders during the dry season. Vegetables with shallow root systems and some crops like corn respond well to drip irrigation with increased yield and quality of seed or cob (Camp, 1998). This irrigation technology delivers water directly to the crop root zone efficiently, with far less effort and for a minimum cost (Ngigi *et al.*, 2000). In Kenya, the use of bucket drip irrigation systems by smallholders during the dry season has shown that it is possible to produce enough vegetables for their domestic use and even for sale (Lusaka, 1999). It, therefore, has the potential to improve household nutrition and income of small-scale farmers in African (Nyakwara *et al.*, 2000; Winrock, 2000).

The bucket drip irrigation system is a small-scale drip irrigation system that operates at pressure heads of 0.5 to 2 m (0.05-0.2 bar) and with water distribution uniformity of 73 to 84 percent (Ngigi et al., 2000; Keller,2002). It consists of a 20 liter bucket or a 200 liter drum, drip tape, filters, rubber washers, male and female adapters, two supply tubes, barbed fittings and emitters. The drip lines are supplied in lengths of 15 m and the emitters are spaced at planting distances of crops (Ngigi *et al.*, 2000; Opar *et al.,* 2014). In countries like Kenya, the Philippines, Vietnam and Indonesia there are various types or versions of drip kits. These include International Development Enterprises (IDE), Chapin, T-Tape and Waterboys. Researchers in these countries have carried out extensive studies to evaluate and assess the performances of these kits using overall water application uniformity (UC), emission uniformity (EU) and coefficient of variation (CV) of emitter discharge and performance rating of ASAE standards (ASAE, 1996; Ella *et al.,* 2008; Jiang and Kang, 2010; Opar *et al.,* 2014).

At present in Nigeria, low head drip systems are not available for use by small-holder farmers to grow vegetables in the season thereby depriving them of improved nutrition and income during this period. Despite the popularity and acceptance, the technology has gained in other developing countries of the world as a panacea to poverty alleviation and food security, Agricultural Engineers in Nigeria are yet to see the need to develop or adapt existing drip irrigation technologies to suit our environment. Given the

scenario, this study was conducted to develop and evaluate an affordable and easy to-operate bucket irrigation system for vegetable production by smallholder farmers.

MATERIALS AND METHODS

The study was conducted at Students Research and Demonstration Farm of Federal College of Land Resources, Owerri located at Oforola, Imo State, Nigeria. The area is located on Latitude 5° 12' N and 6° 38' E, 60 m above mean sea level and about 7 km from Owerri. Mean annual rainfall varies from 2000-2500 mm, mean temperature ranges from 26-28°C and humidity 70-80%. Many smallholder farmers in the area grow vegetables with a hand-held watering system (Obineche and Ahaneku, 2008).

The materials and equipment used for the study include:
1. A 20 liter metallic bucket with a hole at the bottom
2. A simple support
3. Water outlet fitting and filter for keeping sand and silt from blocking the emitters
4. 2 lengths of 16 mm by 11 mm with 1 mm thick plastic tube as laterals
5. 2 mm by 5 cm micro-plastic tubes as emitters
6. Plastic containers to catch water from emitters
7. Stopwatch to record time of water collection from emitters
8. 250 ml graduated cylinders to measure the volume of water collected from emitters 2 inches nail to make perforations at 30 cm intervals on the lateral to receive the emitters.

A timber framework (12 m long) experimental layout was assembled to support the lateral line laid at the land slope 2% as shown in Figure 1, A 20-litre PVC bucket fitted with a faucet used as water source was placed on a wooden stand at a head of 1 m. The water was allowed to flow through the lateral line 11 m long, 1 mm thick and internal diameter of 16 mm and then through drip lines fitted with micro tubes 5 cm long and internal diameter 1.2 mm as emitters. The drip lines were located at 30 cm interval along the lateral line. Catch cans were placed below the emitters to collect the emitter discharges.
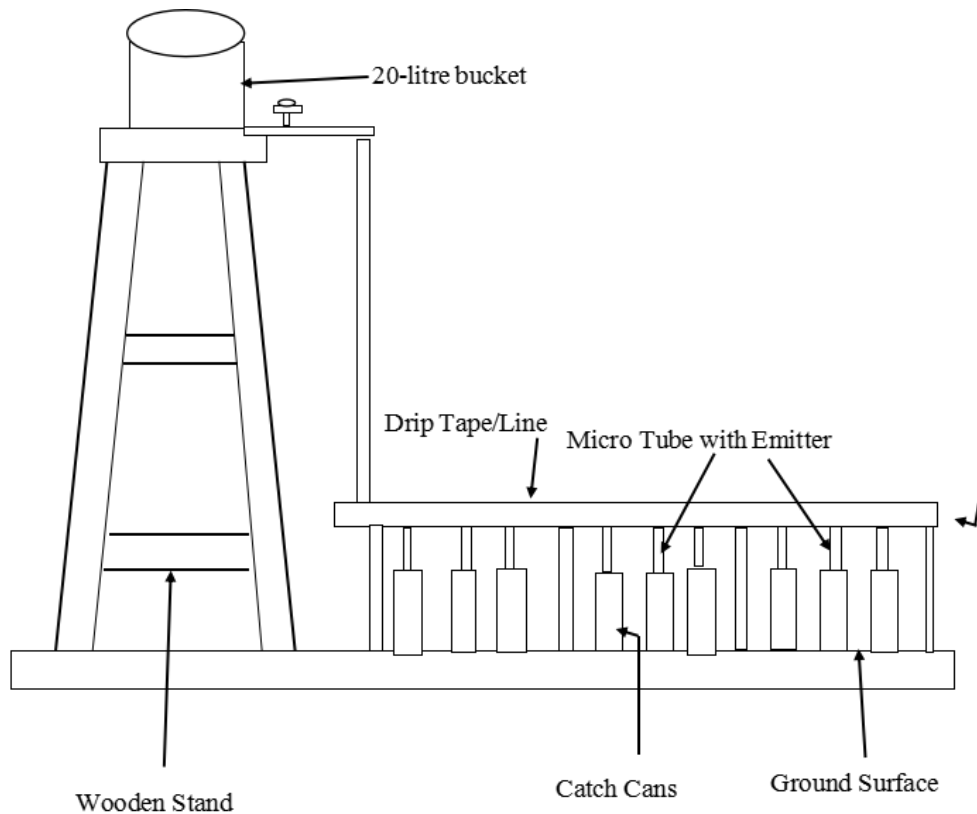
Figure 1. Side view of experimental layout of the drip system.

General Considerations
1. Consumptive use of okra (*Abelmoschus esculentus)* = 6.5 mm d^{-1}
2. Along with the row spacing of okra = 30 cm
3. Inter row spacing = 45 cm
4. No. of crop stands = 22
4. Operating head = 1 m
5. Land slope = 2%

Design Procedure
The crop water requirement of the test crop Okra was calculated using the equation proposed by Allen *et al.* (1998) and applied by Al-Kalifa *et al.* (2013).

$$ET_c = ET_o \ x \ K_c \tag{1}$$

Where:
ET_c = Crop evapotranspiration [mm d^{-1}]
ET_o = Reference crop evapotranspiration [mm d^{-1}]
K_c = Crop coefficient [dimensionless]

The volume of water applied in liters per plant was calculated by modifying the equation according to Choudhary and Kadam (2006). ET_c was assumed to be equal to the net depth of water in mm required and water applied to plants on daily basis.

The capacity of the bucket was then calculated thus:

$$V_b = ET_c \; x \; A_p \; x \; N_p \tag{2}$$

Where:
V_b = Volume of bucket
ET_c = Crop evapotranspiration
A_p = Area occupied by crop [row spacing x plant spacing]
N_p = Number of stands of the plant.

Length of Drip Lines and Emitter Spacing

The lengths of drip lines were determined from the planting distance of the crop and the distance between the ground surface and bottom of the hung bucket. The emitter spacing was determined from the planting distance of the crop (Okra) which is 30 cm apart.

System's Performance Evaluation

The discharge from each emitter was determined by volumetric measurement and time over which water was collected thus:

$$Q = V/t \tag{3}$$

Where:
Q = Emitter discharge (l s^{-1})
V = Volume of water collected in a graduated cylinder (l)
T = Time taken to collect water (s)

Total Energy Drop

The total energy drop by friction at the lateral was calculated using modified Hazen Williams Equation:

$$D_H = 5.35[Q^{1.852}/D^{4.871}] \; L \tag{4}$$

Where;
D_H = Total energy drop by friction at the end of lateral (m)
Q = Total discharge at the inlet of lateral (l s^{-1})
D = Inside diameter of lateral (cm)
L = Total length of lateral (m)

Emitter Flow Variation

Flow variation of system was calculated using the equation:

$$FV = (q_{max} - q_{min})/q_{max} \tag{5}$$

Where:
FV = Flow variation
q_{max} = Maximum emitter discharge rate in the system (l s^{-1})

q_{min} = Minimum emitter discharge rate in the system (l s^{-1})

Pressure Variation

The pressure variation along the lateral was calculated using the equation below:

$$hvar = h_{max} - h_{min}/h_{max} \tag{6}$$

Where:
h_{var} = Maximum pressure head (m)
h_{max} = Maximum pressure head (m)
h_{min} = Minimum pressure head (m)

Coefficient of Uniformity (UC)

Christiansen (1942), equation was used to calculate the uniformity coefficient of the system thus:

$$UC = [1 - D/q_{avg}] \times 100 \tag{7}$$

Where;
UC = Coefficient of uniformity (%)
D = Average of the absolute values of the deviation from the mean discharge

$$(l\ h^{-1}) = \frac{1}{n\Sigma(qi-qavg)qavg} = \text{average of emitter discharge values } (l/s) = \Sigma\frac{qi}{n}$$

q_i = Emitter discharges (l s^{-1})
n = Number of observed discharge values

Coefficient of Variation of the Emitter

The coefficient of emitter (5 cm long, 1.2 mm diameter plastic tubes) flow was computed from discharge measurements using the following equation:

$$CV = \frac{(q_1{}^2 + q_2{}^2 + q_3 \ldots + q_n{}^2 - nq_m{}^2)^{1/2}}{q_m(n-1)^{1/2}} \tag{8}$$

Where:
CV = Coefficient of variation of emission device
$q_1,\ q_2 \ldots q_n$ = Discharge of emission devices (l s^{-1})
q_m = Average discharge of emission devices tested (l s^{-1})
n = Number of emission devices tested

Emission Uniformity (EU)

Emission Uniformity of the system was calculated using the following equation [15];

$$EU = (1 - 1.27\,CV)\ 100\,q_{min}/q_{avg} \tag{9}$$

Where:

EU = Design emission uniformity (%)

q_{min} = The lowest emitter discharge rate in the system (l s^{-1})

q_{avg} = Average emitter discharge rate (l s^{-1})

RESULTS and DISCUSSION

Table 1 and Figure 2 show emitter discharge rates and their variability along the laterals of the system respectively. The emitter flow rates along the laterals show an only slight variation on the average after every 4 emitters indicating that field crops will receive a nearly equal amount of water from the micro-irrigation system.

Table 1. Average emitter discharge rates along the lateral at the general land slope of 2 % and head of 1 m.

Emitter position	Lateral length (m)	Average emitter discharge (l h^{-1})
1	1.5	1.18
2	1.95	1.18
3	2.40	1.18
4	2.85	1.18
5	3.30	1.16
6	3.75	1.16
7	4.20	1.16
8	4.65	1.16
9	5.10	1.14
10	5.55	1.14
11	6.00	1.14
12	6.45	1.14
13	6.90	1.14
14	7.35	1.12
15	7.80	1.12
16	8.25	1.12
17	8.70	1.12
18	9.15	1.10
19	9.6	1.10
20	10.05	1.08
21	10.50	1.08
22	10.95	1.08
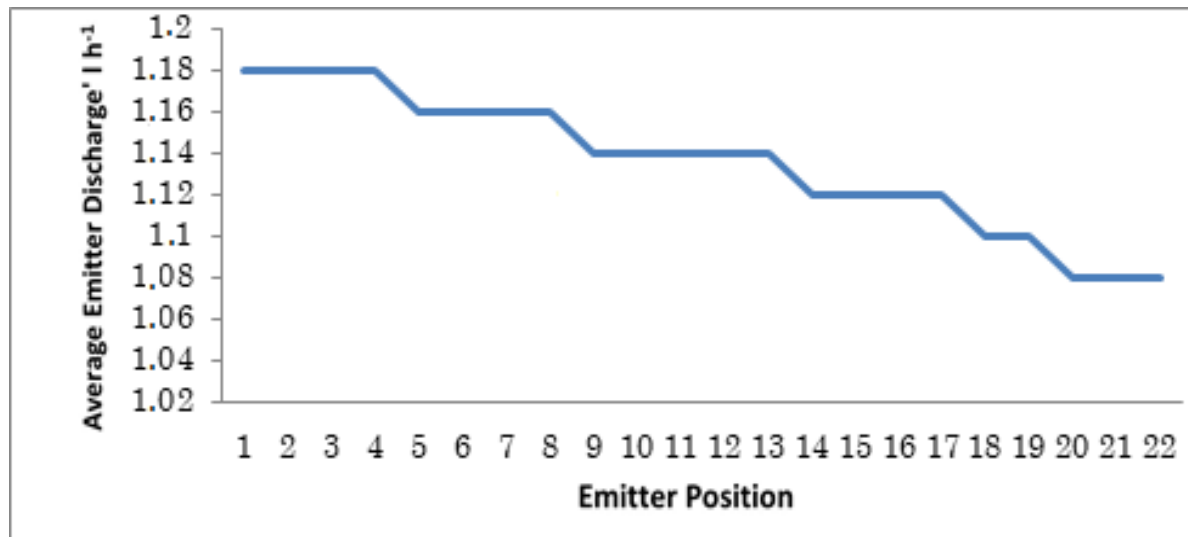
Figure 2. Variation of average emitter discharge rates along the lateral under the general land slope of 2% and a hydrostatic head of 1 m.

Table 2. System's performance parameters.

B_c (l)	Q (l s^{-1})	h_v	D_H (m)	CV (%)	FV (%)	EU (%)	UC (%)
20	0.0025	0.24	0.000025	0.02	8	73	97

B_c is bucket capacity; Q = Average emitter discharge; h_v = pressure variation along the drip line; D_H = Total energy drop; CV = Coefficient of variation; FV = Flow variation; EU = Emission uniformity; UC= Coefficient of uniformity

Table 3. Assessment of indices of performance of the system based on ASAE (1996) standard criterion.

Parameter	Calculated value	Rating
%CV	0.02	Excellent
%FV	8	Good
%EU	73	Fair
%UC	97	Acceptable

Table 2 shows the system's performance parameters. The system's pressure variation of 24% and average emitter discharge of 0.0025 l s^{-1} or 9 l h^{-1} are below standard 40% and within the range of 2 - 10 l h^{-1} respectively recommended by Rajput (1985). The low value of 0.000025 m recorded for the total energy drop of the system accounts for the nearly uniform discharge rates of the emitters. The negligible energy drop was attributed to the smoothness of the wetted surface of the laterals.

Table 3 shows the rating of the system with respect to the values of water distribution uniformities. The coefficient of variation of emitter flow (CV) of 0.02 was considered excellent, which conforms to the report by ASAE EP405.1, (1996) that for line-source emitters, values of CV less than 0.05 are excellent. A 73% EU was considered as fair, which is in conformity with ASAE EP405.1, (1996) report that for most micro-irrigation systems operating with design emission uniformity ranging from 70-80% are classified as fair. The flow variation (FV) of the 16 mm internal diameter PVC lateral line of 11 m at 1 m head was 8%, which confirms the report by ASAE EP409, 1996b that emitter flow variation of less than 10% is generally considered good. An acceptable coefficient

of uniformity (UC) of 97% agrees with the report by Bralts *et al.* (1987), that acceptable UC should be greater than 90%.

CONCLUSION

The greatest irrigation choices that have the highest chance to work are those that benefit small holders move to a substantially higher productivity and increased income to manage their irrigation system independently. The values of CV, EU, FV and UC of 0.02, 73%, 8% and 97% respectively obtained when the drip irrigation system was evaluated indicate that the system is generally good and acceptable to irrigate field crops especially vegetables during the dry season. The use of drip/trickle irrigation systems, especially micro systems related to one suggested by Batcher *et al.* (1996) as an alternative of the sprinkler system, would moderate fuel consumption, cost of pumping and labor, as well as save more water for effective irrigation water management usage for dry season vegetable productivity. The above performance rating recommends the system well for promotion by extension providers to ensure enhanced crop production, improved farmers' income and poverty alleviation in different countries of the world.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Donatus Okwudiri Igbojionu: Writing original draft, methodology and investigation.
Christopher Ikechi Obineche: Analysis of figures, validation and review.
Juliet Nnennaya Igbojionu: Compilation and statistical review.

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Mechanical Properties of Bell Pepper Fruits, as Related to the Development of its Harvesting Robot

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ABSTRACT

Adequate knowledge of the mechanical properties of fruits is required for the optimization of fruits harvesting robots. This study was carried out to evaluate some physical and mechanical properties of bell pepper fruits, which will be useful for the design and utilization of bell pepper fruits harvesting robots. Some mechanical properties (failure force, failure energy and compressibility) of matured bell pepper fruits were evaluated at three different dimension sizes and two fruit orientations, according to the American Society of Agricultural and Biological Engineers (ASABE) approved procedure. Results obtained from this study revealed that the fruit size and orientation had significant ($p \leq 0.05$) effect on the mechanical properties of the bell pepper fruits. The failure force and failure energy of the fruit increased significantly ($p \leq 0.05$) as the fruit locule number increases from 3 to 4. Relatively, the results revealed that the failure force and failure energy of the fruit increased significantly ($p \leq 0.05$) as the fruit size increased from small to large size. As portrayed by this study results, the failure force and failure energy of the fruit when loaded in the natural position was higher than values obtained, when the fruit was compressed at the vertical position; irrespective of the fruit size. This revealed that the fruit at the natural position absorbed higher compressive force (pressure) and compressive energy, regardless of the fruit locule number. Results obtained from this study will present useful information for the design, programming and optimization of bell pepper harvesting and handling robots.

To cite: Idama O, Uguru H, Akpokodje OI (2021). Mechanical Properties of Bell Pepper Fruits, as Related to the Development of its Harvesting Robot. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2(1): 193-205. *https://doi.org/10.46592/turkager.2021.v02i01.015*

INTRODUCTION

There is a global increment in food demand, due to the growing world human population. This has necessitated increase in food production through modern farming techniques. Pepper (genus Capsicum) is a berry fruits bearing plant belonging to the nightshade family, which is extensively cultivated for its edible and medicinal value. The fruits are used as vegetables and relishes, and may be pickled, or ground into a fine powder for use as spices (Britannica, 2020). There is sharp increment in pepper fruit production globally between 2012 and 2019. According to the Food and Agriculture Organization (FAO) portal, global pepper fruits produced increased from 30.964 million tons to 38.027 million tons, between 2012 and 2019 (FAOSTAT, 2019). Bell pepper (*Capsicum annuum*), which is one of the genus of *Capsicum* is widely cultivated in Nigeria due to its flavor, medicinal and nutritional qualities. Bell pepper is susceptible to pests and diseases, mostly the viral diseases, although some cultivars (e.g. cv. Goliath) are resistant to some of these pests and diseases. Bell pepper can thrive well in dry, sub-arid, sub-humid and humid regions, if well managed (Madagascar Catalogue, 2014; CABI, 2017).

According to Gallardo *et al.* (2010), harvesting of fruits and vegetable which are susceptible to damage is highly cost intensive, due to the dwindling skilled labor force. Poor labor supply can lead to delay in crop harvesting, which will then lead to food wastage (FAO, 2011). According to Młotek *et al.* (2015), manual fruits harvesting can lower the nutritional status of the fruits, and at the same time expose the workers to some health challenges. For instance, the juice or fluids produced by some crops (e.g. cashew fruit) are toxic to the human skin. Grubben and Denton (2004) reported that labor alone amounts to about 50% of the total cost of crop production; therefore, full automation of the agricultural sector has become inevitable. This is because, automated fruit harvesting system will augment the increasing labor demand, while decreasing the labor time, energy, and cost, which is profitable to both producers and consumers (Fennimore and Doohan, 2008; Gongal *et al.,* 2015). Although, the exact amount of agricultural products lost due to delay harvest and processing is not ascertainable; it is necessary to develop an automation system that will help crop harvesting; thus preventing food waste and improving food security (Ibeawuchi *et al.,* 2015)

Several scientists have designed and developed agricultural robots, which operate based on the engineering properties of agricultural products. Lehnert *et al.* (2017) designed sweet pepper harvesting robots, which can be utilized in a farming method where the plants are grown on planar trellis structures. Under performance of the sensing skills of a robot, which is caused by inadequate engineering information about the targeted crop, is one of the main hindrances during the application of intelligent automated crop management systems. Out of all the engineering properties of agricultural products, mechanical properties are some of the major obstacles in the optimization of agricultural robots (Tanigaki *et al.,* 2008). Li *et al.* (2011) stated that mechanical damage occurring to agricultural products, during robotic harvesting and handling operations is a major hindrance in the robotization of the agricultural sector. This is due to shortfall in the adequate knowledge of the mechanical properties of the targeted crop, during the design, programming and operation of the robot. According to Myhan *et al.* (2012), during the automatized harvesting and handling operations of agricultural products, they are often subjected to several mechanical forces. If these

forces are above the bearing capacity of the targeted product, they cause internal mechanical damage to the products. Since agricultural products are non-homogeneous, their mechanical properties vary widely along their dimension and orientation. Thus, adequate information on the mechanical properties of agricultural products in this regard is necessary for the optimization of harvesting robots (Idama and Uguru, 2021). Onishi *et al* (2019) stated that accurate information on the targeted crop is crucial, during the design and programming of agricultural robot, with the purpose of minimizing the rate of mechanical damage inflicted on the target crop, by the robot's grippers and its accessories.

Several researches have been done analysis in fruit detection and harvesting operations. Kurtulmus *et al.* (2011) investigated the application of texture analysis to segment green citrus fruits, and they observed a 75.3% true fruit identification and 27.3% false fruits detection. Despite breakthroughs made in the field of automation in the agricultural sector, through the application of computer-assisted technologies, total robotization of the agricultural sector is still in the infancy stage (Barth *et al.,* 2018). This is mainly due to the lack of detailed and clear engineering data of the various crops, that are necessary to produce automated crop management systems which is caused by genetic, structural and morphological differences, farming method, prevailing climatic conduction, etc. (Gongal et al., 2015; Iweka and Uguru, 2019). Sistler (1987) stated that lack of clear direction for agricultural automation and robotics; variable environmental conditions; and complex plant structure, including its shape and size are some of the challenges hindering the optimization of agricultural robots. Therefore, the objective of this present study was to evaluate the mechanical properties of bell pepper (cv. Goliath) fruits, cultivated under Nigerian climatic conditions; which will be useful during the design, programming and optimization of bell pepper harvesting and handling robots.

MATERIALS AND METHODS

The steps to be taken in order to achieve the objectives of this study are presented in Figure 1.
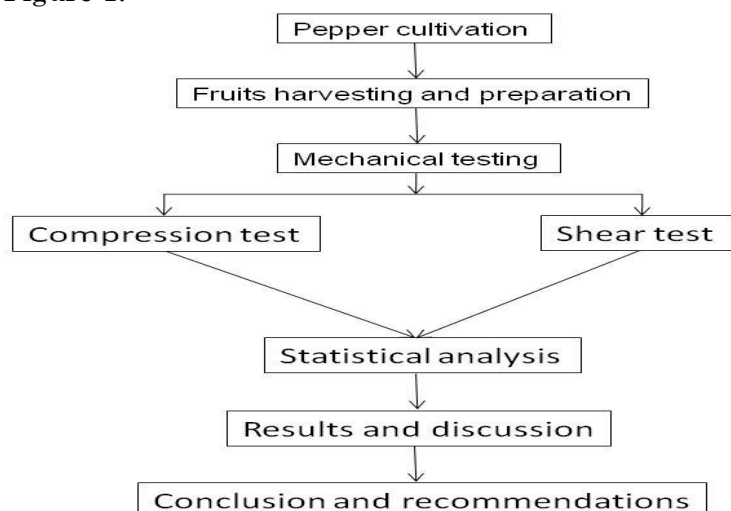
Figure 1. Flowchart of how the study objectives will be accomplished.

Pepper Cultivation

The bell pepper (*Capsicum annuum* L., cultivar Goliath F1) was cultivated at the research station of Delta State Polytechnic, Ozoro, Nigeria. Pure organic farming method was adopted; compost manure at the rate of 3 tons ha^{-1} was used for soil amendment, while neem seeds extract was used as the insecticide. Sprinkler irrigation was used as the irrigation method, while weeding was done manually throughout the experimental period.

Fruits Collection and Preparation

The pepper fruits used for this study were harvested at the deep green maturity stage. The fruits were manually inspected to remove damage, deformed and pests infected fruits, before they were taken to the laboratory for storage and mechanical analysis. After which, the fruits were further sorted based on the numbers of locule (Figure 2).
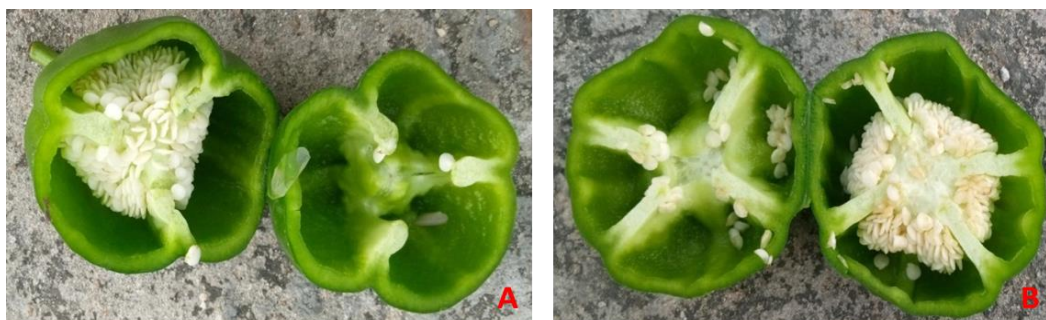
Figure 2. Locule of bell pepper fruit.
A) A three locule bell pepper fruit, B) A four locule bell pepper fruit.

Fruits Size Arrangement

The two principal dimensions (Length "*L*" and Width "*W*") of the fruits were used to categorize the fruits into different sizes. Each fruit was measured with a digital vernier caliper (accuracy of 0.01 mm); and categorized into three sizes (small, medium and large) as presented in Table 1.

Table 1. Classifications of the bell pepper fruit size

	Size		
	Small	Medium	Large
Width (mm)	$W < 55$	$55 \leq W \leq 85$	$W > 85$
Length (mm)	$L < 65$	$65 \leq L \leq 95$	$L > 95$

The Mechanical Test of the Bell Pepper Fruits

The Universal Testing Machine (UTM) (Testometric M500 100AT, England), equipped with 500 N loading cell and micro-processor, was used to determine the mechanical properties of the pepper fruits. The mechanical properties of the bell pepper fruits were tested at two loading positions, which were the natural and vertical positions (as shown in Figures 3 and 4) at three fruit sizes (small, medium and large) for both the 3 locule and 4 locule fruits.

During the mechanical (compression) test, each pepper fruit was placed between the two-loading platen of the machine (Figure 3) and compressed with a compression speed of 10 mm min^{-1}, until the fruit ruptured. As the compression progressed, the deformation of the fruit was determined electronically, in relation to the force (load)

applied, which was then plotted by the machine (Figure 5). Due to the heterogeneous structure of bell pepper, the fruit shape and size changed continuously during compression, as the mechanical properties of fruits are anisotropic in nature (Li *et al.*, 2013). According to Kilickan and Guner (2008) compressibility of a fruit, is related to its relative deformation, at the failure or rupture point. All the laboratory tests were replicated 8 times in accordance with ASABE recommendations (ASABE, 2008), and the mean values recorded.

Figure 3. A four locule bell pepper fruit undergoing compression test, in the natural position.

Figure 4. A three locule bell pepper fruit undergoing compression test, in the vertical position.
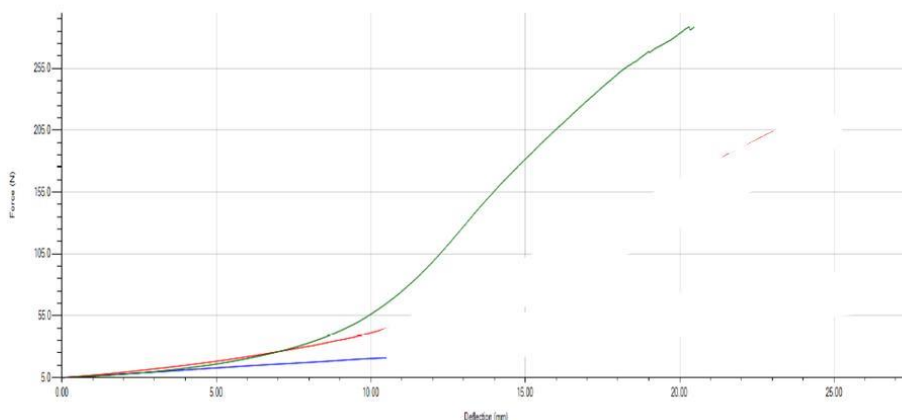
Figure 5. A force-deformation relationship of the bell pepper fruit under compression test.

Statistical Analysis

The results obtained from this study were subjected to analysis of variance (ANOVA) using SPSS 20.0 software (IBM Corporation, USA), to ascertain if the fruit size, locule number and fruit position have significant effects on the mechanical properties of bell pepper fruits. Duncan's Multiple Range Test (DMRT) was used to separate and compare the mean at 95% confidence level.

RESULTS AND DISCUSSION

The compressive parameters of the fruit at bio-yield (failure) point were considered in this study. Failure point is a crucial point to be considered during the design and development of machines for automated harvesting and handling. This is because; studies (Ince *et al.*, 2009) had shown that failed agricultural products are susceptible to microbial attacks, resulting in deterioration of their biochemical/mechanical properties during storage. According to Oghenerukewve and Uguru (2018), once an agricultural product had failed, its ability to store adequately will drop significantly, which will then lead to a shorter shelf life and high food wastage.

Effect of Locule Number and Fruit Position on the Compressive Properties of the Pepper Fruit

The statistical analysis of results presented in Table 2, revealed that the bell pepper locule number and fruit loading position had significant ($p < 0.05$) effect on the compressive properties of the pepper fruit. But in contrast, the ANOVA results showed that the interaction of locule number and loading position did not significantly ($p < 0.05$) influenced the compressive properties of the pepper fruit. The mean values and the standard deviation of failure force, failure energy and compressibility (specific deformation), as a function of the fruits locule number and fruit loading position are presented in Table 3. As portrayed in the results presented in Table 3; irrespective of the loading position, the failure force and failure energy of the fruit increased significantly ($p < 0.05$) as the locule number increases from 3 to 4; while the

compressibility decreased as the locule number increases from 3 to 4. The highest failure forces (300.12 N and 277.21 N) were obtained when the 4 locule fruit and 3 locule fruit were compressed along the natural orientation respectively. This portrayed that the fruits can absorb more pressure, when compressed along with the natural orientation, compared to the vertical orientation. Similar results were obtained by Oghenerukevwe and Uguru (2018) for *Gmelina arborea* fruits, in which the mechanical properties of the fruits were also affected by the loading orientation of the fruits.

In terms of the failure energy of the fruits, fruits with higher locule numbers had significantly ($p \leq 0.05$) higher failure energy values, when compared to the fruits with lower locule number (Table 3). On average failure energy of 1.124 N m was obtained when the 4 locule number fruit was compressed at the natural orientation, which was higher than the average failure energy of 0.854 N m that was obtained, when fruits with a locule number of 3 were compressed along with the same natural orientation. This portrayed that during compression, the 4 locule number fruits required more energy for failure than the fruits with 3 locule number. Kilickan and Guner (2008) reported the higher rupture energy (0.3398 N m) was observed when an olive fruit was compressed along the *X*-axis; which was significantly higher ($p \leq 0.05$) than the rupture energy value (0.257 N m) recorded when the same size olive fruit was compressed at the *Y*-axis.

As presented in Table 3, irrespective of the loading position, the compressibility of the fruits decreased as the locule number increases from 3 to 4. Compressibility values of 31.37% and 37.79% were recorded when the 3 locule fruits were compressed along with the natural and vertical positions, respectively. However, it was observed from the results that the compressibility of the fruits declined to 24.41% and 29.28%, as the 4 locule fruits were compressed along with the natural and vertical positions, respectively. The differences in the compressibility and other mechanical properties of the fruits, across the locule numbers line, could be attributed to the difference in the internal structure of the green pepper fruit, as shown in Figure 2. According to Li *et al.* (2011), when fruits are loaded along with the natural orientation, they tend to have lower compressibility than those compressed in other orientations. This is because, the tissues arrangement of the fruit in the natural position gives the fruit a lower compression resistance. Additionally, the lower compressibility observed in the 4 locule fruit, regardless of the fruit loading orientation, could be ascribed to the better resistance offered by the fruit cross wall tissues (Li *et al.* 2011).

Table 2. ANOVA results of the effect of locule number and compression position on the failure properties of bell pepper fruit.

Source		df	MSS	F Sat	P-value
Locule	Failure force	1	6894.41	5.35	2.29E-03*
	Failure energy	1	1.22	71.59	3.91E-13*
	Compressibility	1	123.39	3.26	7.39E-03*
Position	Failure force	1	635947.28	493.15	9.88E-39*
	Failure energy	1	8.69	515.73	1.72E-39*
	Compressibility	1	765.42	20.27	1.96E-05*
locule * position	Failure force	1	852.58	0.661	0.4182[ns]
	Failure energy	1	0.05	2.975	0.0878[ns]
	Compressibility	1	14.56	0.385	0.536[ns]

MSS: mean sum of square, *: significant at Duncan $p \leq 0.05$ according to Duncan's Multiple Range Test,
[ns]: not significantly different at $p \leq 0.05$ according to Duncan's Multiple Range Test.

Table 3. Means and standard deviations of the mechanical properties of bell pepper fruit as a function of locule number and compression position.

Parameter	Position	Locule number	
		3 locule	4 locule
Failure force (N)	Natural	277.21±47.48	300.12±43.86
	Vertical	120.39±19.02	131.38±24.87
Failure energy (Nm)	Natural	0.854±0.17	1.124±0.15
	Vertical	0.298±0.07	0.476±0.10
Compressibility (%)	Natural	31.37±4.66	24.41±5.08
	Vertical	37.79±7.27	29.28±7.11

Mean± standard deviation; n: 8

Effect of Fruit Size and Fruit Position on the Compressive Properties of the Pepper Fruit

The ANOVA analysis results presented in Table 4, showed that the pepper fruit size and fruit loading position had significant ($p < 0.05$) effect on the failure parameters of the pepper fruit. In addition, an interaction of the fruit size and loading position significantly ($p < 0.05$) influenced the failure force of the pepper fruit, but the interaction of the fruit size and loading position, did not exhibit any significant ($p < 0.05$) effect on the failure energy and compressibility of the pepper fruit. As reflected by the results (Table 5), the large bell pepper fruits had better failure parameters than the medium and small bell pepper fruits, regardless of the loading position (Table 5). As presented in Table 5, regardless of the loading position, the failure force of the pepper increased significantly ($p < 0.05$), as the fruit size increases from small to large. As seen in the results given in Table 5, there was a drastic increment in the failure force of the fruits, as the size increased from small to large.

This result of the study further clarified that, regardless of the fruit size, the failure forces recorded when the fruits were loaded at the natural orientation, were higher than the failure forces recorded when the fruit was loaded in the vertical orientation. As revealed by the results, when the fruit was compressed at the natural orientation, failure forces of 251.63 N, 272.92 N and 341.45 N, were recorded for the small, medium and large fruits size, respectively. These were superior in magnitude, when compared to the failure force values of 108.39 N, 116.33 N and 152.95 N obtained when the small, medium and large fruits size were compressed at the vertical orientation. Similar results were reported by Nyorere and Uguru (2018), in which the failure force of gmelina seed increased from 427.71 N to 657.64 N, as the gmelina seed size increases from small to large size. Likewise, Khazaei et al. (2004) stated that the failure force of chickpea, regardless of the variety is highly influenced by the pea orientation and size.

Table 5 revealed that regardless of this loading position, the failure energy of the pepper fruits increased gradually, as the fruit size increases from small to large size. In terms of the fruit loading positions, it was also observed from the results that failure energy varied significantly ($p \leq 0.05$) across the two-fruit loading orientation considered. The rupture energy recorded at the natural orientation was higher than the rupture energy recorded at the Vertical orientation. At the vertical loading position, failure energies of 0.348 N m, 0.352 N m and 0.460 N m, respectively, were recorded for the small, medium and large fruits. While at the natural loading position, failure energies of 0.872 N m, 0.941 N m and 1.153 N m, respectively, were recorded for the small, medium and large fruits. These results are in conformity with previous research results of Kilickan and Guner (2008), which stated that the rupture energy of olive fruits increased as the fruit size increased from 10 mm to 30 mm. In addition, Saiedirad et al

(2008) reported that the failure energy of cumin seed increased with an increment in the seed size. This depicted that as the fruit size increases, the energy absorbed by the fruit increases, probably due to increase in the body mass of the fruit.

   In terms of the fruit compressibility, the compressibility of the fruits increased with increment of the fruit size (Table 5). As shown in Table 5, regardless of the loading position, the small fruits had the least compressibility while the large fruits had the highest compressibility. In all cases, the highest compressibility of 33.44%, 36.04% and 44.46% was observed when the small, medium and large fruits were compressed at the natural orientation. According to Li et al. (2011) compressibility of tomato fruits decreased slowly as the locule increases from 3 to 4, and it is attributed to the better deformation resistance offered by the 4 locule tomato fruits. This portrayed that the larger fruits experience more deformation and higher modulus of elasticity, during compression when compared to smaller fruits (Oghenerukevwe and Uguru, 2018).

Table 4. ANOVA results of the effect of fruit size and compression position on the failure properties of bell pepper fruit.

	Source	df	MSS	F. Stat	p-value
	Failure force	1	635947.27	1513.71	4.42E-58*
Position	Failure energy	1	8.69	392.22	1.45E-34*
	Compressibility	1	765.42	57.67	2.77E-11*
	Failure force	2	39960.75	95.11	6.35E-23*
Size	Failure energy	2	0.34	15.71	1.39E-06*
	Compressibility	2	1190.66	89.72	3.72E-22*
	Failure force	2	4326.66	10.29	9.39E-05*
Position * size	Failure energy	2	0.058	2.62	0.07819[ns]
	Compressibility	2	17.79	1.34	0.26685[ns]

MSS = mean sum of square, * = significant at Duncan $p \leq 0.05$ according to Duncan's Multiple Range Test, ns = not significantly different at $p \leq 0.05$ according to Duncan's Multiple Range Test.

Table 5. Means and standard deviations of the mechanical properties of bell pepper fruit as a function of fruit size and compression position.

Parameter	Size	Position	
		Natural	Vertical
	Small	251.63±24.57	108.39±7.15
Failure force (N)	Medium	272.92±27.14	116.33±10.51
	Large	341.45±28.04	152.95±15.24
	Small	0.872±0.18	0.348±0.11
Failure energy (N m)	Medium	0.941±0.18	0.352±0.12
	Large	1.153±0.16	0.460±0.11
	Small	33.44±2.61	33.60±4.35
Compressibility (%)	Medium	36.04±2.59	35.67±5.07
	Large	44.46±4.10	46.35±4.01

Mean± standard deviation, n=8

Engineering Applications of the Results in Agricultural Robot's Design

Information obtained from this present study is essential for the design, development, programming and utilization of bell pepper harvesting robot. According to Li et al. (2011) and Gongal et al. (2015), the mechanical forces that a harvesting robot applies on the targeted fruit, is a crucial factor to be considered during the design of harvesting robots and associated storage accessories. Thus, the mechanical properties of the fruit affect the mechanical design of the end-effector and its control system, which affects the overall performance of the fruit harvesting robot. Hence compressive failure parameters of bell pepper fruits are critical factors to be considered, during the design, programming and utilization of bell pepper fruits automated harvesters.

Therefore, to avert mechanical damage been done to the bell pepper fruits during automated harvesting operations, the force and energy applied by the robot grippers and suction tubes, must be within the permissible limits of the failure parameters of the bell pepper fruits. As depicted by the study's results, the force and energy to be exacted on a fruit, by the harvesting robot grippers and other accessories, should not exceed the values stated in Tables 3 and 5, in order to minimize the rate of mechanical damages and wastage of the harvested bell pepper fruits. Furthermore, to prevent excessive mechanical damages to the pepper fruits, the robot gripper must first read and interprets the size parameters of the bell pepper fruits. According to the analysis of the results, the small pepper fruit swiftly attained its failure point, when compared to the large pepper fruit.

Additionally, to prevent the robot causing excessive mechanical damages to the pepper fruits, the robot must read and interpret the size, numbers of locule and orientation of the bell pepper fruit. This is because, as shown by this study, the smaller and 3 locule fruits swiftly attained its failure point, when compared to the larger and 4 locule fruits. Similarly, the analysis of the results revealed that the pepper fruit will withstand higher failure force when the robot's grippers grasped it at the natural position. Results obtained from this study will be helpful in addressing some of the major challenges in agricultural robots production and utilization with respect to bell pepper mechanization, which include: fruit orientation detection, gripper's pressure and manipulation, fruit picking orientation and method. This will help to improve the optimization of the fruit harvesting robots; hence, minimizing the effect of occlusions as earlier stated by Lehnert *et al.* (2017).

Figure 6 shows a simple flowchart of how the results obtained from this study, can be used to design and programme a bell pepper harvesting robot, for effective applications in the field. As shown in the flowchart, if the fruit is considered matured through a digital imaging system, but the appropriate fruits size, locule number and position are not detected by the robot sensors, the system will abort the operation. This study results and its potential applications, also affirmed the conclusions of a previous report by Hua *et al.* (2019). Hua *et al.* (2019) stated that the development of agricultural robots, requires the services of agricultural engineers, computer engineers, horticulturists, mechanical engineers, software developers, system integration specialists, structural engineers, etc.
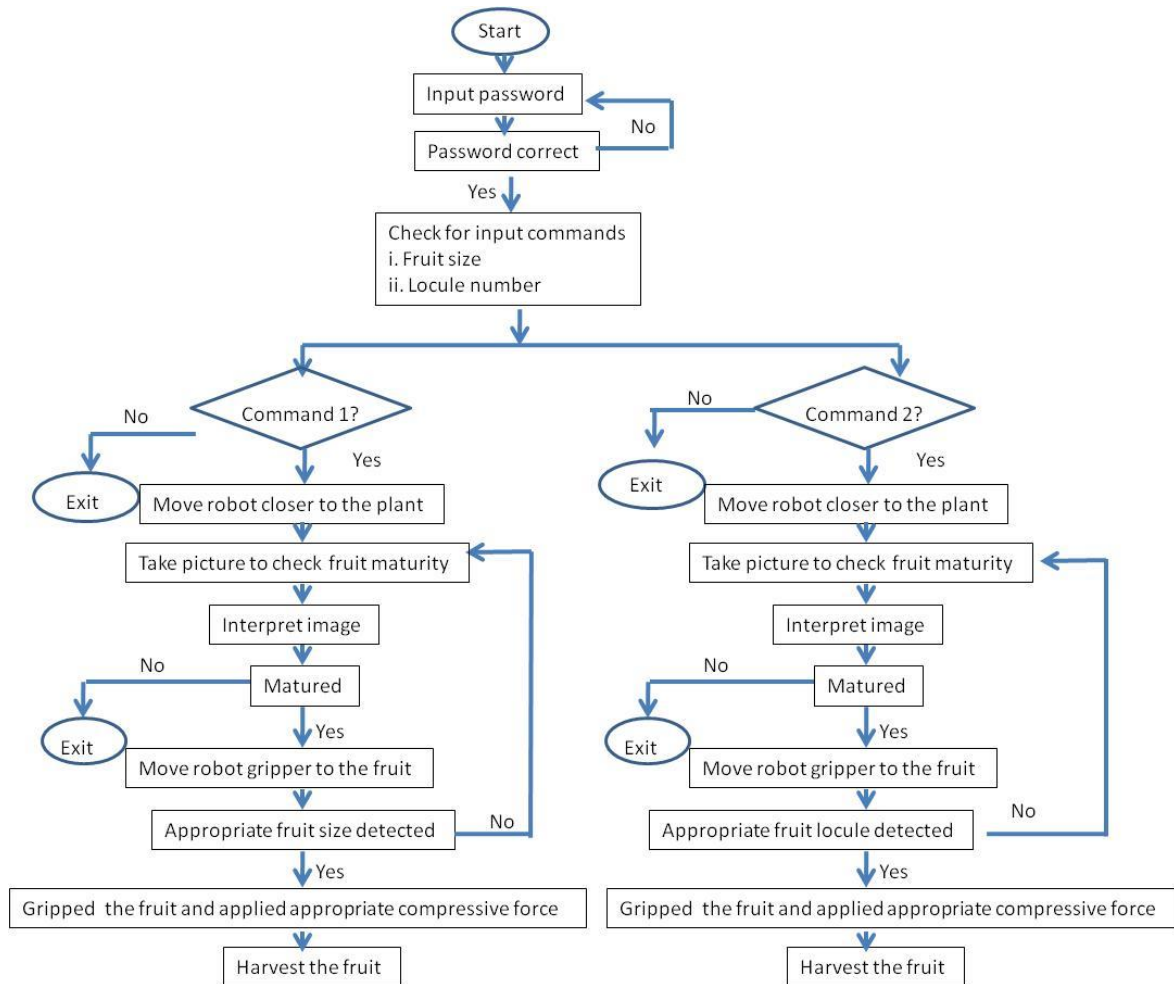
Figure 6. A simple flowchart of the proposed bell pepper harvesting robot.

CONCLUSION

In this research, some mechanical properties of bell pepper fruits were evaluated for the purpose of enhancing the efficiency of bell pepper harvesting robots. The failure force, failure energy and compressibility of matured bell pepper fruit, were tested at three fruit size levels, two locule levels and two fruit orientations levels, in according with ASABE recommended standards. Results of the tests showed that the revealed locule number, fruit size, and fruit loading position had significant ($p \leq 0.05$) effect on the compressive properties of the bell pepper fruits tested. The highest failure forces and energies were obtained when the 4 locule fruit and 3 locule fruit were compressed along their natural orientation. The results further revealed that large size bell pepper fruits required the highest failure forces and failure energies, irrespective of the fruit positions and the locule number. Similarly, analysis of the results indicates that, the pepper fruit will withstand a higher failure force, when the robot's grippers grasped it at the natural position. During robotic harvesting of matured bell pepper fruits, it is proposed that the pressure applied by the robot's accessories, should best fall within the permissible limit of the failure parameters of the bell pepper fruit, as determined by this report. This will help to reduce the occurrences of mechanical damages, and improve the efficiency of harvesting robots, particularly in Nigeria.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Hilary Uguru: Data analysis and review of the original draft.

Ovie Isaac Akpokodje: Edited the manuscript.

Omokaro Idama: Designed the research and writing the original draft.

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The Effect of Different Nitrogen Doses on Yield and Yield Components of Oregano (*Origanum syriacum* var. *bevanii*)

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ABSTRACT

In this study, It is aimed to determine the effect on yield and yield components of *Origanum syriacum* var.*bevanii* of different nitrogen doses (0, 4, 8, 12 and 16 kg da^{-1}). The study was carried out in a randomized complete block design with three replications under Eskişehir ecological conditions in 2019-2020. The plant height, fresh herb yield, dry herb yield, dry leaf yield, essential oil content and essential oil yield of *Origanum syriacum* var. *bevanii* were investigated in the study and the effects of different nitrogen doses on examined parameters, except the essential oil content, were found to be significant. The results (2019 and 2020 mean) obtained from the experiment showed that fresh herba yield, dry herb yield, dry leaf yield and essential oil yield ranged between 787.65-1267.50 kg da^{-1}, 440.10-708.22 kg da^{-1}, 235.92-379.62 kg da^{-1} and 8.33-12.53 L da^{-1}, respectively.In addition, essential oil contents were determined between 3.23-3.47%. In the parameters studied (except essential oil content), the highest values were obtained from a nitrogen dose of 16 kg da^{-1}.

Farklı Azot Dozlarının Dağ Kekiği (*Origanum syriacum* var. *bevanii*)'nin Verim ve Verim Öğeleri Üzerine Etkisi

ÖZET

Bu araştırmada, farklı azot dozlarının (0, 4, 8, 12 ve 16 kg da⁻¹) *Origanum syriacum* var. *bevanii* 'nin verim ve verim öğeleri üzerine etkisinin belirlenmesi amaçlanmıştır. Çalışma tesadüf blokları deneme desenine göre 3 tekerrürlü olarak Eskişehir ekolojik koşullarında 2019-2020 yıllarında yürütülmüştür. Çalışmada bitki boyu, taze herba verimi, kuru herba verimi, kuru yaprak verimi, uçucu yağ oranı ve uçucu yağ verimi incelenmiş, farklı azot dozlarının uçucu yağ oranı hariç incelenen parametrelerin üzerine etkisi önemli bulunmuştur. Çalışmada iki yılın ortalaması olarak verimler (2019 ve 2020 yılları ortalaması) taze herbada 787.65-1267.50 kg da⁻¹, kuru herbada 440.10-708.22 kg da⁻¹, kuru yaprakta 235.92-379.62 kg da⁻¹ ve uçucu yağda 8.33-12.53 L da⁻¹ arasında değişmiştir. Uçucu yağ oranları ise %3.23-3.47 arasında belirlenmiştir. Çalışılan parametrelerde (uçucu yağ oranı hariç) en yüksek değerler 16 kg da⁻¹ azot dozundan elde edilmiştir.
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GİRİŞ

Origanum cinsi ballıbabagiller (Labiatae/Lamiaceae) familyasına ait olup dünyada 38 tür, 6 alt tür ve 17 melez ile temsil edilmektedir. Türkiye'de ise Origanum cinsinin 22 türü veya 34 taxa'sı doğal yayılış göstermekle birlikte yaklaşık %62'si (21) endemik bitkilerdir (Kaçar ve ark., 2006; Tonçer ve ark., 2009; Bozdemir, 2019; Anonim, 2020). Bu cinse ait olan türlerden biri de *Origanum syriacum* L. olup, *Origanum majorana* L. ve *Origanum onites* L. türleri ile birlikte Majorana bölümünde yer almaktadır. *O. syriacum* türü içerisinde var. *syriacum*, var. *bevanii* (Holmes) Ietswaart ve var. *sinaicum* (Boissier) Ietswaart olmak üzere üç varyete tanımlanmıştır (Ietswaart, 1980). Bu varyetelerden var. *syriacum*, Filistin, Ürdün ve Suriye'de, var. *bevanii* (Holmes) Ietswaart, Türkiye, Suriye, Lübnan ve Kıbrıs'ta ve var. *sinaicum* (Boissiér) Ietswaart ise Sina Yarımadasında yayılış göstermektedir (Ietswaart, 1980; Başer ve ark., 2003). *Origanum syriacum* var. *bevanii* genel olarak Dağ kekiği, Suriye kekiği ve Filistin kekiği olarak isimlendirilmekte olup halk arasında *Origanum syriacum*'a Tarsus kekiği denildiği de bildirilmektedir (Başer, 2001; Gülbaba ve Özkurt, 2006).

Dağ kekiği *(Origanum syriacum)* türü 90 cm'ye kadar boylanabilen tüylü yapraklara sahip otsu-çalı formunda çok yıllık bir bitkidir (Ietswaart, 1980; Davis,1982). Doğu Akdeniz Bölgesinde Güney Anadolu'da Toros dağları, Hatay, Amanos dağları, Kıbrıs ve Lübnan'da kalkerli kayalık ve yamaçlarda, genellikle kısmi gölgeli yerlerde ve 200-2700 m rakımlarda doğal yayılış gösteren dağ kekiğinin ömrü, iklim koşullarının uygun olması halinde yaklaşık 3-4 yıldır. Bitkinin vejetasyon süresinin Doğu Akdeniz

koşullarında Mart-Kasım ayları arasında olduğu, haziran ayında çiçeklenmeye başlaması ile ilk biçimin yapıldığı ve ilk biçimi takiben ikinci ve üçüncü biçim için bitkinin hasat olgunluğuna gelebileceği belirtilmiştir (Özgüven ve ark., 2006; Türker, 2016).

Origanum'lar günümüzde gıda, eczacılık ve kozmetik sanayinde yaygın olarak kullanılmaktadır. Gaz giderici, hazmı kolaylaştırıcı, balgam ve idrar söktürücü, ishal kesici, terletici ve kadınlarda adet söktürücü özelliklere sahip olup, uçucu yağı kronik romatizma, kas kasılmalarında, diş ve kulak ağrısı, öksürük ve bronşit tedavisinde kullanılan ilaçların hammaddesidir (Baytop, 1983; Deans ve ark., 1992). Bitkinin uçucu yağının içerdiği yüksek miktardaki fenol nedeni ile antibakteriyal, antispazmodik ve antiseptik etkileri bilinmektedir (Başer ve ark., 1993). Bitkinin en önemli sekonder metaboliti yaprak ve çiçeklerinde bulunan uçucu yağdır. *O. syriacum*'dan elde edilen uçucu yağ ve ekstraktları gıda endüstrisinde doğal koruyucu maddeler olarak kullanılmaktadır (Tepe ve ark., 2004). Diğer taraftan *O.syriacum*'dan elde edilen uçucu yağın ana bileşenlerini karvakrol ve timol oluşturmaktadır (Başer ve ark., 2003; Lukas ve ark., 2009). Yapılan bir araştırmada *O. syriacum* L. var.*bevanii* taksonunun uçucu yağında %64.1 oranında karvakrol belirlenmiştir (Scheffer ve ark., 1986).

Gübreleme, tarımsal ürünlerin verimi ve kalitesi üzerinde önemli etkileri olan bir tarımsal uygulamadır. Bu bakımdan azot en önemli makro besin elementi olup, bitki büyüme ve gelişimi üzerinde diğer mineral besinlerden daha yüksek bir etkiye sahiptir. Diğer taraftan özellikle tıbbi ve aromatik bitkilerde azot uygulaması, ürünün verimi, uçucu yağ oranı ve uçucu yağın kompozisyonu üzerinde etkili olan önemli bir agroteknik uygulama olarak bilinmektedir (Aboukhalid ve ark., 2017). Bilindiği gibi aşırı veya yetersiz azotlu gübre uygulamaları ürünün veriminde ve kalitesinde kayıplara neden olmakta, aşırı azot uygulamasının zaman içinde çevre sorunlarına da neden olduğu bilinmektedir. Bitkilerin azotlu gübre ihtiyaçları, bitki türüne, üretimin yapıldığı bölgenin ekolojik koşullarına (iklim ve toprak özelliklerine) ve diğer agroteknik uygulamalara bağlı olarak büyük ölçüde değişiklik göstermektedir. Bu durum dikkate alınarak değişen üretim bölgelerine, üretimde kullanılan bitkinin genotipine ve diğer üretim uygulamalarına bağlı olarak bitkilerin optimum verim ve kalitede üretilebilmesi için ihtiyaç duyulan azotlu gübre miktarlarının tarla denemeleriyle belirlenmesine ihtiyaç duyulmaktadır. *Origanum onites*, *Satureja hortensis*, *Thymus vulgare* gibi kekik türlerinde en uygun azot dozlarının belirlenmesine yönelik farklı çalışmalar yürütülmüştür (Baranauskieneú ve ark. 2004; Batıray; 2009; Katar; 2015). Yapılan literatür taramasında *Origanum syriacum* türünde azotlu gübrelemenin verim ve kalite üzerindeki etkisini belirlemek üzere yürütülen çok az çalışma olduğu görülmüştür (Özgüven ve ark., 2006).

Bu çalışmanın amacı, farklı azot dozlarının Eskişehir ekolojik koşullarında *Origanum syriacum* var. *bevanii* (Holmes) Ietswaart bitkisinin verim ve verim öğeleri üzerine etkisinin belirlenmesidir.

MATERYAL ve YÖNTEM

Bu çalışma 2019 ve 2020 yıllarında Eskişehir Orman Fidanlık Müdürlüğü deneme sahasında yürütülmüştür. Çalışmanın yürütüldüğü Eskişehir ilinin uzun yıllar, 2019 ve 2020 yıllarına ait bazı iklim verileri Çizelge 1'de verilmiştir. Plantasyonun kurulduğu 2019 yılında toplam yıllık yağış miktarı uzun yıllara kıyasla %26 daha fazla gerçekleşirken, 2020 yılında %12 daha az gerçekleşmiştir. Aylar dikkate alındığında ise

2020 yılı Nisan ayı yağış miktarının (13.0 mm) hem 2019 yılının hem de uzun yılların aynı ayına nispeten daha az olduğu görülmektedir. Çalışmanın yürütüldüğü her iki yılın (2019 ve 2020) sıcaklık ortalaması birbirine çok yakın olup uzun yılların ortalamasından yüksek olmuştur (Çizelge 1).

Çalışmanın yürütüldüğü sahanın toprak özelliklerini tespit etmek üzere alınan toprak numunelerinde yapılan analiz sonuçları Çizelge 2'de sunulmuştur. Deneme alanı toprağının bünyesi killi-tınlı olup organik madde içeriği yetersizdir. Toprak pH açısından hafif alkalin bir özellikte ve orta kireçlidir. Faydalanılabilir fosfor (P_2O_5) açısından ise yeterli düzeydedir.

Çizelge 1. Deneme alanına ait bazı iklim verileri*.
Table 1. Some climatic data of the experimental area.

Aylar	Toplam Yağış (mm)			Ortalama Sıcaklık (°C)		
	2019	2020	UY	2019	2020	UY
Ocak	40.3	52.7	30.6	1.7	0.3	-0.2
Şubat	51.5	43.3	26.1	4.1	4.1	0.9
Mart	13.3	20.0	27.6	7.3	8.2	4.9
Nisan	38.6	13.0	43.1	10.2	10.9	9.6
Mayıs	30.3	38.9	40.0	17.4	16.3	14.9
Haziran	57.5	74.3	23.7	21.1	19.5	19.1
Temmuz	17.4	1.2	13.1	21.8	23.2	22.1
Ağustos	2.9	0.9	9.2	22.7	23.4	21.8
Eylül	6.6	6.9	18.1	18.8	21.5	16.7
Ekim	69.9	38.4	32.8	15.2	16.2	11.7
Kasım	22.4	1.6	34.0	9.9	6.3	5.6
Aralık	76.1	10.4	40.5	3.3	5.7	1.7
Toplam	426.8	301.6	338.8	-	-	-
Ortalama	-	-	-	12.8	13.0	10.7

*Veriler Eskişehir Meteoroloji 3. Bölge Müdürlüğü'nden temin edilmiştir. UY: Uzun Yıllar (1970-2011)

Çizelge 2. Deneme alanı toprağının bazı fiziksel ve kimyasal özellikleri*.
Table 2. Some physical and chemical characteristics of soil in experiment area.

Derinlik	Tekstür	Kireç (%)	Faydalanılabilir Fosfor (P_2O_5) (kg da^{-1})	pH	Organik Madde (%)
0-60 cm	Killi-tınlı	8	13.8	7.6	1.7

*Toprak analizi Orman, Toprak ve Ekoloji Araştırma Enstitüsü Müdürlüğü laboratuvarında yapılmıştır.

Atatürk Bahçe Kültürleri Merkez Araştırma Enstitüsü Müdürlüğü'ndeki *Origanum syriacum* var.*bevanii* taksonuna ait plantasyondan (sera koşullarında) 2019 yılı Mart ayı başında 8-10 cm uzunlukta çelikler alınmış, alınan bu çelikler Eskişehir Orman Fidanlık Müdürlüğü sera ortamında hazırlanan ve içerisine kum, orman toprağı ve torf karışımı (1:1:1) ile doldurulmuş köklendirme kasalarına dikilmiştir. Dikimi yapılan çelikler gerekli bakımları yapılarak köklendirilmiş, bu şekilde yetiştirilen fideler deneme tarlasında hazırlanmış olan parsellere 50 cm x 20 cm mesafe ile 27.04.2019 tarihinde dikilmiştir. 2019 yılında tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulmuş olan plantasyon 5 farklı azot dozu (0, 4, 8, 12 ve 16 kg da^{-1})

içermektedir. Bloklardaki her parsel 6 sıradan oluşmakta olup, sıra uzunlukları ise 5 m'dir. Çalışmada her parsel dikim öncesi dekara 5 kg P_2O_5 hesabı ile gübrelenmiştir. Azotlu gübreler ise ikiye bölünerek 2019 yılında ilk yarısı dikim öncesinde ikinci yarısı ise bitkiler yaklaşık 25-30 cm boya ulaştıklarında, 2020 yılında ise ilk yarısı ilkbaharda bitkiler uyanırken ve ikinci yarısı ise ilk biçimden sonra uygulanmıştır. Çalışmada azotlu gübre olarak Amonyum Sülfat (%21) gübresi kullanılmıştır. Plantasyonda ihtiyaç duyuldukça yabancı ot mücadelesi elle çapasıyla yapılmış, sulama işlemi damla sulama yöntemiyle gerçekleştirilmiştir. Parsellerdeki bitkilerde 2019 yılında tek biçim (17.10.2019) ve 2020 yılında iki biçim (27.07.2020 ve 20.10.2020) yapılmıştır. Her parselin kenarlarındaki birer sıra ve sıra uçlarından 3'er bitki kenar tesiri olarak bırakılmış, rastgele seçilen 10'ar bitkinin boyları ölçülerek belirlendikten sonra bitkiler toprak seviyesinin 8-10 cm yüksekliğinden makasla biçilerek hasat edilmiş ve parseldeki taze herbalar tartılarak verimleri belirlenmiştir. Biçim işlemi tamamlanan parsellerden alınan örneklerde taze herbaların ve saplarından ayrılmış yaprakların kurutma işlemi etüvde (35-38°C ve 48 saat) yapılmıştır. Kuru yaprak numunelerinin uçucu yağ oranlarını belirlemek için Clevenger cihazı kullanılmıştır. 2000 ml'lik balonlara 100 g kuru yaprak numuneleri konulmuş ve 1000 ml saf su eklenmiştir. Uçucu yağın distilasyon işlemi 3 saat sürmüştür. Distilasyon işlemi sonrası clevenger aparatının dereceli kısmından yağ miktarı okunmuş ve uçucu yağ oranları yüzde (%) olarak belirlenmiştir.

Çalışmadan elde edilen veriler SPSS paket programı kullanılarak tesadüf blokları deneme desenine göre varyans analizine tabi tutulmuş, incelenen özelliklerin önemlilik düzeyleri belirlenmiştir. Önemli çıkan ortalama değerler arasındaki farklar Tukey testi ile karşılaştırılmıştır.

BULGULAR ve TARTIŞMA

O. syriacum var. *bevanii* (Holmes) Ietswaart bitkisine *O. syriacum* türüne uygulanan farklı azot dozlarının incelenen parametreler üzerine etkisi (uçucu yağ oranı hariç) istatistiksel olarak önemli bulunmuştur. Yılların etkisi incelenen tüm özellikler üzerinde, yıl x azot interaksiyonunun etkisi ise taze ve kuru herba verimi, kuru yaprak verimi ve uçucu yağ verimi üzerinde istatistiksel olarak önemli olmuştur (Çizelge 3).

Çalışmada ortalama bitki boyu değerleri 2019 yılında 57.47 cm olarak belirlenirken, 2020 yılında 71.76 cm olarak belirlenmiştir. Çalışmanın ikinci yılında bitki boyu ilk yıla nispetle daha fazla olmuştur. Bu durum plantasyonun tesis yılı olan 2019 yılında bitkilerin henüz yeterli gelişme göstermemeleri ile izah edilebilir. Farklı azot dozu uygulamasının iki yıllık ortalama değerleri incelendiğinde, en yüksek bitki boyu (76.77 cm) 16 kg da^{-1} azot uygulamasında, en düşük değer (54.10 cm) ise kontrol bitkilerinde ölçülmüştür. Kontrol bitkileri ile kıyaslandığında tüm azot dozları uygulamasında bitki boyu önemli derecede artış göstermiştir (Çizelge 3). *O. syriacum* L. ile yapılan çalışmalarda bitki boyunu Atallah ve ark. (2011), 66.3-81.5 cm arasında ölçerken, Hamed (2018) 20.17-65.67 cm arasında kaydetmiştir. Çalışmalar arasında elde edilen bitki boyu değerleri arasındaki farklılıklar çalışmalarda kullanılan materyalin genotipik farklılığı ile birlikte çalışmaların yürütüldüğü bölgelerin ekolojik koşulları ve gübreleme, sulama gibi yetiştiricilik uygulamalarındaki farklılıklarla açıklanabilir. Bu çalışmadan elde edilen bulgulara benzer şekilde *O. onites*, *Salvia officinalis*, *Mentha spicata* ve *Menta x piperita* gibi tıbbi

ve aromatik bitkiler ile yürütülen çalışmalarda da artan azot dozları ile bitki boyunun arttığı bildirilmiştir (Batıray, 2009; Sönmez ve Bayram, 2017; Can, 2020).

Taze ve kuru herba verimi üzerine yılların, farklı azot dozlarının ve yıl x azot interaksiyonunun etkisi önemli ($p < 0.01$) bulunmuştur (Çizelge 3). Çalışmanın ikinci yılı olan 2020 yılında ilk yıla (2019) nispetle daha yüksek taze ve kuru herba verimleri alınmıştır. 2019 yılında tek biçim ve 2020 yılında iki biçim alınması ile taze herba verimleri ve buna bağlı olarak kuru herba verimleri 2020 yılında daha fazla olmuştur. Yıllar ortalamasında taze herba verimleri 787.65-1267.50 kg da^{-1} arasında elde edilmiştir. Kurutulduktan sonra *O. syriacum* var. *bevanii* herbasının ağırlığı yaklaşık %45 azalmış, kuru herba verimleri 440.10-708.22 kg da^{-1} arasında değişmiştir. Farklı azot dozu uygulanan *O. syriacum* var. *bevanii'* de en yüksek taze ve kuru herba verimleri her iki yılda ve yıllar ortalamasında 16 kg N da^{-1} uygulamasında elde edilirken, bunu sırasıyla 12 kg da^{-1} ve 8 kg da^{-1} azot uygulamaları izlemiştir. En düşük taze ve kuru herba verimleri kontrol bitkilerinde gözlenmiş, artan azot dozlarında taze ve kuru herba verimlerinin önemli derecede artış gösterdiği belirlenmiştir. En yüksek taze ve kuru herba verimlerinin alındığı 16 kg da^{-1} azot uygulamasında taze ve kuru herba verimleri sırasıyla 1267.50 kg da^{-1} ve 708.22 kg da^{-1} olarak kaydedilmiştir (Çizelge 3). Katar (2015), *Satureja hortensis* L. üzerine yürüttüğü çalışmasında taze ve kuru herba veriminin dekara 10 kg azot dozuna kadar önemli derecede arttığını bu dozdan sonra artan azot dozlarının taze ve kuru herba verimini önemli derecede etkilemediğini bildirmiştir. Diğer taraftan Özgüven ve ark. (2006), Çukurova koşullarında *O. syriacum* var. *bevanii* ile yaptıkları çalışmada taze herba veriminin 1080-1813 kg da^{-1} arasında, kuru herba veriminin 497-748 kg da^{-1} arasında değiştiğini ve en yüksek verimlerin 4 kg da^{-1} azot uygulamasından alındığını saptamışlardır. Çalışmalar arasındaki bu farklılıklar, kullanılan bitki materyallerinin genetik yapısının farklı olmasından, çalışmaların yürütüldüğü bölgelerin değişen ekolojik koşulları ve agronomik uygulamalardaki farklılıklar ile izah edilebilir. Bulgumuza benzer olarak *O. onites* ve *Thymus vulgaris* üzerine yürütülen çalışmalarda da azot uygulamasının taze ve kuru herba veriminde artışa neden olduğu rapor edilmiştir (Baranauskıeneú ve ark. 2004; Batıray, 2009).

Kuru yaprak verimi üzerine de herba verimlerinde olduğu gibi yıllar, farklı azot dozları ve yıl x azot interaksiyonu önemli etki göstermiştir. Değişen dozlarda azotlu gübre uygulaması dağ kekiğinin (*O. syriacum* var. *bevanii*) kuru yaprak verimi üzerinde de önemli düzeyde ($p < 0.01$) etkili olmuş, artan azot dozlarında kuru yaprak verimi fazla alınmıştır (Çizelge 3). Taze ve kuru herba verimlerine benzer şekilde kuru yaprak verimleri 2020 yılında 2019 yılına göre yüksek bulunmuştur. En yüksek kuru yaprak verimi 2019, 2020 ve yıllar ortalamasında sırasıyla 166.47, 592.77 ve 379.62 kg da^{-1} olmak üzere 16 kg da^{-1} azot uygulamasından alınmıştır. Kuru yaprak verimi ortalaması ise 303.16 kg da^{-1} olarak kaydedilmiştir (Çizelge 3). Tıbbi ve aromatik bitkilerde azotlu gübre uygulaması yaprak sayısı ve iriliğini, yaprakta klorofil oranını ve fotosentetik oranını arttırarak vejetatif gelişimi teşvik etmekte (Frabboni ve ark., 2011) buna bağlı olarak da kuru yaprak verimini arttırmaktadır. Atallah ve ark. (2011), *O. syriacum* L. üzerine yaptıkları çalışmada plantasyonun ikinci ve üçüncü yılında kuru yaprak verimini ortalama 337.1-599.4 kg da^{-1} arasında elde ettiklerini bildirmişlerdir. Diğer taraftan Batıray (2009), *O. onites* ile, Katar (2015), *S. hortensis* ile, Yılmaz (2019), *S. fruticosa* ile, Can (2020), *M. spicata* ve *Mentha x*

piperita ile yaptıkları çalışmalarında azotlu gübreleme ile daha fazla kuru yaprak verimi alındığını rapor etmişlerdir.

Çalışmada *O. syriacum* var. *bevanii* türünün uçucu yağ oranı bakımından yıllar arasındaki farklılık istatistiksel olarak önemli bulunurken, azot dozları ile yıl x azot dozları interaksiyonu arasındaki farklılık ise önemsiz bulunmuştur (p > 0.05). Farklı azot dozu uygulamalarının ortalaması 2019 yılında (%3.29) 2020 yılına (%3.49) kıyasla daha düşük olmuştur (Çizelge 3). Bu durum 2019 yılı tek biçim zamanında (Ekim ayı) gerçekleşen ortalama sıcaklık değerinin (15.2°C) 2020 yılı her iki biçim zamanlarında (Temmuz ve Ekim ayları) gerçekleşen ortalama sıcaklık değerlerinden (23.2°C ve 16.2°C) daha düşük olmasının uçucu yağ sentezine negatif etki yapması ile izah edilebilir (Can ve Katar, 2020). Denemede uçucu yağ oranı üzerine azotlu gübre uygulamasının etkisi önemsiz olmuştur. Bununla beraber uçucu yağ oranı en düşük oranda (%3.23) en yüksek azot dozu uygulamasında (16 kg da⁻¹) kaydedilirken, en yüksek oranda (%3.47) ise azot uygulanmayan parseller ile 8 kg da⁻¹ azot uygulamasında kaydedilmiştir (Çizelge 3). *O. syriacum* L. üzerine yürütülen çalışmalarda uçucu yağ oranını Hamed (2018) %0.89-2.60 arasında, Özgüven ve ark. (2006) ise %2.42-4.40 arasında belirlemişlerdir. Benzer olarak kekik türleri üzerinde yapılan bazı çalışmalarda da azot uygulamasının uçucu yağ oranı üzerinde önemli bir etkisinin olmadığı bildirilmiştir (Batıray, 2009; Katar, 2015).

Uçucu yağ verimi tek biçim yapılan çalışmanın ilk yılında (2019) 3.47-5.23 L da⁻¹, iki biçim yapılan çalışmanın ikinci yılında (2020) ise 13.20-19.83 L da⁻¹ arasında değişmiştir. Yıl ortalamaları ise 2019 yılında 4.36 L da⁻¹ ve 2020 yılında 16.50 L da⁻¹ olarak belirlenmiştir (Çizelge 3). Diğer verimlerde olduğu gibi uçucu yağ veriminde de yıllar arasındaki fark önemli bulunmuştur. 2020 yılı uçucu yağ oranları ile kuru yaprak verimlerinin 2019 yılı ile kıyaslandığında daha yüksek olması uçucu yağ verimlerinin de 2020 yılında fazla olmasına sebep olmuştur. 2019 ve 2020 yılı ortalaması incelendiğinde; en yüksek uçucu yağ verimi 12.53 L da⁻¹ ile 16 kg da⁻¹ azot dozundan alınırken, en düşük değer ise 8.33 L da⁻¹ ile kontrol uygulamasından alınmıştır (Çizelge 3). Artan azotlu gübre uygulaması ile bitkilerde daha fazla vejetatif gelişme ve oransal olarak daha fazla büyüme gerçekleştiğinden bir başka ifade ile özellikle kuru yaprak veriminde yaşanan artışa bağlı olarak uçucu yağ verimi de artış göstermiştir. Uçucu yağ verimine ait bulgular, Özgüven ve ark. (2006)'in Adana ekolojik koşullarında yürütmüş oldukları çalışmada buldukları 11.3-30.2 L da⁻¹ değerinden daha düşük bulunmuştur. Bu durum çalışmaların yürütüldüğü lokasyonların iklim ve toprak özelliklerinin etkisinin yanı sıra kullanılan bitki materyallerinin farklı genotipik yapısı ile açıklanabilir. Diğer taraftan tıbbi ve aromatik bitkilerde uçucu yağ oranı ve verimini bitkinin genotipi, bitkinin yaşı, yetiştirme lokasyonu, hasat zamanları, gübreleme, sulama, kurutma, depolama ve damıtma işlemlerinin etkilediği rapor edilmiştir (Mammadov, 2014; Sourestani ve ark., 2014; Kotyuk, 2015; Sönmez ve Bayram, 2017; Can ve Katar, 2020; Katar ve ark., 2020).

Çizelge 3. Farklı azot dozlarının dağ kekiğinin (*Origanum syriacum* var. *bevanii*) verim ve verim öğelerine etkisi.

Table 3. The effect of different nitrogen doses on yield and yield components of oregano (Origanum syriacum var. bevanii).

Azot dozları	Bitki boyu (cm)			Taze herba verimi (kg da⁻¹)		
	2019	2020	Ortalama	2019	2020	Ortalama
0	47.00	61.20	54.10 e	281.30 d	1294.00 d	787.65 e
4	51.67	65.93	58.80 d	320.10 c	1472.50 c	896.28 d
8	55.33	69.93	62.63 c	358.90 b	1650.90 b	1004.90 c
12	63.67	77.87	70.77 b	394.47 b	1814.60 b	1104.50 b
16	69.67	83.87	76.77 a	452.67 a	2082.30 a	1267.50 a
Ortalama	57.47 B	71.76 A	64.61	361.49 B	1662.80 A	1012.20
Yıl (Y)	**			**		
Azot (A)	**			**		
Y x A	öd			**		

Azot dozları	Kuru herba verimi (kg da⁻¹)			Kuru yaprak verimi (kg da⁻¹)		
	2019	2020	Ortalama	2019	2020	Ortalama
0	151.50 d	728.70 d	440.10 e	103.43 d	368.40 d	235.92 e
4	172.40 c	829.20 c	500.80 d	117.70 c	419.20 c	268.45 d
8	193.30 b	929.70 b	561.50 c	131.97 b	470.00 b	300.98 c
12	212.50 b	1021.90 b	617.18 b	145.07 b	516.57 b	330.82 b
16	243.83 a	1172.60 a	708.22 a	166.47 a	592.77 a	379.62 a
Ortalama	194.71 B	936.41 A	565.56	132.93 B	473.39 A	303.16
Yıl (Y)	**			**		
Azot (A)	**			**		
Y x A	**			**		

Azot dozları	Uçucu Yağ Oranı (%)			Uçucu Yağ Verimi (L da⁻¹)		
	2019	2020	Ortalama	2019	2020	Ortalama
0	3.36	3.57	3.47	3.47 d	13.20 d	8.33 c
4	3.30	3.50	3.40	3.90 cd	14.73 cd	9.32 c
8	3.37	3.57	3.47	4.43 bc	16.80 bc	10.62 b
12	3.27	3.47	3.37	4.77 ab	17.93 ab	11.35 b
16	3.13	3.33	3.23	5.23 a	19.83 a	12.53 a
Ortalama	3.29 B	3.49 A	3.39	4.36 B	16.50 A	10.43
Yıl (Y)	**			**		
Azot (A)	öd			**		
Y x A	öd			**		

(**) : $p < 0.01$, (öd) : önemli değil,

SONUÇ

Çalışmada uygulanan farklı azot dozları *Origanum syriacum* var. *bevanii* 'in uçucu yağ oranı hariç bitki boyu, taze ve kuru herba verimi, kuru yaprak verimi ile uçucu yağ verimi üzerine önemli derecede etkili olmuştur. Yapılan bu iki yıllık çalışmanın sonuçlarına göre, Eskişehir ve benzer ekolojik koşullarda *O. syriacum* var. *bevanii* yetiştiriciliğinde en yüksek kuru yaprak ve uçucu yağ verimini sağlayacak olan en uygun azot dozunun 16 kg da⁻¹ olduğu ifade edilebilir. Bununla birlikte çalışmaların farklı yıllarda, değişen iklim koşullarında ve daha ileri azot dozlarında sürdürülmesi faydalı olacaktır.

ÇIKAR ÇATIŞMASI

Yazarlar, herhangi bir çıkar çatışması olmadığını beyan ederler.

YAZAR KATKISI

Duran Katar: Arazi ve laboratuvar çalışmaları, istatistik analizi, makalenin yazılması.
Nimet Katar: Arazi ve laboratuvar çalışmaları, istatistik analizi, makalenin yazılması.
Mustafa Can: Arazi ve laboratuvar çalışmaları, istatistik analizi, makalenin yazılması.

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Research Article

Analysis of Egg Poultry Enterprise in Southeastern Anatolia Region in Turkey

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ABSTRACT

In this paper, in Southeastern Anatolia of Turkey, the technical structure of enterprises engaged in the egg producing, such as firm characteristics, hens characteristics, egg farming and health-protection were investigated. For this purpose, in the Southeastern Anatolia Region, the provinces of Gaziantep, Diyarbakır, Şanlıurfa, Batman, Adıyaman, Mardin and Kilis were included in the study. The enterprises surveyed in these provinces were determined using the simple random sampling method. As a result of this statistical study, a survey was conducted in determined 17 enterprises. It was reported that in recent years an increase in the number of enterprises established has been determined in Southeastern Anatolia Region. The vast majority of them have modern enterprises. In general, the enterprises in the region are concluded to have similar properties, the structural and technical specifications. It was observed during the fields investigation that the main problems of the enterprises in the region are raised the disease, the feeding, the marketing, animal material, the education of workers and the climatic conditions. These mentioned egg poultry farming should be solved by supplying economical funds, educational programs and supporting the enterprises with leading edge technologies.

To cite: Aydın F, Celen MF (2021). Analysis of Egg Poultry Enterprise in Southeastern Anatolia Region in Turkey. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2(1): 216-229. *https://doi.org/10.46592/turkager.2021.v02i01.017*

INTRODUCTION

The egg poultry farming is definitely an important farming activity due to playing crucial roles in economic and political areas. The egg poultry farming also helps to reduce unemployment in the countries. The egg industry has been reported to be a part of the agriculture, as it has completed its industrialization, produces high-quality outputs, provides employment opportunities and export enterprises (Dogan *et al.*, 2018). Costantini *et al.* (2021), reported that more research is needed in order to understand

the performance of this sector that is still limited in some respects, which were highlighted. Also, economic and social aspects should have to be increasingly taken into consideration in the life cycle perspective. Among the livestock-based enterprises, poultry occupies an important position because of its enormous potential to bring about rapid food security, economic growth and development (Ekunwe, 2006). Poultry production is the easiest, fastest and most economic means of bridging the animal protein deficiency gap, unemployment and poverty in the developing countries (Ahmadu and Giroh 2013).

Promising developments are observed in the sector in egg production enterprises, especially through various enterprises and cooperatives established in some regions. Today, especially laying hens stay in the poultry house during the whole breeding period. Therefore, in the productivity, health and feed utilization abilities of chickens, in addition to rearing material and feeding, the control of indoor environmental conditions also has an important effect. The environmental conditions inside the shelter, which is called the shelter climate, consist of ventilation and lighting with ambient air temperature, relative humidity. The fact that these conditions are below or above the optimum limits negatively affects chicken health and thus yield (Alagöz, 1983). In another study carried out in Kastamonu region, it was reported that the structural traits of family or village poultry in the country show similarities with each other (Sarica *et al.,* 2020).

When the egg chickens' assets of various countries in the world are evaluated, it is seen that China ranks first with 3 137 132 000 laying hens. With this number of egg chickens, China alone meets 41.54% of the total egg chickens in the world. The number of egg chickens owned by the USA, which ranks second, is 399 656 000, which corresponds to 5.29% of the world's total egg chickens. India ranks third. India has 319 352 000 egg chickens, and this value corresponds to 4.23% of the world's total egg chicken assets. Our country, on the other hand, ranks eighth with its 120 725 000 egg chickens, which corresponds to 1.60% of the world's egg chickens. Our country is among the important countries in the world in terms of egg chicken's production. Egg chicken production quantities of various countries are shown in Table 1.

Table 1. Egg chicken production quantities of various countries (FAO, 2019).

Country ranking	Countries	Egg chicken (piece)	Ratio (%)
1	Çin	3 137 132 000	41.54
2	ABD	399 656 000	5.29
3	Hindistan	319 352 000	4.23
4	Endonezya	263 918 000	3.49
5	Brezilya	249 068 000	3.30
6	Meksika	207 182 000	2.74
7	Japonya	141 792 000	1.88
8	Türkiye	120 725 000	1.60
9	Ukrayna	97 800 000	1.30
10	Malezya	97 796 000	1.30
Top 10 countries total		5 034 421 000	66.67
Other countries		2 517 107 000	33.33
World total		7 551 528 000	100.00

When the asset of egg chickens in our country is evaluated according to the regions, Aegean region ranks first with its 41 672 296 egg chickens. While Central Anatolia Region ranks second with 27 716 371 egg chickens, the Marmara region ranks third with 17 913 022 egg chickens. Southeastern Anatolia Region, on the other hand, ranks fifth after the Black Sea region. The number of egg chickens of the Southeastern Anatolia Region is 9 460 376 and this amount corresponds to 7.80% of the total Turkish laying hens. Egg chicken assets of regions are given in Table 2.

Table 2. Number of egg chickens in our country by region (TÜİK, 2020).

Regions	2016	2017	2018	2019	2020
Ege	37 810 995	42 480 554	44 347 679	40 252 430	41 672 296
İç Anadolu	28 497 501	33 336 682	31 614 893	28 896 627	27 716 371
Marmara	17 467 376	19 635 656	18 409 881	19 698 242	17 913 022
Karadeniz	10 709 014	10 595 347	12 979 551	13 641 838	12 993 846
Güneydoğu Anadolu	5 661 601	6 228 252	7 078 669	8 049 182	9 460 376
Akdeniz	4 934 571	5 171 318	5 363 182	5 322 126	6 593 781
Doğu Anadolu	3 608 178	4 108 218	4 260 955	4 864 854	4 953 177
Total	108 689 236	121 556 027	12 405 4810	120 725 299	121302 869

A study has been carried out to estimate egg production rate of Gaziantep province in 2018-2025 periods, as the city may symbolize the Southeastern Anatolia Region, by observing the egg production in recent years, by using data of 1991-2017 periods (Uzundumlu and Kurtoglu, 2020). It was concluded that Gaziantep province has cost advantages for reasons like suitable climatic conditions for egg poultry, having a well-developed feed industry and also not being close to the leading cities of egg production. Gaziantep province gradually increasing its share in egg production has four organic fertilizer plants which were established 2015-2019 years. This shows that it is thought that the number and capacity of these plants will increase with the growing production in the coming years Uzundumlu and Kurtoğlu (2020).

Aydın and Çelen (2017), reported that GAP (Southeastern Anatolian Project) provinces are in an extremely important position in the egg export of Turkey, to the northern part of Iraq, and almost all of the egg demand of the region is met from Turkey. Thus, there is a demand for enterprises that produce eggs at a level that can meet their egg needs.

With this study, a research was conducted on the technical structure of egg poultry in the Southeastern Anatolia Region. With this research, the general structure of the poultry in the region was tried to be determined by collecting the information of the egg poultry enterprises in the provinces of Gaziantep, Diyarbakır, Şanlıurfa, Batman, Adıyaman and Mardin.

MATERIALS AND METHODS

Within the scope of this study, it was aimed to reveal the technical structure, management characteristics, poultry characteristics, breeding and health-protection forms and problems of the egg poultry enterprises in the region.

The data on the technical, structural and improvement aspects of the poultry houses in the provinces where the study was conducted were determined by the survey study. Ethics Committee Approval Decision was taken in the study.

The southeastern Anatolia region is one of the seven geographical regions of Turkey and includes the provinces of Gaziantep, Diyarbakır, Şanlıurfa, Batman, Adıyaman, Siirt, Mardin, Kilis and Şırnak. The southeastern Anatolia region is surrounded by Eastern Anatolia region to the East and North, Mediterranean region to the west, Syria to the south and Iraq with a short border (Anonymous, 2021). The map of the Southeastern Anatolia Region where this study was carried out in is shown in Figure 1.

Figure 1. Southeastern Anatolia Region provinces map (HGM, 2021).

The number of large-capacity and closed-type structure egg chicken breeding enterprises in the provinces located in the Southeastern Anatolia Region is 52. The total capacity of these enterprises is 6.105.450. The enterprises where laying hens are raised in the Southeastern Anatolia Region and their capacities are given in Table 3.

Table 3. Number and capacity of egg chicken breeding enterprises (Anonymous, 2018; Anonymous, 2020).

Provinces	Number of enterprises	Capacity
Gaziantep	19	4 330 500
Mardin	7	1 008 700
Diyarbakır	11	254 900
Şanlıurfa	8	248 900
Batman	3	190000
Adıyaman	1	40 000
Kilis	1	30 000
Şırnak	2	2 450
Siirt	0	0
Total	52	6 105 450

In this study, the simple random sampling method was used to determine the number of questionnaires that were carried out under field conditions. In this method, for a finite population of size N, if we want to do sampling according to the known or predicted ratio (p) of those having a certain property, our sample volume formula is as follows:

$$n = \frac{Np(1-p)}{(N-1)\sigma_{p_x}^2 + p(1-p)} \qquad (1)$$

Here p is the population ratio of the feature we are working on. p can be derived from previous research or experience, or it can be predicted intuitively. To reach the maximum sample volume, it should be taken p=0.5. Less or higher values of p than 0.5 reduce the sample volume. Therefore, in the cases where p is not known, it can be suggested to take p=0.5, since working with maximum sample volume that will reduce the possible error. $\sigma_{p_x}^2$ is the variance of the ratio. Regardless of the actual rate, we might want this to extend the confidence interval at any desired probability level further by a certain r on either side of the sample rate. In this case, we can obtain the $\sigma_{p_x}^2$ parameter as follows:

$$Z_{\alpha/2}\sigma_p = r \qquad\qquad\qquad (2)$$

For 95% confidence interval and 0.20 margin of error of population ratio, $1,96\sigma_p = 0.20$, $\sigma_p = 0.10204$ (Miran, 2003).

When we apply the mentioned equation to the total number of enterprises (N) it will be conclude that 17 enterprises should be included in the study.

$$n = \frac{52(0.5)(0.5)}{(52-1)(0.10204)^2 + (0.5)(0.5)} \cong 17\ enterprices$$

Şırnak province, which has a very low production capacity, and Siirt province, where there are no enterprises, are not included in the survey studies we conducted within the scope of the studies. The survey studies were carried out in 7 provinces, namely Gaziantep, Mardin, Diyarbakır, Şanlıurfa, Batman, Adıyaman and Kilis.

RESULTS AND DISCUSSION

In the number of daily egg production, Gaziantep province ranks first with 1 490 000 eggs, and it alone meets 59.89% of the total daily egg production. The daily egg production of the province of Mardin, which ranks second, is 330 000 pieces, and its ratio in total egg production is 13.26%. The province of Diyarbakır, which is in the third place, has a daily egg production capacity of 288 000 pieces and its rate in the total production is 9.16%. The total egg production of the enterprises in Gaziantep, Mardin and Diyarbakır provinces meets 82.31% of the total egg production of the enterprises examined in the region. The distribution of the production capacities of the egg enterprises in the Southeastern Anatolia Region according to the enterprises and provinces is shown in Table 4.

Table 4. Daily total egg production of the enterprises

Provinces	Enterprise capacity (Daily egg production)					Total	Ratio in total business
	Enterprise 1.	Enterprise 2.	Enterprise 3.	Enterprise 4.	Enterprise 5.		
Gaziantep	160 000	180 000	1 000 000	60 000	90 000	1 490 000	59.89
Mardin	60 000	60 000	210 000	-	-	330 000	13.26
Diyarbakır	50 000	28 000	150 000	-	-	228 000	9.16
Batman	90 000	40 000	60 000	-	-	190 000	7.64
Şanlıurfa	180 000	-	-	-	-	180 000	7.23
Adıyaman	40 000	-	-	-	-	40 000	1.61
Kilis	30 000	-	-	-	-	30 000	1.21
					Total	2 488 000	100.00

It has been determined that all enterprises are doing cage-type breeding throughout the region. Apartment cage method is used in all egg production enterprises. Generally, cage floors are 4 or above. It has been determined that more than half of the cages found throughout the region are consist of 4 or 6 floors. The number of cage floors is less than 4 only in 1 enterprise in Diyarbakır. It has been determined that businesses with relatively newer technology have 6 floors cages. In the province of Mardin, which generally has newer enterprises, the number of cage floors of the poultry houses is 6, which is higher than those in other provinces. The type of cultivation, cage type and distribution of the cage floor in the enterprises are shown in Table 5. The set up stage of an additional cage in Mardin Province is shown in Figure 2.

Table 5. Type of cultivation, cage type and distribution of cage floor in enterprises.

Provinces	Cultivation style	Cage type	Cage floor			
	Cage	Apartment	<4	4	5	6
Gaziantep	5	5	-	3	1	1
Mardin	3	3	-	-	-	3
Diyarbakır	3	3	1	-	1	1
Batman	3	3	-	1	2	-
Şanlıurfa	1	1	-	1	-	-
Adıyaman	1	1	-	1	-	-
Kilis	1	1	-	1	-	-
Total	17	17	1	7	4	5

Figure 2. Set up stage of additional cage in Mardin province.

When the cage type in the enterprises examined, it was observed that the closed-type cage system was applied in 15 enterprises. In 2 enterprises, open-type cage system was preferred. When the egg poultry enterprises are evaluated according to the long axis directions of the coops, it has been determined that the houses in 9 enterprises are located in the north-south direction, and the houses in 8 enterprises are located in the east-west direction. The distribution of cage type and structure long axis direction of are given in Table 6.

Table 6. Distribution of cage type and structure long axis direction of enterprises.

Provinces	Cage type		Structure long axis direction	
	Open	Closed	East-West	North-South
Gaziantep	-	5	3	2
Mardin	-	3	-	3
Diyarbakır	-	3	1	2
Batman	2	1	2	1
Şanlıurfa	-	1	-	1
Adıyaman	-	1	1	-
Kilis	-	1	1	-
Total	2	15	8	9

When the average cage widths of cage systems in poultry enterprises are examined; cage widths were determined to vary between 12.0 m and 15.6 m in general. The average cage widths of the poultry houses in Şanlıurfa province are above the general average of the region and measured as 50.0 m. The distribution of average cage widths by enterprises is shown in Table 7.

Table 7. Distribution of average cage widths by enterprises.

Provinces	Poultry enterprises					Average cage widths (m)
	Enterprise 1.	Enterprise 2.	Enterprise 3.	Enterprise 4.	Enterprise 5.	
Gaziantep	12	12	20	12	12	13.6
Mardin	12	16	19	-	-	15.6
Diyarbakır	14	10	18	-	-	14.0
Batman	16	12	15	-	-	14.3
Şanlıurfa	50	-	-	-	-	50.0
Adıyaman	12	-	-	-	-	12.0
Kilis	12	-	-	-	-	12.0

When the average cage lengths of cage systems in poultry enterprises are examined, cage widths were determined to vary between 57.3 m and 100.0 m in general. Cage lengths of poultry houses in Şanlıurfa province are greater than cage lengths of poultry houses in other provinces, and average cage lengths were measured as 100.0 m. The distribution of average cage lengths by enterprises is shown in Table 8.

Table 8. Distribution of average cage lengths by enterprises.

Provinces	Poultry enterprises					Average cage lengths (m)
	Enterprise 1.	Enterprise 2.	Enterprise 3.	Enterprise 4.	Enterprise 5.	
Gaziantep	60	60	80	60	60	64.0
Mardin	90	90	100	-	-	93.3
Diyarbakır	57	60	55	-	-	57.3
Batman	70	50	60	-	-	60.0
Şanlıurfa	100	-	-	-	-	100.0
Adıyaman	60	-	-	-	-	60.0
Kilis	60	-	-	-	-	60.0

Roof insulation has been used in most of the egg production enterprises in the Southeastern Anatolia Region. While insulation was applied on the roofs in 15 of the coops in the enterprises examined in the region, it was determined that no insulation was applied on the roofs of the coops in 3 enterprises in Diyarbakır and Batman.

In most of the Southeastern Anatolia Region egg production enterprises, the roofing material is polyurethane panel (PU panel). Roof tile was used only in 1 enterprise in Batman, galvanized sheet in 2 enterprises and galvanized sheet roof cover material in was used 1 enterprise in Diyarbakır. Existence of roof insulation and type of roof covering material of enterprises are given in Table 9.

Table 9. Existence of roof insulation and roofing material of enterprises.

Provinces	Roof insulation		Roof material		
	Available	Not Available	Roof tile	Polyurethane panel	Other
Gaziantep	5	-	-	5	-
Mardin	3	-	-	3	-
Diyarbakır	2	1	-	2	1
Batman	1	2	1	-	2
Şanlıurfa	1	-	-	1	-
Adıyaman	1	-	-	1	-
Kilis	1	-	-	1	-
Total	14	3	1	13	3

It has been determined that the use of polyurethane panels as wall construction material is preferred in most of the poultry houses in the enterprises examined within the scope of field studies. While polyurethane panels were used in 11 (64.71%) of the existing poultry houses in the region, it was observed that briquettes were preferred as wall construction material in 6 (35.29%) poultry houses. Briquette is generally used as wall material in Batman and Diyarbakır. Approximately 1 meter of polyurethane panel wall building material were used in most of the enterprises in Gaziantep, Şanlıurfa, Mardin, and Adıyaman provinces. The distribution of the type of wall building material used by provinces is given in Table 10. Figure 3 shows the polyurethane panel wall building material in Mardin Province. Figure 4 shows briquette wall material used in Diyarbakır Province.

Table 10. Distribution of wall building material type.

Provinces	Wall building material	
	Briquette	Polyurethane panel
Gaziantep	-	5
Mardin	-	3
Diyarbakır	3	-
Batman	3	-
Şanlıurfa	-	1
Adıyaman	-	1
Kilis	-	1
Total	6	11

Figure 3. Polyurethane panel wall building material in Mardin province.

Figure 4. Briquette wall building material used in Diyarbakır province.

The average indoor temperature required for hen type Lohmann is between 18-22°C. There is a decrease in egg size, thinning in the shell, and a decrease in appetite in the temperature values after 22°C for the hen type Lohmann (Grashorn, 2016). When the temperature is low, the animal tries to warm up by consuming more feed to keep warm.

The Lohmann type is used in the vast majority of enterprises in the GAP region. Therefore, when looking at the values obtained from the enterprises, it has been determined that the average temperature values are between 18-22^{0}C. House temperatures are regularly checked to keep them at the same values. Therefore, the heading, the middle and the end of the house were controlled with at least 3 thermometers mounted 50 cm above the floor. Natural ventilation systems were used in poultry house along with fans located at the center and ends of the poultry houses. Besides, poultry houses of all enterprises were located in the direction of wind. The proper ventilation of the poultry house will remove the pollutant and poisonous gases from the house that is it another crucial point to be considered.

It has been determined that all enterprises in Mardin, Batman, Adıyaman and Kilis use Lohmann breeds. It has been determined that only 1 enterprise in Gaziantep and Diyarbakır and Şanlıurfa use supernick chicken. The reasons why the Lohmann breed is preferred in the Southeastern Anatolia Region are that it is an industrial breed, has an annual yield of 280-320 eggs, eats less feed and gives more eggs, in other words, its high profit rate. In addition, its high adaptation to the climatic conditions of the region is also an important factor (Gavril and Usturoi, 2012). In the Southeastern Anatolia Region, it has been observed that approximately 82.35% of the laying hen species preferred by egg enterprises are Lohmann and 17.65% supernick. Different animal genotypes used in enterprises are shown in Table 11.

Table 11. Animal genotype used in enterprises.

Province	Genotype of the animals	
	Lohmann	Supernick
Gaziantep	4	1
Mardin	3	-
Diyarbakır	2	1
Batman	3	-
Şanlıurfa	-	1
Adıyaman	1	-
Kilis	1	-
Total	14	3

While pullets and chicks are generally preferred in the egg production enterprises in the Southeastern Anatolia Region, some enterprises have preferred the 2nd egg laying period chickens. Large enterprises produce their own chicks. For example, some enterprises in Gaziantep have very large production enterprises. Some enterprises use pullets. Unlike chicks and pullets, in Batman province, large enterprises buy laying hens whose egg yield has decreased due to the lack of capital, that is, the 2nd laying period chickens, and produce eggs by forced moulting method. The distribution of animal material used in the enterprises according to the provinces is given in Table 12.

Table 12. Distribution of animal materials used in enterprises by provinces.

Provinces	Animal materials		
	Chicks	Pullets	2nd laying hens
Gaziantep	5	-	-
Mardin	-	3	-
Diyarbakır	-	3	-
Batman	-	1	2
Şanlıurfa	-	1	-
Adıyaman	1	-	-
Kilis	1	-	-
Total	7	8	2

Since 88.24% of the visited egg production enterprises use closed cage system, they deploy an average of 16 hours of lighting per day with artificial lighting. Differently, 50% of surrounding of the poultry house in 2 enterprise in Batman province are open windows. For this reason, these two enterprises in Batman make their lighting only with sunlight. Therefore, the duration of lighting is shorter than other enterprises. The average lighting duration of chicken coops in the enterprises in Batman is 10 hours.

When the average egg production time of the enterprises was evaluated, it was seen that the egg production times ranged between 8 and 17 months. While the lowest average egg production period was 8 months in Batman, the highest average egg production period was recorded in Diyarbakır with 17 months. Egg enterprises want to feed their chickens during the period when egg yield is high. It is desirable to dispose of chickens in periods when egg production is low. in Batman province, unlikely, due to lack of capital, 2 enterprises use the chicken of the second laying period and the egg yield period is nearly 50% less. Average egg production periods of the enterprises are presented in Table 13.

Table 13. Average egg production period of the enterprises.

Provinces	Average egg production period (months)
Gaziantep	15.0
Mardin	15.0
Diyarbakır	17.0
Batman	8.0
Şanlıurfa	16.0
Adıyaman	16.0
Kilis	16.0
Average	14.7

The egg production efficiency of each enterprise was changed according to reason such as the selection of chicken breed, the adaptation of the breed to the geographical conditions, the feeding patterns and facility conditions. It is an expected result that the yields of each egg facility in the Southeastern Anatolia region will differ. However, except for the two enterprises in Batman, the egg production yield of the region showed an almost homogeneous distribution. While the highest average egg yield was recorded in Gaziantep and Mardin with 85%, the lowest average egg production was recorded in Batman with 65%. Since the enterprises in Gaziantep and Mardin provinces have relatively newer and more modern technology, the egg yield of the poultry houses in these enterprises is higher than the enterprises in other provinces. Due to the lack of capital of two of the enterprises in Batman province, the second laying hens use the forced way method. For this reason, egg yields of poultry houses in this province remained at lower levels compared to other provinces. Average egg yields of poultry enterprises are shown in Table 14.

Table 14. Average egg yield of poultry houses in enterprises.

Provinces	Average egg yield (hen house^{-1})
Gaziantep	85%
Mardin	85%
Diyarbakır	75%
Batman	65%
Şanlıurfa	80%
Adıyaman	80%
Kilis	80%
Average	**79%**

Since the purpose of the egg production enterprises is to reach the highest efficiency, the necessary, protein, energy, vitamin, mineral and anticoccidial content of the feed ration during the spawning period should be controlled and balanced. Egg yield increases or decreases at the rate of adaptation to these factors. The spawning period consists of 3 different periods in itself. In accordance with these periods, the enterprises should prepare the chicken feed in a controlled manner. In other words, the chicken should be fed appropriately in according to lifecycles and their weights. In order to obtain the highest amounts of eggs, the appropriate daily feeding must be applied by taking into account the conditions.

The average daily feed consumption of the enterprises during the spawning period has remained quite close to each other throughout the region. Considering the average feed consumption of the provinces, it has been identified that the highest feed consumption rate is in the enterprises in Şanlıurfa and Mardin with 130 and 126 gr. It has been determined that the lowest average feed consumption is applied in the enterprises in Diyarbakır province. It has been determined that the average daily feed consumption of the enterprises in the whole region is 117 g. The daily feed consumption values of the spawning period of the enterprises are given in Table 15.

Table 15. Daily feed consumption during the spawning period.

Province	Daily feed consumption during the spawning period (g)					
	Enterprise 1.	Enterprise 2.	Enterprise 3.	Enterprise 4.	Enterprise 5.	Average
Gaziantep	115	110	110	105	110	110
Mardin	120	150	110	-	-	126
Diyarbakır	110	100	115	-	-	108
Batman	120	120	110	-	-	116
Şanlıurfa	130	-	-	-	-	130
Adıyaman	120	-	-	-	-	120
Kilis	110	-	-	-	-	110
Average						117

There are 3 different feeding periods in laying hens. The first period of these is 19-45 weekly feed time, second period covers the 46-65 weekly feed time, and the third period covers the 65 weekly feed time and after. Since egg yield decreases after 65th week and the cost increases, egg production enterprises usually apply 1st and 2nd feeding periods. However, some enterprises also provide 3rd period feeding. Two of the enterprises in Batman province use the laying hens in the 3rd laying period with the moulting method because of the lack of capital. Feeding periods applied in production are presented in Table 16.

Table 16. Feeding periods applied in feeding during the production period.

Province	Feeding periods	
	Period 1 or period 2	Period 3
Gaziantep	5	-
Mardin	3	-
Diyarbakır	3	-
Batman	1	2
Şanlıurfa	1	-
Adıyaman	1	-
Kilis	1	-
Total	15	2

When the enterprises are evaluated according to the cage disinfection method, it has been determined that all of the enterprises use disinfectants for the cleaning of the cages, and none of the enterprises applies calcification or burning.

It has been observed that all businesses in the region use disinfectant drugs in the disinfection process. Before the animals came to the egg production facilities, it was determined that while the coops were empty in the facility, every equipment in the coop and the coop itself was cleaned, disinfected with necessary medicines, and dried. In addition, all enterprises except only 1 Enterprise in Gaziantep subject their tools and equipment to disinfection with disinfectant drugs.

All businesses in the region apply combination vaccines. In egg production enterprises, vaccination is usually performed on the first day of the pullet or chicks. The vaccination schedule and application patterns vary according to the environment and house conditions. For this reason, the needed vaccines are made at the appropriate time in a controlled manner. Since it can be applied easily in egg enterprises located in the Southeastern Anatolia Region and does not cause stress in animals, the vaccination method with drinking water is preferred. The types and periods of vaccines used are not fixed. Plague, typhoid fever, mixed vaccines can be made according to the need for a single vaccine and period in the interviews with the employees of the enterprise.

However, all enterprises make an initial vaccine upon arrival of the animals. The vaccine programs applied are given in Table 17.

Table 17. Vaccine application program in enterprises.

Provinces	Vaccine program	
	Initial vaccine	4 months of lower
Gaziantep	5	5
Mardin	3	3
Diyarbakır	3	3
Batman	3	3
Şanlıurfa	1	1
Adıyaman	1	1
Kilis	1	1
Total	17	17

CONCLUSION

In this study, the technical structure, management characteristics, poultry characteristics, breeding and health-protection characteristics of the egg poultry enterprises in the provinces of Gaziantep, Mardin, Diyarbakır, Batman, Şanlıurfa, Adıyaman and Kilis in the Southeastern Anatolia Region were revealed.

It has been determined that all enterprises are doing cage-type breeding throughout the region. Apartment cage method is used in all egg production enterprises. It has been determined that more than half of the cages found throughout the region are 4 floors and the remaining ones consist of 6 floors. It has been determined that businesses with relatively newer technology have 6-storey cages.

Especially in Gaziantep, there are enterprises with very high capacity. These enterprises have increased the egg production capacity of the region. The total daily egg production capacity of the enterprises visited in the whole region has been determined as 2 488 000 eggs. 59.89% of this capacity is located in the province of Gaziantep. The egg production capacity of the region has increased by 160% in the last 2 years.

Roof insulation has been used in most of the egg production enterprises in the Southeastern Anatolia Region. Roof insulation is not available only in 3 enterprises, 1 in Diyarbakır and 2 in Batman. The roofing material in most of the coops is polyurethane panel. Roof tile was used only in 1 enterprise in Batman, galvanized sheet in 2 enterprises and galvanized sheet roof cover material in 1 enterprise in Diyarbakır and Batman.

In the Southeastern Anatolia Region, it has been observed that approximately 82.35% of the laying hen species preferred by egg enterprises are Lohmann and 17.65% supernick. While pullets and chicks are generally preferred, some enterprises have preferred the second laying hen.

Average egg yield of all enterprises in the region has been determined as 79%. Since the enterprises in Gaziantep and Mardin provinces have relatively newer and more modern technology, the egg yield of the poultry houses in these enterprises is higher than the enterprises in other provinces with 85%. It has been determined that the average daily feed consumption of the enterprises in the whole region is 117 g.

It has been observed that all enterprises in the region use disinfectant drugs in the disinfection process. All enterprises in the region apply combination vaccines. In egg production enterprises, vaccination is usually carried out on the first day of the pullet

or chicks. The vaccination schedule and application patterns vary according to the environment and house conditions.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Fadile Aydın: Writing of original manuscript draft, data collection, writing and editing of manuscript, investigation.

Mehmet Fatih Celen: Conceptualization, methodology, data analysis, validation, analysis.

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Research Article

Investigation of Some Physical Properties of Two Varieties of Sweet Potato (*Ipomoea batatas* (L.) Lam)

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ABSTRACT

Physical properties of agricultural materials are essential in the development of machineries, equipment and devices. In this research, forty sample each of two unique varieties namely Jewel-orange flesh sweet potatoes (JOFSP) and Oriental-purple flesh sweet potatoes (OPFSP) physical properties were determined using standard methods and equations. The results show that JOFSP gave the mean length (110.68±24.59 mm), width(61.40±8.09 mm), geometric mean (39.72±8.19 mm), volume (187.78±73.85 ml), surface area (4950.00±203.32 mm²) and roundness (1.81±0.50) which were of higher values compared to that of OPFSP which gave the length (68.46±10.16 mm), width (59.32±5.82 mm), geometric mean (36.32±3.90 mm), volume (137.83±10.97 ml), surface area (4320.20±98.00 mm²) and roundness (1.41±0.30) respectively. JOFSP gave moisture content, thickness, mass, sphericity and true density of 58.00±10.17 %, 37.60±7.17 mm, 202.87±65.12 g, 0.35±0.08, and 1.17±0.27 g cm⁻³ which were of lower values compared to that of OPFSP which gave 79.32±3.84 %, 45.94±9.04 mm, 271.87±15.72 g, 0.53±0.08, and 1.89±0.14 g cm⁻³ for OPFSP respectively. The mean of the angle of repose and the static coefficient of friction considered for the three-separate surfaces namely plywood (9.35±2.87°, 0.17±0.05), stainless steel (8.50±3.50°,0.15±0.05) and galvanized steel (8.30±3.20°) of lower values for JOFSP compared to that of plywood which gave (11.80±2.25°, 0.21±0.04), stainless steel (9.90±2.02°, 0.19±0.05), galvanized steel (10.90±2.28°) for OPFSP while the coefficient static of friction of stainless steel for JOFSP gave a higher value of 0.20±0.13 compared to that of 0.17±0.04 for OPFSP respectively. These findings provide engineers with valuable information for designing different handling, grading, and drying systems for industrial processing.

INTRODUCTION

Ipomoea batatas (sweet potato) is ranked amongst the root and underground stem crops of the flora and fauna, the seventh utmost precious sustenance produces, and following to cassava (Ray and Ravi, 2005). Bulkiness, storage problems, transportation, and fairly low-slung money worth for every piece of weight have led to an actual little level of significance in foreign jobs. According to Naskar *et al.* (2008), sweet potato is expected to lead in the fight against food shortages and the resultant malnutrition that may likely occur due to population explosion and the attendant over usage of land. In a unit area and in a unit duration, it can generate a high number of calories. Sweet potato efficiency of production of consumable energy is outstanding in the developing countries (Ramesh and Tomlins, 2010).

Fresh roots and tubers must be converted to non-perishable commodities through processing operations to reduce post-harvest losses (Oluwamukomi and Akinsola, 2015). According to Balami *et al.* (2012), the ever-growing significance of farming crops, along with the intricacy of recent expertise used intended for their making, handing out and storing, demands a clear understanding of their engineering possessions.

It is important to comprehend the physical regulations governing the reaction of farming crops consequently that equipment, methods and supervision processes can be strategic meant for optimum productivity in addition to the best standards of last harvests (Mohsenin, 2010). Over the years most agricultural produce has been underexploited in their region of production especially in unindustrialized nations. The various current sweet potato uses to make it important to evaluate the engineering properties of this highly valued agricultural commodity in order to carry out a more elaborate study to recognize and locate more areas of sweet potato value. The most important criteria for deciding the appropriate type of development of sorting, conveying, processing and packaging systems are the physical features of farming products, according to Tabatabaeefar and Rajabipour (2005).

Knowledge of engineering properties of food materials such as specific heat energy, density, thermal diffusivity, and thermal conductivity are relevant not only since they are significant, but because other properties and characteristics are the most common indicators (Oke *et al.,* 2007). Density, size, and drag coefficients all have a role in determining an object's terminal velocity in a fluid (Isik and Unal, 2007). According to Kachru et al. (1994), determining the physical properties of biomaterials (such as sweet potato) is critical for the right design of equipment for sweet potato handling, transporting, separation, drying, aeration, and mechanical expression. Textural measurement of unprocessed and processed food materials; reduction of mechanical damage to agricultural produce during postharvest handling, processing, and storage; and determination of design parameters for harvesting and postharvest systems are all goals of determining engineering properties of biomaterials under static or dynamic loading (Anazodo, 1983).

The scarcity or inaccessibility of sweet potato processing and preservation machinery and equipment may be attributable to the lack or inaccessibility of data on the engineering properties of sweet potatoes essential for machine development. The objective of the study was to determine the selected physical properties of two varieties of sweet potato that are considered to be critical in the development of devices, equipment and agricultural machinery for harvesting, handling, conveying, separation, processing, dehydration, size reduction and packaging.

MATERIALS AND METHODS

Two types of sweet potato (*Ipomoea batatas*) are the agricultural crops used to determine these physical properties: jewel-orange flesh and oriental-purple flesh. The specimens were obtained from Oja Oba market Akure, Ondo State. Forty (40) pieces from each of the two varieties were used for the experiment.

Determination of cassava tubers' physical properties

Sweet potato physical properties with Jewel's average moisture content of 58.00% (orange flesh) and 79.32% for Oriental (purple flesh) were determined as shown in Table 1.

Statistical analysis

Excel was used to compute the raw data and analyzed. Models were developed using Linear Regression. IBM SPSS (Statistical Package for Social Science) Windows Statistics, Version 21.0 was utilized to analyze the data produced from the analysis for specific physical properties (IBM SPSS, 2012).

Table 1. Determination of sweet potato physical properties.

Property	Method or equation for determining physical properties	Reference
MC	The moisture content of sample was determined by oven drying (100±2° C) method until constant weight was reached. $$MC\,(\%\ \text{wb}) = \frac{Wi - Wf}{Wi} \times 100$$	Kashaninejad *et al.* (2003)
L (mm)	Measuring tape	Olukunle and Akinnuli (2012)
W (mm)	Digital vernier caliper	Olukunle and Akinnuli (2012)
T (mm)	Measuring three different segments of the sweet potatoes using digital vernier caliper.	Olukunle and Akinnuli (2012)
D_g (mm)	$D_g = (LWT)^{1/3}$	Ozguven and Vursavus (2005) Akaaimo and Raji (2006)
S_a (mm²)	$S_a = \pi D_g{}^2$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
S_p (mm)	$S_p = \frac{(LWT)^{1/3}}{L} 100\%$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
R_o	$R_o = \frac{A_P}{A_C}$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
a (⁰)	The apparatus consisting of a plywood box with a fixed stand attached with a protractor and an adjustable plate at the surface. The sweet potatoes were placed on the adjustable surface and allowed to incline gradually in order for the tuber to follow and assume a natural slope.	Tabatabaeefar (2003)
μ (⁰)	$\mu = \tan \alpha$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
M (g)	A digital weighing balance of 10 kg was used in weighing each of the sweet potatoes.	Yalcin et al. (2007); Olukunle and Akinnuli (2012)
V_t (cm³)	By putting a known mass of a (unit) sample into a cylindrical container of water, a change in level of the liquid in the cylinder gives the unit volume.	Ozguven and Vursavus (2005)
ρ_t (g cm⁻³)	$\rho_t = \frac{W_t}{V_t}$	Akaaimo and Raji (2006); Yalcin *et al.* (2007)
ρ_b (g cm⁻³)	$\rho_b = \frac{W_s}{V_s}$	Akaaimo and Raji (2006), Yalcin *et al.* (2007), Zwedu and Solomon, (2007)
Ws (g)	By weighing together all the sweet potatoes in a bucket.	Olukunle and Akinnuli (2012)
vs (cm³)	The whole sample in a stand was put into the cylindrical container of water, and the change in level of the liquid in the cylinder	Ozguven and Vursavus (2005)
ε	$\varepsilon = (1 - \frac{\rho_b}{\rho_t}) \times 100$	Akaaimo and Raji (2006)

RESULTS AND DISCUSSION

The length, width, thickness and geometric mean diameter

The physical property outcomes are presented in Tables 2 and 3. The mean and standard deviation of the length (L), width (W), thickness (T) and geometric mean diameter (D_g) of Jewel and Oriental were found as 110.68±24.59 mm, 61.40±8.09 mm, 37.6±7.17 mm, 39.72±8.19 mm and 68.46±10.16 mm, 59.32±5.82 mm, 45.94±9.04 mm, 36.32±3.90 mm at the 58.00 % and 79.32 % moisture contents correspondingly. The mean length and width of the Jewel and Oriental varieties were marginally higher, while the small diameters were lower in the Norchip potato variety than what was observed by McClure and Morrow (1987). The width, thickness, and geometric mean diameter (size) were greater in Jewel than Oriental for these moisture contents. The main diameter (length) was, however, higher in Oriental than in Jewel. The maximum ratio is shown by L/T in Jewel, followed by L/W and L/D_g. The size values (D_g) are usually the lowest, followed by W and T in Jewel. A comparable pattern in groundnut Bambara was recorded by Baryeh (2001). L/W, however, indicates the highest ratio in Oriental, followed by L/T, and L/D_g suggests that D_g is usually the highest, followed by T and W in Oriental. Baryeh (2001) reported the ratio for Bambara groundnut which was lower than the ratios obtained from this study.

Mass of root

The average and standard deviations were 202.87±65.13 g and 272.91±14.51 g respectively for the unit root mass of Jewel and Oriental ipomoea batatas varieties respectively. The individual root masses are normally higher than the Jewel in the Oriental (Tables 2 and 3). Since the Oriental had a higher moisture content than Jewel's, this was not surprising. These variations may be due to the different configurations of cells and the fact that weight is influenced by moisture. It has been reported that the mass of cocoa bean increases as the moisture content increases (Bart-Plange and Baryeh, 2003).

Surface Area

Surface area of the Jewel ipomoea batatas variety was greater than that of the Oriental, showing a mean value of 4950.00±203.32 mm² to 4320.20±98.00 mm², respectively, as shown in Tables 2 and 3.

The bulk volume

The experimental bulk volume was found to be 7511 ml for Jewel and 5513 ml for the Oriental variety of sweet potato the standard volume of the roots. The Jewel and Oriental average volumes, which could be utilized in designing storage and packaging structures, are 187.78±73.85 ml and 137.83±39.32 ml, respectively (Tables 2 and 3). With a rise in moisture, the volume increased linearly. In equation 1, the relationship between the volumes and the content of moisture is presented. Obviously, the increase in volume is due to the rise in the moisture content.

$$V = 0.175MC + 3.905 \ (R^2 = 0.866) \tag{1}$$

The sphericity

Tables 2 and 3 revealed that the sphericity for jewel was 0.35±0.08 at an average moisture content of 58.00±10.17% moisture content while that of Oriental was 0.53±0.08 at 79.32±3.84% moisture content. The sphericity decreased as the moisture content decrease and increased as the moisture increases as shown in JOFSP with lower moisture content of content of 58.00±10.17 % and of OPFSP with higher moisture content of 79.32±3.84%. Deshpande et al. (1993) reported that as the moisture content increases the soybean sphericity also increases.

Table 2. Selected physical properties of Jewel-orange flesh sweet potato (JOFSP) samples.

S/N	Measured parameters	Unit	Maximum value	Minimum value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Moisture content	%	87.00	41.18	58.00	10.17	18
2	Length	mm	170.08	60.89	110.68	24.59	22.21
3	Width	mm	89.08	30.20	61.40	8.09	11.52
4	Thickness	mm	55.75	24.06	37.60	7.17	19.06
5	Geometric mean diameter	mm	52.75	25.59	39.72	8.19	20.61
6	Mass	g	371.00	80.00	202.87	65.13	32.10
7	Volume	ml	500.00	75.00	187.78	73.85	39.32
8	Spericity		0.57	0.24	0.35	0.08	196.00
9	True density	g cm^{-3}	1.89	0.74	1.17	0.27	23.07
10	Surface area	mm^2	8709.69	2215.36	4950.00	203.32	4.10
11	Roundness		2.90	1.07	1.81	0.50	27.62
12	Bulk volume	ml			7511.00		
13	Bulk mass	g			7333.74		
14	Bulk density	kgm^{-3}			114.90		
15	Porosity	%			0.9764		
16	500-Root weight	kg			202.80		

Table 3. Selected physical properties of oriental-purple flesh sweet potato (OPFSP) samples.

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Moisture content	%	82.29	66.70	79.32	3.84	5
2	Length	mm	88.60	54.26	68.46	10.16	14.84
3	Width	mm	82.28	29.00	59.32	5.82	12.91
4	Thickness	mm	60.00	25.10	45.94	9.04	19.67
5	Geometric mean diameter	mm	44.48	30.15	36.32	3.90	10.73
6	Mass	g	281.63	225.00	272.91	14.51	5.31
7	weight	g	281.90	225.00	271.87	15.72	6
8	Volume	ml	156.00	120.00	137.83	10.97	16.72
9	Sphericity		0.68	0.36	0.53	0.08	15.09
10	True density	g cm^{-3}	2.17	1.60	1.89	0.14	7.40
11	Surface area	mm^2	6663.5	2905.62	4320.20	98.00	22.68
12	Roundness		2.00	1.00	1.41	0.30	21.27
13	Bulk volume	ml			5513		
14	Bulk mass	g			5368.61		
15	Bulk density	kgm^{-3}			171.00		
16	Porosity	%			0.97381		
17	500-Root weight	kg			272.91		

The densities of the root and bulk

For Jewel and Oriental, the mean root densities were 1.17±0.27 g cm^{-3} and 1.89±0.14 g cm^{-3} at 58 and 80 percent moisture content, respectively. 114.9 kg m^{-3} and 171 kg m^{-3} were the corresponding bulk densities. The recorded densities of particles

and bulk suggested that the Oriental sweet potatoes were higher than that of Jewel. The values of bulk densities obtained conform with that of apple with a bulk density of 577 kg m^{-3} (Tables 2 and 3). An increase in moisture content from 58 percent in Jewel to 80 percent in Oriental led to increase in the densities. The true density increases as the moisture content increase but the moisture content had a little impact on the true density as indicated in Equation 2.

$$\rho_t = -0.004\ MC^2 + 0.051MC + 1.073 \tag{2}$$

Equation 3 showed that as the bulk density increases the moisture content increase but the moisture content had a little impact on the bulk density.

$$\rho_b = -0.005MC^2 + 0.069MC + 0.937, \qquad R^2 = 0.872 \tag{3}$$

Researchers had reported that the bulk densities of seeds such as Bambara groundnut, pumpkin and karinga increases as the moisture content increases. On the other hand, seeds like sunflower, cumin and soybeans densities decreases as the moisture content increase (Deshpande *et al.,* 1993; Joshi *et al.,* 1993; Singh and Goswami, 1996; Suthar and Das, 1996; Baryeh, 2001). The variations recorded as the moisture increases may be due to the composition of the cells and the features of different grains, roots, and seeds increasing in volume and mass.

Porosity
The porosity of Jewel sweet potato was 0.9764 while that of Oriental sweet potato was 0.97381 (Tables 2 and 3 respectively). Jewel porosity is significantly higher than Oriental porosity. This shows that from a moisture content of 58 percent in Oriental to 80 percent in Jewel, the porosity increased. The porosity values mean that the air spaces between the Oriental are greater than the Jewel variety when the roots of the two varieties are put in a jar. The documented values are consistent with the porosity of grains and seeds (wheat, sorghum, soybeans, and shelled maize) which had porosity ranging from 39-48% (Thompson and Isaac, 1967). The variation is not significant, as found in these grains and seeds.

The weight of the 500-root
Tables 2 and 3 showed that, for the Jewel and Oriental, the 500-Root weight was 202.80 kg and 272.91 kg respectively. On average, the Oriental variety's 500-tuber weight was heavier at 80% and 58% moisture content, respectively, than the Jewel variety. The Oriental had a larger amount of moisture than the Jewel. These variations may be due to the different configurations of cells and the fact that weight is influenced by moisture. Bart-Plange and Baryeh (2003) reported that the mass of cocoa bean increases as the moisture content increases.

The repose angle
In Jewel, the angle of repose was reported to be 9.35±2.87° (plywood), 8.50±3.50° (stainless steel), 8.30±3.20° (galvanized steel), and in Oriental 11.80±2.25° (plywood), 9.90±2.02° (stainless steel), 10.90±2.28° (galvanized steel) as reported in Tables 4 and 5 respectively. A low angle of repose allows the roots to spread broader on a flat surface related to a high angle of rest. A low angle of repose is usually chosen during belt conveying, whereas a high angle of repose is often chosen when unloading to a horizontal surface. This means that the Jewel sweet potato spreads wider than the

Oriental as it forms a natural heap. The resting angle of several grains rises from 19.80 at 5 percent moisture content to 23.50 at 20 percent grain moisture content and then decreases gently to 210 at 35 percent moisture content ([Baryeh, 2001](#)). The small change in the root angle of repose may be due to the variations in the surface roughness of the two sweet potato types.

Table 4. Angle of repose of Jewel-orange flesh sweet potato (JOFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood	$(^0)$	16	6	9.35	2.87	31
2	Stainless Steel	$(^0)$	15	3	8.5	3.50	41
3	Galvanized Steel	$(^0)$	15	5	8.3	3.20	39

Table 5. Angle of repose of oriental-purple flesh sweet potato (OPFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood	$(^0)$	15	9	11.80	2.25	19
2	Stainless Steel	$(^0)$	13	7	9.90	2.02	20
3	Galvanized Steel	$(^0)$	15	8	10.9	2.28	21

The friction coefficient

The static coefficient of friction of the moisture content considered for the three separate structural surfaces of plywood, stainless steel, and galvanized steel gave 0.21±0.04, 0.17±0.04, 0.19±0.05 for Oriental and 0.17±0.05, 0.20±0.04, 0.15±0.04 for Jewel as reported in Tables 6 and 7 respectively. For plywood and galvanized steel, the coefficient of friction values was more in Oriental but less for stainless steel in Jewel. The highest was recorded by plywood. This pattern could be ascribed to the purity of the materials and the better polished surface. As they slip on them, the roots may also stick to certain surfaces. Various researchers had reported that the coefficient of friction on plywood was greater than of galvanized iron for millet and guna seeds ([Aviara *et al.,* 1999](#); [Baryeh, 2000](#)). To improve the discharging process, however, discharging requires less friction. This is helpful in determining the sieve hole's diameter.

Table 6. The coefficient of friction of Jewel-orange flesh sweet potato (JOFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood		0.29	0.11	0.17	0.05	32
2	Stainless Steel		0.52	0.08	0.20	0.13	64
3	Galvanized Steel		0.27	0.09	0.15	0.06	40

Table 7. The coefficient of friction of oriental-purple flesh sweet potato (OPFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood		0.27	0.16	0.21	0.04	20
2	Stainless Steel		0.23	0.12	0.17	0.04	21
3	Galvanized Steel		0.27	0.11	0.19	0.05	26

CONCLUSION

At 79.32 percent and 58 percent moisture content, the physical properties of Jewel-orange fleshed sweet potato and Oriental-purple fleshed sweet potato were determined.

The selected engineering properties are critical factors that will determine the efficiency of any device, equipment and machinery used for harvesting, sorting, handling, processing and packaging sweet potatoes. The data collected is needed for the design and manufacture of sweet potato harvesting, handling, processing equipment, storage devices and machineries.

DECLARATION OF COMPETING INTEREST

The author(s) must declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Olufemi Adeyemi Adetola: Planning, perform the statistical analysis, manage the analyses of the study, manage the literature searches, draft of the manuscript, and approve the final manuscript.

Oluwatusin Seun Adeniyi: Planning, perform the statistical analysis, manage the analyses of the study, manage the literature searches, and approve the final manuscript.

Deji Lawrence Akindahunsi: Planning, perform statistical analysis, manage the analyses of the study, manage the literature searches, and approve the final manuscript.

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Review Article

Important Fungal Diseases in Medicinal and Aromatic Plants and Their Control

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ABSTRACT

Aromatic plants constitute the main raw materials of the perfumery, food and cosmetics industry and in recent years with the increasing demand for therapeutic herbal medicines, interest in medicinal and aromatic plants has increased. Raw materials from medicinal and aromatic plants have recently begun to be used and spread in the food sector, especially in industrial sectors such as paint and perfumery. For this reason, growing healthy plant material is very important in terms of the protection of these crops. However, fungal diseases such as root rot, wilt, leaf spots, blight and anthracnose, which are problems during the cultivation of both medicinal and aromatic plants, negatively affect both the quantity and quality of these plants. For this reason, an integrated management practices including cultural measures, herbal products, biological control and, if necessary, chemical control methods with especially these fungal diseases are very important. In this review, 27 medicinal and aromatic plants, 37 fungal diseases, their chemical and biological control were included, and 161 references were used.
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INTRODUCTION

The term '*Herbal treatment*' has been used in many different countries with many names such as traditional therapy, complementary therapy, or natural therapy. The first records about herbal therapy were found in the Mesopotamian civilization in 5000 BC and it was determined that 250 herbal drugs; obtained from medicinal and aromatic plants as usually dried and sometimes fresh, whole, shredded or cut plant or plant parts were used (Demirezer, 2010). According to the World Health Organization (WHO), traditional medicine is used in the prevention of physical and mental diseases, diagnosis, healing, or treatment as well as maintaining good health. In addition, it is the whole of knowledge, skills and practices that can or cannot be explained based on theories, beliefs, and experiences specific to different cultures (WHO, 2017).

The therapeutic use of plants varies according to the development level of the countries. In developing countries, 80% of the population benefits from herbal products for therapeutic purposes. While this rate reaches up to 95% in some countries of Asia, Africa, and the Middle East, it is less in developed countries (40-50% in Germany, 42% in the USA, 48% in Australia, and 49% in France). However, the most important trade centres for medicinal plants are in Germany, USA, Japan, and England (Titz, 2004). World Health Organization predicts that the treatment with herbs will increase all over the world in the coming years.

According to the World Health Organization, 25% of the pharmaceutical drugs used today are manufactured from medicinal plants and 30% of drugs sold worldwide contain compounds derived from plant materials (FAO, 2005).

The use of herbal medicine in countries that apply traditional medical treatment varies according to the recommendations of the people practicing traditional/alternative medicine or their own experience. Also, in some countries, training is provided at universities related to complementary medicine. For example, in the universities of many countries in the Economic Community of West African States, such as Democratic Republic of Congo, South Africa and Tanzania there are complementary medicine courses in the curricula of pharmacy and medical studies (WHO, 2014). Complementary medicine is seen as a primary health care service in some African countries. For example, the ratio of traditional healers to the population in Africa is 1/40.000, while the ratio of medical doctors is 1/500 (Abdullahi, 2011).

Medicinal and aromatic plants are plants that have many uses such as food, medicine, cosmetics and spices and are known to have been used for similar purposes since the beginning of human history. While some of these plants are collected from nature, some of them have been cultivated and produced. However, most of the herbs used for therapeutic purposes are collected from nature. The most prominent and researched properties of medicinal and aromatic plants are their therapeutic uses (Kumar, 2014). Extracts of these plants in water or alcohol are also applied against pests and plant diseases due to their biological effects (Isman, 2000; Bakkali *et al.,* 2008). The aromatic parts of aromatic plants are used to extract therapeutic oils/essential oils containing allelochemical aroma of economic value (Nagpal and Karki, 2004).

More than 6 000 medicinal plant species have been identified from different tropical regions (Khare, 2008), more than 1 000 of them are classified as aromatic (Panda, 2015). Climate changes, intensive cultivation practices and market-oriented crop management have led to an increase in pests and diseases. These problems in medicinal and aromatic products have gradually increased (Sharma, 2013; Sharma *et al.,* 2014). Damages caused by pests or diseases can reduce their biomass and oil content (Gupta *et al.,* 2000; Zadotani and Ikegami, 2002). Besides changing climatic conditions, the indiscriminate and unplanned large-scale cultivation of medicinal and aromatic plants to meet the increasing demand of the pharmaceutical industries is leading to increased incidence and severity of diseases.

Losses caused by plant diseases not only reduce the yield of plant secondary metabolites but also reduce the quality of raw materials (Singh *et al.,* 2016).

In this review, fungal diseases causing an infection on medicinal and aromatic plants, grown or cultured spontaneously and reducing plant quality and yield and even causing death, their symptoms and methods of controlling them are included.

In this context, diseases and management of important medicinal and aromatic plants listed in Table 1 and reported from Turkey and the world were presented.

Lavandula spp. (Lavender), *Humulus lupulus* L. (Hops), *Papaver somniferum* L. (Poppy), *Rosa* spp. (Rose), *Salvia officinalis* L. (Sage), *Origanum* spp. (Oregano), *Carthamus tinctorius* L. (Safflower), *Dianthus caryophyllus* L. (Clove), *Sesamum indicum* Linn. (Sesame), *Pimpinella anisum* L. (Anise), *Asparagus* spp. (Asparagus fern), *Rosmarinus officinalis* L. (=*Salvia rosmarinus*) (Rosemary), *Mentha piperita* L. (Mint), *Aloe vera* L. Burm. (=*Aloe barbadensis* Mill.), *Withania somnifera* (L.) Dunal (Indian Ginseng-Poisonous Gooseberry-Winter Cherry), *Rauwolfia serpentina* (L.) Benth. ex Kurz (Snakeroot) (Serpentine/Sarpagandha), *Ocimum sanctum* L. (=*Ocimum tenuiflorum* L.) (Holy Basil, Tulsi), *Coleus forskohlii* Briq (Coleus flower, *Chlorophytum borivilianum* Santapau & Fernandez (Musli), *Hyoscyamus* spp. (Henbane), *Plantago ovata* Forssk. (Psyllium Blond), *Catharanthus roseus* (L.) G. Don (Pink periwinkle), *Pogostemon cablin* (Blanco) Benth. (Patchouli), *Zingiber officinale* Roscoe (Ginger), *Vetiveria zizanioides* (L.) Nash (Vetiver), *Santalum* spp. (Sandalwood) and *Cymbopogon citratus* Stapf. (Lemon grass). Fungal disease agents that cause leaf spots, blight, rust, powdery mildew, root rot, damping-off and dieback frequently occur in these medicinal and aromatic plants (Avan, 2021).

OCCURRENCE OF FUNGAL DISEASES

The cultivation of medicinal and aromatic plants has increased considerably in recent years due to their huge worldwide demands on plant-based medicines and aromatic compounds. These plants are affected by various diseases caused by fungi, bacteria, viruses and phytoplasmas. Among these diseases, especially fungal diseases are very important (Table 1).

Fungi infect leaves, stems and underground parts of medicinal and aromatic plants. Among these fungal diseases, Powdery mildew appears on the leaves and fresh stems, and as the disease progresses, it covers the entire developing surface of the plant. Rust diseases are airborne diseases that infect leaves, branches and fruits and cause pustules on leaves. Leaf spots and blights cause dead areas on the leaves with distinct spots over time, and in this way, they are separated from healthy tissues (Bhandari *et al.*, 2014). Blights appear on the leaves, twigs or blossoms of the plant and cause sudden death of the plant (Sattar *et al.*, 2006; Ramappa and Shivanna, 2013). Medicinal and aromatic plants are also highly affected by root rot, wilt, anthracnose and dieback caused by fungi and bacteria. These diseases manifest themselves with hard, dry, spongy, soft, watery or slimy-looking rotten tissues in plants (Singh *et al.*, 2016).

Table 1. Important fungal diseases of medicinal and aromatic plants.

DISEASES	PLANTS	CAUSAL ORGANISMS	SYMPTOMS
Rusts	*Aloe vera*	*Phakopsora pachyrhizi, Uromyces aloes*	Yellowish red spots appear on the lower surface of the leaf and rust pustules form in these spots (Jones, 1972; Koike *et al.*, 1998; Kalra *et al.*, 2005; Saber *et al.*, 2009; Soni *et al.*, 2011; Afshan *et al.*, 2012).
	Asparagus spp. (Asparagus fern)	*Puccinia asparagi*	
	Cymbopogon citratus (Lemon grass)	*Puccinia nakanishikii*	
	Mentha spp. (Mint)	*Puccinia menthae*	

	Pelargonium spp. (Geranium)	*Puccinia pelargonii-zonalis*	
	Pimpinella anisum (Anise)	*Puccinia pimpinellae*	
	Rosa spp. (Rose)	*Caeoma* spp.	
	Dianthus caryophyllus (Clove)	*Uromyces dianthi*	
	Origanum vulgare (Oregano)	*Puccinia menthae*	
Downy Mildews	*Coleus forskohlii* (Coleus flower)	*Peronospora belbahrii, P. lamii*	Yellow to light brown necrotic lesions, folds, and kinks occur on the leaves (Sain and Sharma, 1999; Garibaldi *et al.*, 2004; Landa *et al.*, 2005; Humphreys-Jones *et al.*, 2008; López-Guisa *et al.*, 2013).
	Ocimum sanctum (Holy Basil, Tulsi)	*Peronospora belbahrii*	
	Plantago ovata (Psyllium Blond)	*Peronospora plantaginis*	
	Humulus lupulus (Hops)	*Pseudoperonospora humuli*	
	Papaver somniferum (Poppy)	*Peronospora* spp.	
	Rosa spp. (Rose)	*Peronospora sparsa*	
	Rosmarinus officinalis (Rosemary)	*Peronospora lamii*	
Powdery Mildew	*Mentha* spp. (Mint)	*Erysiphe cichoracearum*	Chlorotic spots and brownish discolorations in the form of powder appear on the leaf surface. The disease causes the leaves to curl and the bend to stem (Valiyeva *et al.*, 2004; Kalra *et al.*, 2005; Humphreys-Jones *et al.*, 2008; Thines *et al.*, 2009; Baradaran *et al.*, 2012; Venegas-Portilla *et al.*, 2020).
	Cymbopogon citratus (Lemon grass)	*Erysiphe graminis*	
	Humulus lupulus (Hops)	*Podosphaera macularis*	
	Rosa damascena (Damask rose)	*Podosphaera pannosa*	
	Salvia officinalis (Sage)	*Golovinomyces neosalviae* *Peronospora lamii*	
	Rosa spp. (Rose)	*Sphaerotheca pannosa* var. *rosae*	
***Alternaria* Leaf Spots**	*Aloe vera*	*Alternaria alternata* *A. brassicae*	Dark brown circular spots occur on infected leaves (Xiaoyin, 1982; Kumar et al., 1984; Kishore *et al.*, 1985; Kalra *et al.*, 2005; Taba *et al.*, 2009; Garibaldi *et al.*, 2011; Zimowska, 2015).
	Withania somnifera (Indian Ginseng)	*Alternaria alternata, A. tenuis*	
	Mentha spp. (Mint)	*Alternaria alternata*	
	Pelargonium spp. (Geranium)	*Alternaria alternata*	
	Salvia officinalis (Sage)	*Alternaria alternata*	
	Ocimum basilicum (Sweet Basil)	*Alternaria alternata*	
	Hyoscyamus spp. (Henbane)	*Alternaria alternata*	
	Carthamus tintorius (Safflower)	*Alternaria carthami*	
	Papaver somniferum (Poppy)	*Alternaria alternata*	
	Dianthus caryophyllus (Clove)	*Alternaria dianthi*	
	Origanum vulgare (Oregano)	*Alternaria alternata*	

Cercospora Leaf Spots	*Ocimum sanctum* (Holy Basil- Tulsi)	*Cercospora ocimicola*	Necrotic spots with dark brown edges are scattered on the leaves (Bubak, 1906; Enikuomehin, 2006; Bhandari *et al.,* 2014).
	Rauwolfia serpentina (Snakeroot)	*Cercospora rauvolfiae, Cercospora serpitinae*	
	Emblica officinalis (Indian Gooseberry)	*Cercospora* spp.	
	Sesamum indicum (Sesame)	*Cercospora sesami*	
	Pimpinella anisum (Anise)	*Cercospora malkoffii*	
Colletotrichum Leaf Spots	*Ocimum sanctum* (Holy Basil- Tulsi)	*Colleotrichum gleosporioides, C. capsica*	Reddish brown circular spots appear on the leaves first. Holes and premature drying occur in the leaves due to the rupture of the infected tissue (Tekade *et al.,* 2009; Gautam, 2014; Zimowska, 2015).
	Withania somnifera (Indian Ginseng)	*Colletotrichum gloeosporioides, C. dematium*	
	Pelargonium spp. (Geranium)	*C. gloeosporoides*	
	Origanum vulgare (Oregano)	*Colletotrichum fuscum*	
Corynespora Leaf Spot	*Coleus forskohlii* (Coleus flower)	*Corynespora cassiicola*	Yellowish-brown necrotic spots in the form of chlorotic halo occur on the leaves (Shukla *et al.,* 2000; Garibaldi *et al.,* 2007).
	Rauwolfia serpentina (Snakeroot)	*C. cassiicola*	
	Mentha arvensis (Menthol mint)	*C. cassiicola*	
	Ocimum basilicum (Sweet Basil)	*C. cassiicola*	
Curvularia Leaf Spots	*Cymbopogon citratus, C. flexuosus* (Lemon grass)	*Curvularia andropogonis,*	Small oval and long dark brown necrotic lesions appear on the leaves (Thaung, 2008; Bhagat *et al.,* 2014).
	Mentha spp. (Mint)	*C. lunata,*	
	Rauwolfia serpentina (Snakeroot)	*C. trifolii*	
Diplocarpon Leaf Spot	*Rosa chinensis* (China rose), *Rosa damascena* (Isparta rose)	*Diplocarpon rosae*	Brown to black spots with dark purplish margins occur on the upper surface of the leaves (Margina and Zheljazkov, 1995a).
Macrophomina Leaf Spot	*Chlorophytum borivilianum* (Musli)	*Macrophomina phaseolina*	Small water-soaked lesions are formed surrounded by a dark brown border on the leaves (Dadwal and Bhartiya, 2012).
Myrothecium Leaf Spot	*Withania somnifera* (Indian Ginseng)	*Myrothecium roridum*	Small, dull yellow, brown coloured water-soaked spots appear on the leaves (Shivanna *et al.,* 2014).
Stemphylum Leaf Spots	*Asparagus* spp. (Asparagus fern)	*Stemphylium vesicarium*	Light brown, large elliptical spots occur on the stem and branches, the lesions on the stems merge into large areas of infected tissue (Falloon and Tate, 1986; Zimowska, 2015).
	Origanum vulgare (Oregano)	*Stemphylium botryosum*	
Phoma Leaf Spot	*Origanum vulgare* (Oregano)	*Phoma herbarum*	The agent causes angular spots on the leaves. (Basavand *et al.,* 2020).
Alternaria Leaf Blights	*Chlorophytum borivilianum* (Musli)	*Alternaria alternata*	Brown necrotic irregular lesions and surrounding

	Rauwolfia serpentina (Snakeroot)	*Alternaria tenuis,* *A. alternata*	chlorotic halos occur on the leaves (Rai and Tetrawal, 2010; Thakur and Harsh, 2014).
	Mentha spp. (Mint)	*Alternaria alternata*	
	Pelargonium spp. (Geranium)	*Alternaria alternata*	
	Withania somnifera (Indian Ginseng)	*Alternaria tenuis,* *A. alternata*	
	Plantago ovata (Psyllium Blond)	*Alternaria alternata*	
Colletotrichum Leaf Blights	*Chlorophytum borivilianum* (Musli)	*Colletotrichum dematium,* *C. capsici*	Small chlorotic spots appear on the lower leaves, which rapidly expand and merge into brown spots (Sattar *et al.,* 2006; Ramappa and Shivanna, 2013).
	Rauwolfia serpentina (Snakeroot)	*Colletotrichum dematium,* *C. capsici*	
	Cymbopogon citratus (Lemon grass)	*Colletotrichum caudatum*	
Curvularia Leaf Blights	*Cymbopogon citratus* (Lemon grass)	*Curvularia trifolii*	Long, reddish-brown necrotic lesions occur on the leaves (Alam *et al.,* 1983; Sato and Ohkubo, 1990).
	Cymbopogon nardus (Lemon grass)	*Curvularia andropogonis*	
	Vetiveria zizanioides (Vetiver)	*Curvularia trifolii*	
Macrophomina Leaf Blights	*Chlorophytum borivilianum* (Musli)	*Macrophomina phaseolina*	Necrotic lesions appear on the edges and tips of infected leaves (Maiti and Geetha, 2013; Meena and Kadam, 2021).
	Rauwolfia serpentina (Snakeroot)	*Macrophomina phaseolina*	
Sclerotinia Blights	*Mentha* spp. (Nane)	*Sclerotinia sclerotiorum*	The first symptoms are necrosis of the stem, darkening and wilting of the leaves. Then cottony soft rots occur (Garibaldi *et al.,* 2013).
Rhizoctonia Leaf Blights	*Coleus forskohlii* (Coleus flower)	*Rhizoctonia solani*	Water-soaked irregular spots spreading inward from the leaf edge are formed (Mehrotra and Thapar, 1990; Shukla *et al.,* 1993; Kalra *et al.,* 2005; Sato *et al.,* 2010; Aktaruzzaman *et al.,* 2015).
	Mentha spp. (Mint)	*Rhizoctonia solani*	
	Rauwolfia serpentina (Snakeroot)	*Rhizoctonia solani*	
	Rosmarinus officinalis (Rosemary)	*Rhizoctonia solani*	
	Origanum vulgare (Oregano)	*Rhizoctonia solani*	
Botrytis Leaf Blights	*Pelargonium* spp. (Geranium)	*Botrytis cinerea*	Concentric ring lesions on leaves, wilting and drying of flowers appeared (Kalra *et al.,* 2008; Vinodkumar and Nakkeeran, 2017).
	Rosa chinensis, (China rose) *Rosa damascena* (Isparta rose)	*Botrytis cinerea*	
	Dianthus caryophyllus (Clove)	*Botrytis cinerea*	
Passalora Blight	*Pimpinella anisum* (Anise)	*Passalora malkoffii*	The disease causes lesions and drying on all above-ground parts of plants, including inflorescences (Erzurum *et al.,* 2005)
Phoma Leaf Blight	*Origanum vulgare* (Oregano)	*Phoma multirostrata var. macrospora*	Small, black spots are observed on the top and bottom of the infected leaves and on

			young shoots depending on the humidity (Garibaldi *et al.,* 2015b)
Anthracnoses	*Aloe vera*	*Colletotrichum gloeosporioides*	Small necrotic spots on the leaves turn into typical anthracnose lesions as the disease progresses (Sattar *et al.,* 2002; Singh *et al.,* 2004; Ayvar-Serna *et al.,* 2020)
	Rauwolfia serpentina (Snakeroot)	*Colletotrichum gleosporioides*	
	Emblica officinalis (Indian Gooseberry)	*Colletotrichum gloeosporioides*	
	Mentha spp. (Nane)	*Sphaceloma menthae*	
	Salvia officinalis (Sage)	*Colletotrichum dematium*	
	Origanum vulgare (Oregano)	*Colletotrichum tropicale*	
Diebacks	*Rauwolfia serpentina* (Snakeroot)	*Colletotrichum dematium*	Fading and drying appears in the tip buds of young branches. (Kulkarni and Ravindra, 1988; Kulkarni *et al.,* 1992).
	Catharanthus roseus (Pink Periwinkle)	*Pythium aphanidermatum*	
Collar Rots	*Cymbopogon citratus* (Lemon grass)	*Fusarium moniliforme*	Chlorosis on the lower leaves and small brown necrotic lesions in the collar area of the plant occurs (Singh *et al.,* 2001; Trivedi *et al.,* 2006).
	Mentha spp. (Mint)	*Sclerotium rolfsii*	
	Pogostemon cablin (Patchouli)	*Fusarium oxysporum, Rhizoctonia solani*	
	Chlorophytum borivilianum (Musli)	*Corticium rolfsii*	
Fruit Rots	*Rauwolfia serpentina* (Snakeroot)	*Rhizopus stolonifer*	Wet rots appear on the fruit (Shukla *et al.,* 2006; Singh *et al.,* 2011).
	Withania somnifera (Indian Ginseng)	*Myrothecium* sp.	
	Emblica officinalis (Indian Gooseberry)	*Phomopsis phyllanthi*	
Leaf Rots	*Aloe vera*	*Sclerotium rolfsii, Colletotrichum dematium, Phoma* sp., *Rhizoctonia bataticola*	Water-soaked spots occur on the leaves (Shukla *et al.,* 1981).
Rhizome Rot	*Zingiber officinale* (Ginger)	*Pythium aphanidermatum*	Hard or spongy yellowish brown to brown tissues formations appear (Stirling *et al.,* 2009).
Stolon Rots	*Mentha* spp. (Mint)	*Macrophomina phaseoli, Rhizoctonia solani, R. bataticola, Thielavia basicola*	The agent typically causes fading in the stolons and rot in later stages (Kalra *et al.,* 2008).
Root Rots	*Aloe vera*	*Fusarium oxysporum Phytophthora* spp., *Pythium* spp.	With the wilting of the plants, yellowing of the leaves, falling and white cotton-like mycelium growth in the collar area appear (Subbiah *et al.,* 1996; Boby and Bagyaraj, 2003; Kamalakannan *et al.,* 2006; Zimowska, 2008; Martini *et al.,* 2009; Govindappa *et al.,* 2010; Ziedan *et al.,* 2010; Zimowska, 2015; Ağaner and Cere, 2017).
	Asparagus spp. (Asparagus fern)	*Fusarium oxysporum* f.sp. *asparagi, F. proliferatum, F. moniliforme, F. solani, F. redolens, Phytophthora asparagi, Phytophthora megasperma* var. *sojae, Phytophthora* spp., *Rhizoctonia solani*	

	Origanum spp. (Oregano)	*R. solani,* *M. phaseolina*	
	Chlorophytum borivilianum (Musli)	*Rhizoctonia bataticola,* *Fusarium solani*	
	Coleus forskohlii (Coleus flower)	*Fusarium chlamydosporum,* *F. solani,* *Macrophomina phaseolina,* *Ralstonia solanacearum*	
	Ocimum sanctum (Holy Basil- Tulsi)	*Rhizoctonia solani,* *Pythium* spp.	
	Rauwolfia serpentina (Snakeroot)	*Macrophomina phaseolina*	
	Pelargonium spp. (Geranium)	*Rhizoctonia solani,* *Macrophomina phaseolina* *Pythium sp.*	
	Rosa chinensis (China rose), *Rosa damascena* (Isparta rose)	*Phytophthora* spp., *Alternaria* spp., *Rhizoctonia* spp., *Sclerotinia* spp., *Pythium* spp.	
	Salvia officinalis (Sage)	*Phytophthora cryptogea,* *Rhizoctonia solani,* *Fusarium* spp., *Fusarium oxysporum,* *Phoma exigua* var. *exigua*	
	Lavandula spp. (Lavender)	*Phytophthora nicotianae,* *P. palmivora,* *P. cinnamomi,* *P. cactorum*	
	Carthamus tinctorius (Safflower)	*Macrophomina phaseolina*	
	Sesamum indicum (Sesame)	*Macrophomina phaseolina*	
	Origanum vulgare (Oregano)	*Phytophthora tentaculata*	
	Origanum dubium (Oregano)	*Boeremia exigua var. exigua,* *Rhizoctonia solani,* *Fusarium* spp.	
Stem Rots	*Asparagus* spp. (Asparagus fern)	*Fusarium oxysporum* f.sp. *asparagi,* *F. proliferatum,* *F. moniliforme,* *F. solani,* *F. redolens*	Pale green water-soaked lesions appear. The fleshy tissue becomes weak and the water in the tissue comes out quickly, a slight odor is felt and this part turns brown ([Trujillo *et al.*, 1988](#); [Burns and Benson, 2000](#); [Elena, 2006](#); [Oogi *et al.,* 2009](#); [Martini *et al.,* 2009](#); [Zimowska, 2015](#); [Samouel *et al.,* 2016](#))
	Lavandula spp. (Lavender)	*Phytophthora nicotianae,* *P. palmivora,* *P. cinnamomi,* *P. cactorum*	
	Salvia officinalis (Sage)	*Phomopsis sclarea*	
	Rosmarinus officinalis (Rosemary)	*Sclerotinia sclerotiorum*	
	Dianthus caryophyllus (Clove)	*Rhizoctonia solani*	
	Origanum vulgare (Oregano)	*Phytophthora tentaculata*	

	Origanum dubium (Oregano)	*Boeremia exigua* var. *exigua*, *Rhizoctonia solani*, *Fusarium* spp.	
Crown Rots	*Asparagus* spp. (Asparagus fern)	*Phytophthora asparagi*, *Phytophthora megasperma* var. *sojae*, *Phytophthora spp.*	Infected crowns first turn yellowish orange and as the disease progresses, rots appear (Garibaldi *et al.,* 2015a; Mondal *et al.,* 2018).
	Rosa chinensis (China rose), *Rosa damascena* (Isparta rose)	*Phytophthora* spp., *Alternaria* spp., *Rhizoctonia* spp.*, Sclerotina* spp., *Pythium* spp.	
	Papaver somniferum (Poppy)	*Pleospora papaveracea*	
	Salvia officinalis (Sage)	*Phytophthora cryptogea*	
Wilts	*Coleus forskohlii* (Coleus flower)	*Ralstonia solanacearum*	With the fading and falling of the plants, cottony growths appear around the main root. (Nelson *et al.,* 1960; Gupta *et al.,* 2004; Dung *et al.,* 2010; Ziedan *et al.,* 2010).
	Ocimum sanctum (Holy Basil- Tulsi)	*Fusarium oxysporum* f. sp. *basilicum*	
	Withania somnifera (Indian Ginseng)	*Fusarium solani*	
	Emblica officinalis (Indian Gooseberry)	*Fusarium* sp.	
	Vetiveria zizanioides (Vetiver)	*Fusarium* sp.	
	Plantago ovata (Psyllium Blond)	*Fusarium oxysporum*, *F. solani*	
	Mentha spp. (Mint)	*Verticillium alba-atrum* var. *menthae*	
	Pelargonium spp. (Geranium)	*Verticillium albo-atrum*, *Verticillium dahliae*	
	Humulus lupulus (Hops)	*Verticillium nonalfalfae*, *Verticillium albo-atrum*,	
	Lavandula spp. (Lavender)	*Fusarium sporotrichioides*, *F. oxysporum*, *F. solani*, *Sclerotinia sclerotiorum*, *Phytophthora palmivora*	
	Rosmarinus officinalis (Rosemary)	*Phytophthora citrophthora*, *Rhizoctonia solani*, *Fusarium oxysporum*, *Nigrospora oryzae*	
	Carthamus tinctorius (Safflower)	*Fusarium oxysporum* f. sp.*carthami*	
	Sesamum indicum (Sesame)	*Fusarium oxysporum* f. sp. *sesami*	
	Dianthus caryophyllus (Clove)	*Fusarium oxysporum* f.sp. *dianthi*	
Damping-off	*Withania somnifera* (Indian Ginseng)	*Rhizoctonia solani*	Infected seedlings first turn yellow and wilt, then the plant falls over and collapses (Kishore *et al.,* 1985; Alam *et al.,* 1996; Çarkacı and Maden, 1998; Li *et al.,* 2008; Barguil *et al.,* 2009).
	Cymbopogon citratus (Lemon grass)	*Pythium aphanidermatum*	
	Rosa chinensis (China rose), *Rosa damascena* (Isparta rose)	*Phytophthora* spp., *Alternaria* spp., *Rhizoctonia* spp.*, Sclerotinia* spp., *Pythium* spp.	

	Santalum spp. (Sandalwood)	*Fusarium* spp., *Phytophthora* spp., *Rhizopus* spp.	
	Lavandula spp. (Lavender)	*Rhizoctonia solani*, *Botrytis cinerea*, *Alternaria alternata*, *Colletotrichum* spp.	
	Papaver somniferum (Poppy)	*Fusarium solani*	
	Sesamum indicum (Sesame)	*Rhizoctonia solani*, *Fusarium* spp., *Alternaria tenuis*	
	Pimpinella anisum (Anise)	*Rhizoctonia solani*, *Fusarium* spp., *Alternaria tenuis*	
	Rosa spp. (Rose)	*Fusarium oxysporum*	
	Dianthus caryophyllus (Clove)	*Rhizoctonia solani*	
	Salvia officinalis (Sage)	*Fusarium oxysporum*, *F. solani*, *F. moniliforme*, *Rhizoctonia solani*	
Gray Mold	*Ocimum sanctum* (Holy Basil- Tulsi)	*Botrytis cinerea*	The agent causes dense gray-brown hairy growth on the stems and leaves, falling of leaves, damping-off of plants, severe lesions on the stem and death on the plant (Edney, 1967; Moreira *et al.*, 2015).
	Rosa chinensis, (China rose) *Rosa damascena* (Isparta rose)	*Botrytis cinerea*	
	Dianthus caryophyllus (Clove)	*Botrytis cinerea*	
Blue Mold	*Emblica officinalis* (Indian Gooseberry)	*Penicillium citrinum*, *P. islandicum*	Soft, wet and colourless-looking spots occurr on infected fruits. Blue green spores are appeared in these parts (Saini, 2017).
Wet Rots	*Withania somnifera* (Indian Ginseng)	*Choanephora cucurbitarum*	The infected area appears wet and these parts turn into signs of rot (Shukla *et al.*, 2006)
	Rauwolfia serpentina (Snakeroot)	*Rhizopus stolonifer*	

CONTROL OF FUNGAL DISEASES

Essential oils obtained from aromatic herbs are used in the perfume and food industry. Therefore, healthy plant material is very important for maintaining product quality. However, there are major problems in the cultivation of both medicinal and aromatic plants. The damages caused by fungal diseases cause negative effects on both the quality and quantity of the plant's biomass and the limitation of its successful cultivation in large areas and different places. Chemical applications are a form of management that is often used by producers. However, toxic pesticide residues in chemicals cause serious concerns as they pose serious dangers to human health. For this reason, cultural practices, products obtained from plants and biological control methods have been used along with chemical control (Table 2).

The methods of cultural control against fungal diseases on medicinal and aromatic plants include proper field cleaning and irrigation, use of resistant varieties, use of

compost, mulch and fertilizers that strengthen plant growth, avoiding close planting, pruning regularly, removing diseased plants and destroying them are especially recommended. Avoiding close planting, pruning regularly, removing diseased plant debris and destroying them are especially recommended. Various studies show that the management of diseases with biological control is more effective in controlling multiple diseases.

By reducing the chemicals used in agriculture, it seems possible to obtain quality products by preventing the yield loss in the soil with organic and biological solutions, which are alternative methods of control (Avan and Kotan, 2021).

Table 2. Chemical and biological control methods reported on fungal diseases of medicinal and aromatic plants.

Fungal Diseases in Medicinal and Aromatic Plants	Chemical Control	Biological Control
Rusts	- Sulfur, Copper oxychloride (Singh, 2006). - **Chlorothalonil**[1,2,6] (Douglas, 2003; Moorman, 2017) - Azoxystrobin, **Myclobutanil**[1,3], **Propiconazole**[1,2,3,4,7] (Mueller *et al.*, 2004) -**Tebuconazole**[5,7]+**Triadimenol**[2,7], **Triadimenol**[2,7], Flutriafol (Margina and Zheljazkov, 1995b) - **Trifloxystrobin**+ **Tebuconazole**[5,7], **Propiconazole**[1,2,3,4,7] (Mekonnen and Manahlie, 2018) - **Triadimefon**[2,7] (Tamuli *et al.*, 2012)	- *Bacillus subtilis* and *Trichoderma harizianum* (Saber *et al.*, 2009). - *Datura stramonium, Maesa lanceolata* ve *Milletia ferruginea* extracts (Mekonnen *et al.*, 2014). - *Vernonia amygdalina, Artemisia annua* (Mekonnen *et al.*, 2015)
Downy Mildews	- **Mancozeb**[1,2,3,6] (Jat *et al.*, 2015) - Metalaxyl (Yadav *et al.*, 2010) - Acibenzolar-S-methyl, Azoxystrobin, Cyazofamid, Mandipropamid (McGrath and LaMarsh, 2013, 2015) - Metalaxyl-M + **Copper hydroxide**[2], Mineral fertilizer "Alexin", Mandipropamid, Azoxystrobin, Glucohumates activator complex and Acibenzolar-S-methyl (Gilardi *et al.*, 2013)	- *Streptomyces lydicus, Bacillus amyloliquefaciens* strain D747, *Reynoutria sachalinensis* extract, neem oil, potassium bicarbonate and hydrogen dioxide (Wyenandt *et al.*, 2015)
Powdery Mildews	- Sodium bicarbonate (Salamone *et al.*, 2009). - Azoxystrobin, **Boscalid**[7]+Pyraclostrobin, Metalaxyl M+ Copper oxychloride, Mandipropamid and copper-based fungicides (Minuto *et al.*, 2012) - **Boscalid**[7], Monopotassium phosphate and vegetable oils (NTI 3404, NTI 3412) (Amoretti *et al.*, 2005)	- Thyme and clove essential oil (Salamone *et al.*, 2009).
Alternaria Leaf Spots	- **Mancozeb**[1,2,3,6] (Sharma *et al.*, 2010a). - Bordeaux mixture (Smitha *et al.*, 2014). - **Propineb**[1,2] (Parashurama and Shivanna, 2013). - **Propiconazole**[1,2,3,7], **Difenoconazole**[7] (Chauhan and Ravi, 2020). - **Mancozeb**[1,2,3,6]+**Propiconazole**[1,2,3,4,7] (DMAPR, 2012). - Penconazole (Qazi *et al.*, 2006)	- *Trichoderma viride* (Chauhan and Ravi, 2020). - Garlic oil, ginger oil and tulsi oil, turmeric rhizome extract (Sharma *et al.*, 2010a) - Neem extract (Guleria and Kumar, 2006).

	- **Mancozeb**[1,2,3,6], **Propiconazole**[1,2,3,4,7], **Difenconazole**[7], Azoxystrobin (Sharma et al., 2010a). - **Benomyl**[1,2,7], **Mancozeb**[1,2,3,6], **Carbendazim**[2,7] (Singh, 2006)	
Cercospora Leaf Spots	- **Carbendazim**[2,7] (DMAPR, 2014) - **Chlorothalonil**[1,2,6], **Iprodione**[1,2,7], Copper oxychloride, **Maneb**[1,2,3,6], **Mancozeb**[1,2,3,6], **Thiophanate-methyl**[1,2,6], **Benomyl**[1,2,7] (Singh, 2006). - **Zineb**[1,2] (Mondal et al., 2018)	- Soil application of neem cake + leaf waste of eucalyptus, *Millettia* (=*Pongamia*) *pinnata*+*Madhuca longifolia* cake; Neem oil or Neem seed extract+Neem cake and *Pseudomonas fluorescens* (Arumugam et al., 2010).
Colletotrichum Leaf Spots	- **Tebuconazole**[5,7] (Sharma et al., 2010a,b). - Dithane (DMAPR, 2014). - **Mancozeb**[1,2,3,6], Copper oxychloride (Mondal et al., 2018)	- *Trichoderma viride, T. harzianum, T. koningii, T. virens, T. hamatum* (Musheer and Ashraf, 2017). - Gentisyl alcohol obtained from *Phoma herbarum* (Gupta et al., 2016).
Corynespora Leaf Spot	- **Mancozeb**[1,2,3,6] (DMAPR, 2014).	- *Pseudomonas* sp.+Salicylic acid+ *Clerodendron inerme* leaf powder (DMAPR, 2014).
Curvularia Leaf Spots	- **Mancozeb**[1,2,3,6], Bordeaux mixture (Smitha et al., 2014)	
Diplocarpon Leaf Spot	- **Trifloxystrobin+Tebuconazole**[5,7] (IIHR, 2016).	
Macrophomina Leaf Spot		- *T. viride + P. fluorescens* (Senthamarai et al., 2008) - *T. viride* and neem based product (Kulkarni et al., 2007)
Stemphylum Leaf Spot	- **Maneb**[1,2,3,6], **Mancozeb**[1,2,3,6], **Chlorothalonil**[1,2,6], **İprodione**[1,2,7] (Gindrat et al., 1984). - **Mancozeb**[1,2,3,6], **Carbendazim**[2,7], **Propiconazole**[1,2,3,4,7] (Mondal et al., 2018)	
Alternaria Blights	- **Mancozeb**[1,2,3,6] (Sharma et al., 2010a; Jat et al., 2015). - Bordeaux mixture (Smitha et al., 2014). - Copper oxychloride, **Carbendazim**[2,7] (Singh, 2006) - **Mancozeb**[1,2,3,6]+**Propiconazole**[1,2,3,4,7] (DMAPR, 2012).	- *Ocimum sanctum, Zingiber officinale, A. sativum* or neem extracts and *Datura metel* or *Mentha spicata* extracts (Sharma et al., 2010a). - *T. asperellum* (Gatak et al., 2020)
Colletotrichum Blights	- **Mancozeb**[1,2,3,6], **Carbendazim**[2,7], Bordeaux mixture (Shukla et al., 2010; Smitha et al., 2014). - **Hexaconazole**[7], **Propiconazole**[1,2,3,4,7], Tricyclazole, **Thiophanate methyl**[1,2,6] and **Carbendazim**[2,7] + **Mancozeb**[1,2,3,6] (Kadam et al., 2014).	
Curvularia Leaf Blights	- **Mancozeb**[1,2,3,6], Bordeaux mixture (Smitha et al., 2014). - Copper oxychloride (Mondal et al., 2018) - **Propineb**[1,2], **Hexaconazole**[7] and **Epoxiconazole**[1,2,6] (Lakpale, 2011).	- Neem oil, *Kalanchoe heterophylla, Curcuma amada* and *Adhatoda vasica* extracts, *T. viride* and *P. fluorescens* (Lakpale, 2011).
Macrophomina Blight	- Metalaxyl + **Mancozeb**[1,2,3,6] (Meena and Kadam, 2021)	- *Pseudomonas fluorescence* (Meena and Kadam, 2021)
Sclerotinia Blight	- **Tebuconazole**[5,7] (Sharma et al., 2010a, b)	*Trichoderma harzianum, Gliocladium virens* (Mondal et al., 2018)

Rhizoctonia Blight	- **Mancozeb**[1,2,3,6], **Carbendazim**[2,7] (Mondal *et al.*, 2018)	- Trichoderma+ Organic fertilizer (Mondal *et al.*, 2018)
Anthracnose	- **Carbendazim**[2,7] (Prakash, 2012), - **Chlorothalonil**[1,2,6] (Parameswaran *et al.*, 2000). - **Mancozeb**[1,2,3,6], Bordeaux mixture (Mondal *et al.*, 2018)	
Collar Rot	- **Carbendazim**[2,7], **Thiophanate-methyl**[1,2,6] (TNAU, 2013) - **Mancozeb**[1,2,3,6] (Mondal *et al.*, 2018)	- *T. harzianum* (Singh and Singh, 2004).
Rhizome Rot	- Copper oxychloride, **Mancozeb**[1,2,3,6], **Carbendazim**[2,7] (Mondal *et al.*, 2018) - **Tebuconazole**[5,7] (Sharma *et al.*, 2010a,b).	
Stolon Rot	- **Mancozeb**[1,2,3,6], **Carbendazim** (Mondal *et al.*, 2018) - **Captan**[1,6] (Szezeponek and Mazur, 2006)	- *Trichoderma harzianum, Gliocladium virens* (Mondal *et al.*, 2018) - *T. viride, P. fluorescens* and *B. subtilis* (Kamalakannan *et al.*, 2003)
Root Rots	- **Mancozeb**[1,2,3,6], Copper oxychloride (Mondal *et al.*, 2018) - **Carbendazim**[2,7] (DMAPR, 2006) - **Carbendazim**[2,7]+**Mancozeb**[1,2,3,6] (Ingle *et al.*, 2014)	- *Trichoderma harzianum* (Govindappa *et al.*, 2010) - *T. viride+P. fluorescens* (Ingle *et al.*, 2014). - *T. viride* (DMAPR, 2006) - *P. fluorescens* (Govindappa *et al.*, 2010; Ingle *et al.*, 2014) - *Glomus fasciculatum, G. mosesae* (Mondal *et al.*, 2018). - *T. viride, P. fluorescens, Bacillus subtilis,* Neem cake and Mahua cake, *T. viride* + Neem cake (Gnanaprakash *et al.*, 2015). - *Allium schoenoprasum, Annona squamosa, A. indica, Calendula officinalis, Cinnamomum verum, Eucalyptus* sp., *Lawsonia inermis, O. sanctum, Piper nigrum, Z. officinale* aqueous extract sprays or extracts in 50% ethanol (Chathuri *et al.*, 2011) - *Bacillius subtilis* (Elewa *et al.*, 2011) - Neem seed powder+Carbofuran, Carbofuran+Carbendazim, Neem seed powder + Carbendazim (Kahkashan, 2003)
Stem Rot	- **Carbendazim**[2,7], **Mancozeb**[1,2,3,6] (Mondal *et al.*, 2018)	- *T. viride, P. fluorescens* and *B. subtilis* (Kamalakannan *et al.*, 2003) - *Trichoderma* spp., *Glomus fasciculatum* and *G. mosesae* (Mondal *et al.*, 2018)
Crown Rot	- **Carbendazim**[2,7], **Mancozeb**[1,2,3,6] (Mondal *et al.*, 2018)	- *Trichoderma* spp. (Mondal et al., 2018)
Wilts	- **Carbendazim**[2,7] (Singh, 2006; Bhat et al., 2014) - **Benomyl**[1,2,7] (Szezeponek and Mazur, 2006). - Copper oxychloride (Ramadevi *et al.*, 2005). - **Mancozeb**[1,2,3,6], **Carbendazim**[2,7] (Mondal *et al.*, 2018)	- *T. viride* + *P. fluorescens* (Senthamarai *et al.*, 2008) - *Glomus fasciculatus* + *P. fluorescens* (Singh *et al.*, 2009) - Mangiferin (Ghosal *et al.*, 1977) - *Bacillius subtilis* (Elewa *et al.*, 2011) - Vascular arbuscular mycorrhiza (Sahab *et al.*, 2001). - *Trichoderma viride, Pseudomonas fluorescens, Glomus fasciculatum, G. mosesae* (Mondal *et al.*, 2018)

Damping-off	- **Mancozeb**[1,2,3,6], Copper oxychloride ([Mondal et al., 2018](#)) - Copper oxychloride, **Mancozeb**[1,2,3,6], **Carbendazim**[2,7] ([Mondal et al., 2018](#))	- *Trichoderma* spp. ([Mondal et al., 2018](#)) - Azotobacter ve *Trichoderma* sp. ([Bhat et al., 2014](#))
Gray Mold	- **Mancozeb**[1,2,3,6], **Zineb**[1,2] ([TNAU, 2013](#))	- *Aloe vera* cake, Cassava starch, gelatin and thyme oil, chitosan ([Romero et al., 2017](#))
Blue Mold	- Pre-storage - Sodium hypochlorite, Borax, During-storage – **Carbendazim**[2,7], **Thiophanate methyl**[1,2,6] ([Prakash, 2012](#))	
Wet Rot	- **Mancozeb**[1,2,3,6], Copper oxychloride ([Mondal et al., 2018](#))	

[1]: PAN Bad Actor, [2]: Highyl Hazardous Pesticide, [3]: Development or Reproductive Toxin, [4]: Acute Toxicity, [5]: Acute Toxicity Moderate, [6]: Carcinogen, [7]: Carcinogen Possible ([Pesticideinfo, 2021](#))

CONCLUSION

Since some of these chemicals listed in Table 2 are banned and/or restricted plant protection products in the world, including our country, extreme care should be taken in their use in medicinal and aromatic plant growing. Some environmental factors, climate changes, market-oriented crop production and management lead to an increase in the number of pests and diseases in particular. With the frequent use of synthetic pesticides in plant production, theirs damages to health, food and the environment have increased considerably. The use of chemicals can alter the qualitative and quantitative composition of the active ingredients in plants, which reduces their therapeutic value. For this reason, as a control method, the use of chemicals requires great care and expertise. People have become more interested in traditional and complementary medicine practices. With the reason that our country has a rich flora in terms of plant diversity, the production of medicinal and aromatic plants that can be an alternative to the use of chemical pesticides is supported. These plants, which are widely used in public health services, food and cosmetics sectors globally, continue to increase their agenda every year with the increase in market demand. Biopesticides and bioactive substances have been used instead of synthetic pesticides to prevent deterioration of the quality and increase the yield of the crop. Also, cultural practices and the use of durable varieties are preferred by the producers to reduce the application of synthetic pesticides. The most appropriate and effective control method plan should be combined with the integrated controls. The emergence of fungal diseases, which are frequently appeared in these medicinal and aromatic plants that grow spontaneously or are cultured, causes product and quality losses, creating a commercial and economic threat. For this reason, it is very important to identify, detect and control these diseases.

DECLARATION OF COMPETING INTEREST

The author declares that she has no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The author contributed 100% to the article.

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