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Farklı Ağırlığa Sahip Yumurtaların İç ve Dış Kalite Özelliklerinin Belirlenmesi

Determining the Internal and External Quality Traits of Eggs With Different Weights

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ÖZ

Bu çalışmada, Atak-S ırkı tavukların farklı ağırlığa sahip yumurtalarının dış (fiziksel) ve iç kalite özellikleri incelenmiştir. Yumurtalarda ağırlık gruplamasında; en büyük, çok büyük ve büyük olmak üzere sırasıyla Jumbo (≥70 g), XLarge, XL (65-70 g), Large, L (56-65 g) ağırlıkları kullanılmıştır. Bu amaçla 75 haftalık tavuklardan alınan yumurtaların gruplandırılması sonucu; 140 adet Jumbo, 140 adet XLarge ve 60 adet Large yumurtalar denemede kullanılmıştır. Yumurtaların iç ve dış kalite özellikleri olarak boyut özellikleri, geometrik ortalama çap, küresellik, sürtünme katsayısı, şekil indeksi, yüzey alanı, yumurta yüzey alanı, kabuk kalınlığı ve belirlenmiştir. PVC, galvaniz sac, laminant, lastik ve kontrplak yüzeylerde yapılan statik sürtünme katsayılarının ölçümünde her bir yumurta grubu için en düşük sürtünme katsayısı, incelenen sürtünme yüzeyleri için galvaniz sac yüzeyde bulunurken, maksimum sürtünme katsayısı lastik yüzeyde elde edilmiştir. Jumbo, XLarge ve Large grup yumurtaların ortalama ağırlık değerleri sırasıyla 73.19 g, 68.08 g ve 62.75 g olarak belirlenmiştir. Renk özelliklerinden, *L** değeri maksimum 69.86 ile XLarge yumurtada, en düşük değer ise 66.36 ile Large grup yumurtada belirlenmiştir. Hem yumurtanın üretimi ve hem de tüketici istekleri açısından yumurtaların iç ve dış kalite özelliklerinin bilinmesine gerek duyulmaktadır.

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ABSTRACT

In this study, internal (physical) and external quality characteristics of eggs of different weights of Atak-S breed chickens were examined. In egg weight grouping; Jumbo (70 g), XLarge, XL (65-70 g), Large, L (56-65 g) weights were used, respectively. For this purpose, as a result of grouping the eggs taken from 75-week-old chickens; 140 Jumbo, 140 XLarge and 60 Large eggs were used in the experiment. As internal and external quality characteristics of the eggs; parameters such as dimensional properties, geometric mean diameter, sphericity, friction coefficient, shape index, surface area, egg surface area, shell thickness etc. were determined. In the measurement of static friction coefficients on PVC, galvanized sheet, laminate, rubber and plywood surfaces, the lowest friction coefficient for each egg group was found on the galvanized sheet surface for the tested friction surfaces, while the maximum friction coefficient was obtained on the rubber surface. Average weight values of Jumbo, XLarge and Large group eggs were 73.19 g, 68.08 g and 62.75 g, respectively. Among the color characteristics, the *L** value was determined with a maximum of 69.86 in XLarge eggs and the lowest value was determined in Large group eggs with 66.36. It is necessary to know the internal and external quality characteristics of the eggs in terms of both egg production and consumer demands.

Reference / Atıf: Gül, E.N., Altuntaş, E., Demir, R. (2021). "Farklı Ağırlığa Sahip Yumurtaların İç ve Dış Kalite Özelliklerinin Belirlenmesi", Tarım Makinaları Bilimi Dergisi, 17(2): 55-63.

1. GİRİŞ

İnsan diyetinde önemli bir yere sahip olan yumurta, yüksek kalitede protein ile birlikte çok az miktarda aminoasit içeriğine sahiptir. Yumurta proteinleri %100 oranında vücut proteinlerine dönüştüğünden anne sütü ile birlikte "Örnek Protein" kaynağı olarak gösterilmektedir (Şenköylü, 2001). FAO 2018 yılı verilerine göre; dünya genelinde 77.067.008 ton tavuk yumurtası üretimi yapılmıştır. Dünya tavuk yumurtası üretiminde, Türkiye 9. sırada yer almaktadır. Avrupa ise 11.073.316 ton tavuk yumurtası üretimi yapmaktadır. Ülkemiz, Avrupa üretimi ile kıyaslandığında tavuk yumurtası üretiminde 2. sırada yer almaktadır (Anonim, 2020). TÜİK verilerine göre, 2002 yılında 11.555.000 adet olan yumurta üretimimiz 2019 yılında ise 19.898.126 adede ulaşmıştır (TÜİK, 2019). Üretim değerlerinden de görüldüğü gibi, 2002-2019 yılları arasında yumurta üretimi %72.20 artmıştır. Ülkemiz yumurta üretiminde kendine yeter durumda olup, üretim fazlasını ihraç etmektedir (Anonim, 2020).

Yumurta üreticileri merkez birliğinin (YUM-BİR) verilerine göre, ülkemiz 2018 yılı için 124.055.000 adet yumurtacı tavuğa sahip olup, aynı yıl kişi başı yumurta tüketimi 224 adet/yıl ve kişi başına düşen yumurta üretimi ise 295 adet/yıl olarak bildirilmiştir. Türkiye'de yumurta ihracatı 2018 yılında 430.725.307 dolara ulaşmıştır. Sofralık yumurtalar, başlıca Suudi Arabistan (%9.6), Irak (%71.1), Katar (%3.6), Birleşik Arap Emirlikleri (%2.4) ve Azerbaycan-Nahçivan'a (%1.8) ihraç edilmektedir (Anonim, 2019).

Yumurtada kalite, yumurtanın mükemmellik derecesini belirleyen kalıtsal özelliklerin bütünü olarak tanımlanabilir (Altan, 1993). Son yıllarda üreticiden tüketiciye yumurta endüstrisinin bütün aşamalarında yumurta ve yumurta ürünlerinin kalitesine önem verilmeye başlanmıştır. Avrupa Topluluğu yasaları (SI No. 254 sayı 1992 yılı); Konsey yasasını (EEC No 1907/90) ve Komisyon yasasını uygulayarak tavuk yumurtalarını kalite ve ağırlığa göre sınıflandırmış, pazarlama aşamasında ise paketleme, etiketleme, taşıma ve satışa sunma şeklinde düzenlemiştir (Uruk, 2007).

Yumurtalarda dış kalite özelliklerinden şekil özelliği, şekil indeksi esas alınarak belirlenebilmektedir. Şekil indeksi (SI)'ne göre; en sık karşılaşılan yumurta şekilleri, sırasıyla SI<%72, SI=%72–%76 ve SI>%76 olarak sivri, normal (standart) ve yuvarlak olarak gruplandırılmaktadır (Altuntaş ve Şekeroğlu, 2008). Yine dış kalite özellikleri olarak, yumurtalarda ağırlık gruplamasında; Jumbo ≥70 g, Ekstra Large (XL) ve 65-70 g, Large (L) 56-65 g ağırlıkları kullanılmaktadır (USDA, 2000; FAO, 2003).

Ülkemiz için büyüyen ve tüketici talebinin giderek arttığı bir besin kaynağı olan perakende işletmelerde satışa sunulan yumurtalarda fiziksel özelliklerin belirlenmesi konusundaki çalışma sayısının literatürlerde çok az sayıda olduğu gözlenmiştir. Bu konuda yapılan çalışmalardan bazıları içinde; Karademir (2018), farklı sistemlerde üretilen yemeklik yumurtaların bazı kalite özelliklerinin karşılaştırılması; Duman ve ark. (2016), yumurta şekil indeksi ile yumurta kalite özellikleri arasındaki ilişkiyi; Altuntaş ve Şekeroğlu (2008), farklı ağırlıklarda tavuk yumurtalarının mekanik davranışını araştırmışlardır. Hem dış ve hem de iç kalite özelliklerinin belirlenmesi amacıyla, bu çalışmada, 'Atak-S' ırkı hibrit yumurtacı tavuklara ait kahverengi yumurtaların farklı (Jumbo, Xlarge ve Large) ağırlık gruplamasına göre bazı iç kalite özellikleri ile beraber dış kalite özellikleri birlikte incelenmiştir.

2. MATERYAL VE YÖNTEM

Bu çalışmada kullanılan yumurta materyalleri, Tokat ili sınırlarında bulunan perakende satış yapan bir işletmeden temin edilmiştir. Yumurtalar, Ankara-Tavukçuluk Araştırma Enstitüsü tarafından geliştirilen kahverengi yumurtacı 'Atak-S' ırkı hibrit tavuklara aittir. Bu çeşit, bölgede özellikle organik ve serbest sistem tavukçuluk yapmayı düşünen üreticiler tarafından tercih edilen bir ırktır. Yumurtalar temin edilirken üretim tarihlerinin birbirine yakın olmasına özen gösterilmiştir. Yumurtalar 75 haftalık tavuklardan alınmıştır. Yumurtalar temin edildikten sonra, 24 saat süreyle oda sıcaklığında bekletildikten sonra ölçümlere başlanmıştır. Denemeler, Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi Biyosistem Mühendisliği Bölümü Biyolojik Malzeme Laboratuvarında yürütülmüştür. Araştırmada kullanılan yumurtalar, serbest sistemde üretilerek satışa sunulan Jumbo, XLarge (XL) ve Large (L) ağırlık gruplarına göre sınıflandırılmıştır (USDA, 2000; FAO, 2003) (Şekil 1). Bu amaçla 75 haftalık tavuklardan alınan yumurtaların gruplandırılması sonucu; 140 adet Jumbo, 140 adet XLarge ve 60 adet Large olmak üzere çalışmada toplam 340 adet yumurta kullanılmıştır. Denemede kullanılan yumurta ağırlık gruplaması için Jumbo (en büyük), XLarge (çok büyük) ve Large (büyük) yumurta gruplaması olarak kullanılmıştır.

Şekil 1. Farklı ağırlık gruplarına sahip yumurta örnekleri

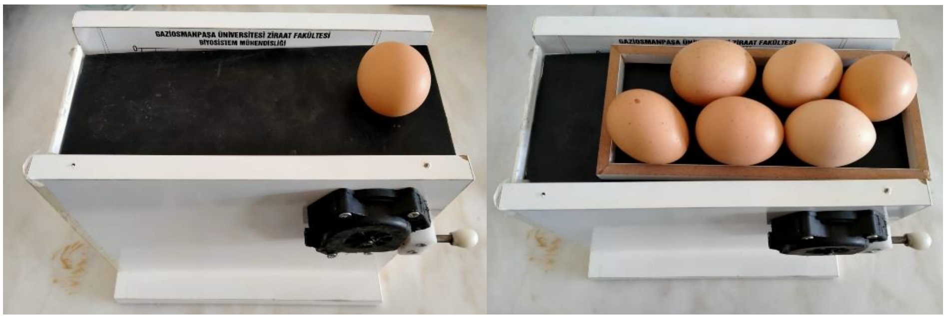
Yumurtaların Jumbo, XLarge (XL) ve Large (L) gibi farklı ağırlık grubu için fiziksel ve dış kalite özellikleri için aşağıdaki metotlar kullanılmıştır.

Dış kalite özelliklerinden, yumurtaların uzunluk ve genişlik ölçümleri 0.01 mm hassasiyetli dijital kumpasla yapılmıştır. Yumurta örneklerinin tartımında ise 0.001 gram hassasiyetli KERN marka EW620-3NM modelli elektronik terazi kullanılmıştır. Yumurtalarda; geometrik ortalama çap ($Gç$), küresellik (Kr) ve yumurta hacmi (Ht) aşağıdaki eşitlikler kullanılarak hesaplanmıştır (Mohsenin 1980):

$$G_ç = (u.g^2)^{1/3} \tag{1}$$
$$K_r = (G_ç/u)100 \tag{2}$$
$$H_t = \pi/6\,(u.g^2) \tag{3}$$

Burada;
$G_ç$: Geometrik ortalama çap (mm),
K_r: Küresellik (%),
H_t: Tane hacmi (mm^3),
u: Uzunluk (mm),
g: Genişlik (mm)'tir.

Yumurtaların farklı sürtünme yüzeylerindeki (PVC, Galvaniz sac, laminant, lastik ve kontrplak) statik sürtünme katsayılarının ölçümünde eğimli masa deney düzeneğinden yararlanılmıştır (Şekl 2). Bir vidalı kol yardımıyla hareket ettirilen eğimli masa düzeneğinde tek ve grup halinde olmak üzere 10 tekrarlı ölçüm yapılmıştır. Örneklerin sürtünme yüzey üzerinden harekete başladığı andaki açı değerinin tanjantı statik sürtünme katsayısı olarak dikkate alınmıştır (Dutta ve ark., 1988).



Şekil 2. Tek ve grup halinde denemeye tabi tutulan yumurta örnekleri

Dış kalite özellikleri içerisinde önemli bir yere sahip olan kabuk kalınlığı, yumurtanın sivri ucunda en kalın değere ulaşırken, küt uçta en ince değerdedir. Diğer kenarlarda ise bu ekstrem iki değer arasındadır. Yumurtanın uçlarına göre kabuk kalınlığının değişmesi nedeniyle, çalışmada kabuk kalınlığının belirlenmesinde uçlardan ve yumurtanın ortasından örnekler alınmış, bunların zarları soyulmuş ve kalınlıkları Insize marka dijital mikrometre ile ölçülerek ortalamaları alınmıştır.

Yumurtaların şekil indeksi ve yumurta yüzey alanı aşağıdaki eşitlikler yardımı ile hesaplanmıştır (Reddy ve ark., 1979; Nordstrom ve Ousterhout, 1982; Anderson ve ark., 2004;).

$$Şİ = (g/u) * 100 \tag{4}$$
$$Y_a = 3.9782\; x\; Yumurta\; ağırlığı^{0.7056} \tag{5}$$

Burada;
Şİ: Şekil indeksi (%),
Y_a: Yumurta yüzey alanı (cm^2)'dır.

Gerçek hacim ağırlığının (özgül ağırlık) belirlenmesi amacıyla sıvı yer değiştirme metodu uygulanmıştır (Saçılık ve ark., 2003). Yumurtaların kabuk yüzeyine ait renk karakteristikleri Minolta renk ölçer (Model CR-400, Tokyo-Japonya) ile yapılmıştır (McGuire, 1992). Renk ölçümlerinde 15 örnek kullanılmıştır. Yumurta kabuğuna ait renk değerleri CIE'e göre $L*$, $a*$, $b*$ renk karakteristikleri belirlenmiştir. Skalaya göre, $L*$ değeri parlaklığı; $a*$ değeri kırmızılığı ve $b*$ renk değeri sarılığı belirtmektedir. Örneklerin renk karakteristikleri için ayrıca hue açısı (h°) ile kroma (C) renk karakteristikleri de hesaplanmıştır (Eşitlik 6 ve 7). Hue açısı renk tonunu ve kroma (K) ise rengin saflığını veya doygunluğunu göstermektedir (McGuire, 1992). Ayrıca yumurta genel renk değeri için ΔE değeri Eşitlik 8 kullanılarak hesaplanmıştır (Ingram ve ark., 2008). ΔE değeri ne kadar düşükse renk o kadar koyu olmaktadır.

$$h^0 = tan^{-1}\,(b/a) \quad (6)$$
$$C = (a^2 + b^2)^{1/2} \quad (7)$$
$$\Delta E = (L^2 + a^2 + b^2)^{1/2} \quad (8)$$

Araştırma sonuçlarının istatistiksel değerlendirmelerinde SPSS (Statistical Package for Social Sciences) istatistik paket programı kullanılmıştır. Genel istatistik hesaplamalarda minimum, maksimum, ortalama ve standart sapma, standart hata ve varyasyon katsayısı değerleri bulunmuştur. İç kalite özellikleri ve dış kalite özelliklerine ağırlık gruplarının etkisi için tek yönlü varyans analizi (One Way Anova) yapılmıştır. Ağırlık grupları arasındaki farklılıklar ise, Duncan Çoklu Karşılaştırma Testi ile belirlenmiştir.

3. ARAŞTIRMA BULGULARI VE TARTIŞMA

3.1. Dış kalite özellikleri

Farklı ağırlık gruplarına ait yumurta örneklerinin genel olarak boyutsal özellikleri, geometrik ortalama çap, küresellik, şekil indeksi ve yumurta hacmi değerleri, Çizelge 1'de, ağırlık grupları arasındaki çoklu karşılaştırmalara yönelik istatistik karşılaştırmalar, Çizelge 2'de verilmiştir. Jumbo ağırlık grubu yumurtaların uzunluk değerleri, XLarge yumurtalara göre (%2.42) fazla iken Large grubu yumurtalardan %5.58 kat daha fazla büyük olduğu gözlemlenmiştir (Çizelge 1). Uzunluk, genişlik, geometrik ortalama çap, yüzey alanı, kabuk kalınlığı bakımından gruplar arasındaki farklılığın önemli olduğu belirlenmiştir (P<0.01).

Çizelge 1. Farklı ağırlık gruplarına ait yumurta örneklerinin bazı dış kalite özellikleri

Ağırlık Grubu	Özellikler	Ortalama	Maksimum	Minimum	Standart Sapma	Varyasyon Katsayısı	Standart Hata
Jumbo	*U (mm)*	61.28	68.21	57.49	1.765	2.881	0.149
	G (mm)	46.30	49.48	43.24	0.796	1.720	0.677
	Gç (mm)	50.63	52.66	48.34	0.653	1.290	0.055
	Kr (%)	82.68	87.53	75.00	2.021	2.444	0.171
	Ht (mm³)	68792.13	77390.15	59854.26	2683.321	3.901	226.823
XLarge	*U (mm)*	59.83	65.67	56.49	1.644	2.748	0.139
	G (mm)	45.29	47.01	43.42	0.699	1.542	0.059
	Gç (mm)	49.49	51.76	48.31	0.496	1.002	0.042
	Kr (%)	82.78	87.68	77.46	2.038	2.463	0.172
	Ht (mm³)	64251.00	73455.64	59743.41	1973.818	3.072	166.849
Large	*U (mm)*	58.04	61.43	55.76	0.941	1.621	0.121
	G (mm)	44.27	45.77	42.88	0.532	1.201	0.069
	Gç (mm)	48.26	49.13	47.52	0.304	0.630	0.039
	Kr (%)	83.17	85.77	78.38	1.398	1.680	0.180
	Ht (mm³)	59554.96	62829.43	56831.88	1127.352	1.893	145.465

U: Uzunluk (mm), G: Genişlik (mm), Gç: Geometrik ortalama çap (mm), Kr: Küresellik (%), Ht: Yumurta hacmi (mm³)

Çizelge 2. Farklı ağırlık gruplarına ait yumurta örneklerinin bazı dış kalite özelliklerine göre istatistik hesaplamalar

Ağırlık Grubu	*U (mm)*	*G (mm)*	*Gç (mm)*	*Kr (%)*	*Ht (mm³)*
Jumbo	61.28^a	46.30^a	50.63^a	82.68	68792.13^a
XLarge	59.83^b	45.29^b	49.49^b	82.78	64251.00^b
Large	58.04^c	44.27^c	48.26c	83.17	59554.96^c
F Değeri	131.90**	194.38**	711.86**	1.82^{ns}	689.51**

U: Uzunluk (mm), *G*: Genişlik (mm), *Gç*: Geometrik ortalama çap (mm), *Kr*: Küresellik (%), *Ht*: Yumurta hacmi (mm³)

Altuntaş ve Şekeroğlu (2008), dört farklı yumurta ağırlığı grubunda ortalama uzunluk, genişlik, geometrik ortalama çap değerlerinin her biri için 52.90-58.63 mm, 41.87-46.61 mm, 45.09-50.11 mm arasında değiştiğini bildirmişlerdir.

Farklı ağırlık gruplarına ait yumurta örneklerinin fiziksel özelliklerinden sürtünme katsayısı değerleri tek ve grup halinde belirlenmiş, Çizelge 3'te; ağırlık grupları arasındaki çoklu karşılaştırmalara yönelik istatistik karşılaştırmalar, Çizelge 4'te verilmiştir. Sürtünme katsayısı için yumurtaların taşıma ve sınıflandırmasında materyallerin sürtünme yüzeylerindeki etkisini daha net görebilmek için yumurtalarda tek ve gruplar halinde sürtünme katsayısı ölçümleri yapılmıştır. Tek ve grup yumurta örneklerinin statik sürtünme katsayısı, en düşük Galvanizli sac yüzeyde gözlenirken en yüksek lastik yüzeyde belirlenmiştir (Çizelge 3). Tek yumurta örneklerinde kontrplak yüzey bakımından boyut grupları arasında önemli fark bulunmazken, diğer yüzeyler P<0.01 düzeyinde önemli fark olduğu belirlenmiştir (Çizelge 4). Grup yumurta örneklerinde tüm sürtünme yüzeyleri bakımından boyut grupları farklılığın önemli olduğu belirlenmiştir (P<0.01) (Çizelge 4). Galvanizli sac, PVC, kontrplak, laminant ve lastik gibi çeşitli yüzeylerdeki statik sürtünme katsayıları test edilen farklı boyutlardaki yumurtalarda ağırlığın artmasıyla sürtünme katsayılarının da doğrusal olarak arttığı belirlenmiştir.

Çizelge 3. Farklı ağırlık grubuna ait yumurta örneklerinin statik sürtünme katsayısı değerleri

Ağırlık Grubu	Sürtünme Ölçümü		Ortalama	Maksimum	Minimum	Ss	Cv	Sh
Jumbo	Tek	Galvaniz sac	0.088	0.105	0.070	0.012	13.398	0.004
		PVC	0.110	0.123	0.087	0.012	10.794	0.004
		Kontrplak	0.126	0.141	0.105	0.011	8.877	0.004
		Laminant	0.110	0.123	0.087	0.012	10.794	0.004
		Lastik	0.142	0.158	0.123	0.010	7.103	0.003
	Grup	Galvanizli sac	0.202	0.213	0.176	0.013	6.289	0.004
		PVC	0.218	0.231	0.194	0.015	6.891	0.005
		Kontrplak	0.274	0.287	0.249	0.015	5.633	0.005
		Laminant	0.238	0.268	0.213	0.018	7.476	0.006
		Lastik	0.296	0.306	0.268	0.013	4.516	0.004
XLarge	Tek	Galvaniz sac	0.061	0.087	0.052	0.012	20.267	0.004
		PVC	0.100	0.123	0.087	0.012	11.922	0.004
		Kontrplak	0.125	0.141	0.105	0.013	10.498	0.004
		Laminant	0.103	0.123	0.087	0.018	16.975	0.006
		Lastik	0.135	0.141	0.123	0.009	6.345	0.003
	Grup	Galvaniz sac	0.189	0.213	0.176	0.015	7.887	0.005
		PVC	0.193	0.213	0.176	0.013	6.937	0.004
		Kontrplak	0.262	0.287	0.249	0.013	4.804	0.004
		Laminant	0.213	0.231	0.194	0.015	7.007	0.005
		Lastik	0.281	0.316	0.268	0.013	4.527	0.004
Large	Tek	Galvaniz sac	0.037	0.052	0.017	0.013	35.161	0.004
		PVC	0.082	0.105	0.070	0.014	17.602	0.005
		Kontrplak	0.119	0.141	0.105	0.011	9.391	0.004
		Laminant	0.084	0.105	0.070	0.014	16.512	0.004
		Lastik	0.123	0.141	0.087	0.019	15.189	0.006
	Grup	Galvaniz sac	0.157	0.194	0.141	0.021	13.695	0.007
		PVC	0.171	0.194	0.141	0.022	13.129	0.007
		Kontrplak	0.233	0.249	0.213	0.016	6.917	0.005
		Laminant	0.171	0.213	0.141	0.028	16.461	0.009
		Lastik	0.251	0.268	0.213	0.020	8.101	0.006

PVC: Polivinil Klorür

Çizelge 4. Farklı ağırlık gruplarına ait tek yumurta örneklerinin statik sürtünme katsayısı değerleri

Sürtünme Ölçümü	Ağırlık Grubu	Galvaniz Sac	Pvc	Kontrplak	Laminant	Lastik
Tek	Jumbo	0.088^{a}	0.110^{a}	0.126	0.110^{a}	0.142^{a}
	XLarge	0.061^{b}	0.100^{a}	0.125	0.103^{a}	0.135^{a}
	Large	0.037^{c}	0.082^{b}	0.119	0.084^{b}	0.123^{b}
	F değeri	**42.371****	**12.324****	**0.967^{ns}**	**8.745****	**5.584****
Grup	Jumbo	0.202^{a}	0.218^{a}	0.274^{a}	0.238^{a}	0.296^{a}
	XLarge	0.189^{a}	0.193^{b}	0.262^{a}	0.213^{b}	0.281^{b}
	Large	0.157^{b}	0.171^{c}	0.233^{b}	0.171^{c}	0.251^{c}
	F değeri	**19.158****	**18.333****	**20.387****	**25.933****	**20.813****

PVC: Polivinil Klorür

Altuntaş ve Şekeroğlu (2008); farklı boyutlardaki Lohmann çeşidi tavuklarının yumurtaları ile yaptıkları çalışmada en yüksek sürtünme katsayısını lastik yüzeyde, en düşük değeri ise cam yüzeyde belirlemişlerdir. Bu çalışmada da en yüksek sürtünme katsayısı değerleri lastik yüzeyde belirlenmiş olup, sonuçlar benzerlik göstermiştir.

3.2. Dış Kalite Özellikleri

Farklı ağırlık gruplarına ait yumurta örneklerinin dış kalite özellikleri olarak, yumurta ağırlığı (g) şekil indeksi (%), özgül ağırlık (g cm^{-3}), kabuk kalınlığı (mm) ve yüzey alanı (cm^{2}), Çizelge 5'te; yumurta dış kalite özellikleri için, ağırlık grupları arasındaki çoklu karşılaştırmalara yönelik istatistik karşılaştırmalar, Çizelge 6'da verilmiştir.

Standart bir yumurtanın ağırlığı 57.6 g olarak bildirilmektedir (Sarıca ve Erensayın, 2004). Türk Standartları Enstitüsü TS 1068'de ve Türk Gıda Kodeksi Yumurta Tebliği'nde belirtilen ve yumurta boy özelliklerine göre ticari ve köy şartlarında yetiştirilen yumurtaların büyük (63-72 g), serbest sistem yumurtalarının ise orta yumurta grubuna girdiği belirlenmiştir.

Kılıç ve Şimşek (2006) yaptıkları çalışmada Isa Brown kahverengi yumurta tavuklarına ait yumurtaların ağırlık değerini 57.13-66.58 g aralığında, Durmuş ve ark. (2010), Barred Rock-1, Rhode Island Red-2 ve Colombian yumurtacı saf hatlarının yumurta ağırlıklarını 57.39-61.89 g aralığında, Duman ve ark. (2016), Atak-S ırkı tavukların yumurta ağırlıklarının 59.80-61.10 g aralığında olduğunu bildirmişlerdir. Tarım (2013), yumurta ağırlığı değerini 55.31- 60.14 g aralığında; Akkuş (2016) ise Nick Chick ve Nick Brown hibritleri ile yaptığı çalışmada yumurta ağırlığı değerini 63.64- 70.41 g aralığında olduğunu belirlemiştir.

Akkuş (2016), yaptığı çalışmada özgül ağırlığı 1.090- 1.103 g cm^{-3} aralığında; Karademir (2018) ise özgül ağırlığı 1.068-1.071 g cm^{-3} aralığında değiştiğini bildirmiştir. Araştırmada bütün yumurta gruplarda elde edilen özgül ağırlık değerinin standart değerden düşük olduğu görülmüştür. Yumurta özgül ağırlığı konusunda Türk Standartları Enstitüsü TS 1068'de ve Türk Gıda Kodeksi Yumurta Tebliği'nde herhangi bir değer belirtilmemiştir.

Çalışmada; ağırlık, özgül ağırlığı, yüzey alanı ve kabuk kalınlığı bakımından yumurta grupları arasındaki farklılığın önemli olduğu belirlenmiştir (P<0.01). Jumbo, XLarge ve Large grubundaki yumurtaların ağırlık ortalamaları sırasıyla 73.19, 68.08 ve 62.57 g olarak belirlenmiştir (Çizelge 5).

Çizelge 5. Ağırlık gruplarına göre yumurta örneklerinin bazı dış kalite özellikleri

Ağırlık Grubu	Özellikler	Ortalama	Maksimum	Minimum	Standart Sapma	Varyasyon Katsayısı	Standart Hata
Jumbo	*Şİ (%)*	75.64	82.38	65.33	2.763	3.653	0.234
	A (g)	73.19	84.36	70.03	2.616	3.574	0.221
	ÖA (g cm^{-3})	1.062	1.065	1.054	0.004	0.421	0.002
	Ya (cm^2)	82.26	90.94	79.75	2.062	2.507	0.174
	Kk (mm)	0.561	0.624	0.517	0.034	6.021	0.009
XLarge	*Şİ (%)*	75.77	82.59	68.57	2.791	3.684	0.236
	A (g)	68.08	77.38	65.00	1.678	2.465	0.142
	ÖA (g cm^{-3})	0.992	0.997	0.987	0.004	0.452	0.002
	Ya (cm^2)	78.17	85.57	75.66	1.354	1.732	0.114
	Kk (mm)	0.535	0.772	0.452	0.114	21.259	0.029
Large	*Şİ (%)*	76.30	79.91	69.80	1.919	2.514	0.248
	A (g)	62.57	64.97	59.84	0.981	1.568	0.127
	ÖA (g cm^{-3})	0.990	0.993	0.985	0.003	0.325	0.001
	Ya (cm^2)	73.66	75.64	71.37	0.815	1.106	0.105
	Kk (mm)	0.441	0.464	0.414	0.016	3.532	0.004

Şİ: Şekil indeksi (%), *A*: Ağırlık (g), *ÖA*: Özgül ağırlık (g cm^{-3}), *Ya*: Yüzey Alanı (cm^2), *KK*: Kabuk kalınlığı (mm)

Çizelge 6. Farklı ağırlık gruplarına ait yumurta örneklerinin bazı dış kalite özelliklerine ait istatistik hesaplamalar.

Ağırlık Grubu	*Şİ (%)*	*A (g)*	*ÖA (g cm^{-3})*	*Ya (Cm^2)*	*KK (mm)*
Jumbo	75.64	73.19^a	1.062^a	82.258^a	0.561^a
XLarge	75.77	68.08^b	0.992^b	78.166^b	0.535^a
Large	76.30	62.57^c	0.990^b	73.655^c	0.441^b
F Değeri	1.74^{ns}	1215.55**	498.729**	1255.769**	11.702**

Şİ: Şekil indeksi (%), *A*: Ağırlık (g), *ÖA*: Özgül ağırlık (g cm^{-3}), *Ya*: Yüzey Alanı (cm^2), *KK*: Kabuk kalınlığı (mm)

Standart bir yumurtanın şekil indeksi değerinin %72-76 arasında, ortalama olarak %74 olması istenmektedir. Bu ortalamanın dışında kalan yumurtalar viyollere iyi yerleştirilemediği, nakil ve depolama sırasında kayıplara neden olduğundan dolayı tercih edilmemektedir (Jacob ve ark., 1998; Şenköylü, 2000; Sarıca ve Erensayın, 2004). Türk Standartları Enstitüsü TS 1068'de ve Türk Gıda Kodeksi Yumurta Tebliği'nde yumurta şekil indeksi özelliği için herhangi bir değer belirtilmemiştir. Şekil indeksi normal değerlerin altında olursa yumurta şekli sivri (Şİ<%72), normal değerin üstünde olursa şekil yuvarlak (Şİ>%76) olarak adlandırılmaktadır (Normal, standart: SI=%72-76) (Erensayın 2000, Altuntaş ve Şekeroğlu 2008). Araştırmada incelenen gruplarda şekil indeksinin standart değerlere yakın olduğu gözlenmiştir. Bu nedenle sofralık kullanım için satılan bu yumurtaların şekil indeksi bakımından uygun özellikte olduğu varsayılmaktadır.

Aygün (2007), 57 haftalık kahverengi (H&N Brown Nick) ve beyaz (Hy- Line, W-36) yumurtacı hibritlerle yaptığı çalışmada şekil indeksi değerlerini %76.94, 76.69, 76.77 ve 76.68 olarak belirlemiştir. Kılıç ve Şimşek (2006) yaptıkları çalışmada şekil indeksi değerini %75.15-77.76 aralığında belirlemiştir. Aygün ve Olgun (2019), şekil indeksi değerini %77.22 olarak Sarıbaş ve Yamak (2020) ise %74.44- 78.54 aralığında bildirmiştir. Koçer (2006), şekil indeksi değerlerini %73.72-74.53; Akkuş (2016) ise %74.60-78.50 aralığında değiştiğini tespit etmiştir. Akkuş (2016), yumurta yüzey alanı değerini 74.49-80.00 cm^2 aralığında değiştiğini bildirmiştir. Buna göre çalışmada şekil indeksi için bulunan sonuçlar Koçer (2006)'nın belirttiği değerlerden daha yüksek bulunmuştur.

Yumurta kabuk kalınlığı, kabuk kalitesini etkileyen önemli parametrelerden biri olup, dayanıklılığını etkilemekte ve yumurtaların toplanması sınıflandırılması, paketlenmesi, nakliyesi depolanması açısından önem arz etmektedir (Cavers,1970; Şenköylü ve Meriç,1989). Yemeklik yumurtalar için kabuk kalınlığının minimum 0.33-0.35 mm arasında olması istenmekte ve 0.33 mm'den ince kabuklu yumurtalar çok ince kabul edilmektedir. Bu tür yumurtaların nakliye ve pazarlama safhalarında kırılma olasılığı yüksek olmaktadır (Doğan, 2008). Kabuk kalınlığı için Türk Standartları Enstitüsü TS 1068'de ve Türk Gıda Kodeksi Yumurta Tebliği'nde belirtilen herhangi bir değer bulunmamaktadır.

Kılıç ve Şimşek (2006), yaptıkları çalışmada kabuk kalınlığı değerini 0.30-0.33 mm aralığında belirlemişlerdir. Durmuş (2006), 4 adet beyaz yumurtacı saf hat (Black, Blue, Brown ve Maroon) kullanarak yapmış olduğu çalışmada kabuk kalınlığını sırası ile 0.35, 0.35, 0.36 ve 0.37 mm olarak belirlemiştir. Altuntaş ve Şekeroğlu (2008) ise kabuk kalınlığının 0.38- 0.40 arağında değiştiğini bildirmiştir. Poyraz (1989), farklı genotip gruplarında kabuk kalınlığının 0.31- 0.36 mm aralığında olduğunu bildirmiştir. Durmuş ve ark. (2010), kahverengi yumurtacı saf hat yumurtalarının kalite özellikleri üzerine yaptığı çalışmada kabuk kalınlığı değerini 0.38-039 mm aralığında belirlemiştir. Çalışmada bulunan yumurta kabuk kalınlığı değerleri, Jumbo için 0.517-0.624 mm aralığında Xlarge için 0.452-0.772 ve Large için 0.414-0.464 aralığında bulunmuştur. Araştırmada incelenen yumurtaların kabuk kalınlıklarının normal sınırlardan daha yüksek olduğu görülmektedir.

Farklı ağırlık gruplarına ait yumurta örneklerinin diğer dış kalite özellikleri olarak, yumurta renk özellikleri için, *L*, a*, b** renk ölçümleri yanında, Kroma, hue açısı ve yumurta genel kabuk rengi (ΔE) Çizelge 7'de, yumurta renk özellikleri için, ağırlık grupları arasındaki çoklu karşılaştırmalara yönelik istatistik karşılaştırmalar, Çizelge 8'de verilmiştir.

Çizelge 7. Ağırlık grubuna ait yumurta örneklerinin bazı renk karakteristikleri

Ağırlık grubu	Renk karakteristikleri	Ortalama	Maksimum	Minimum	Standart sapma	Varyasyon katsayısı	Standart hata
Jumbo	L*	67.72	69.71	65.39	1.468	2.168	0.379
	a*	13.87	14.88	11.83	0.999	7.201	0.258
	b*	21.81	23.48	20.16	1.070	4.905	0.276
	Kroma	69.14	71.12	67.00	1.329	1.922	0.343
	Hue açısı	0.20	0.22	0.17	0.017	8.397	0.004
	ΔE	72.51	74.11	71.11	1.053	1.452	0.272
XLarge	L*	69.86	74.25	65.73	2.864	4.100	0.740
	a*	12.25	14.02	10.18	1.256	10.247	0.324
	b*	21.43	24.12	14.67	3.550	16.562	0.917
	Kroma	70.94	74.95	67.10	2.631	3.708	0.680
	Hue açısı	0.17	0.21	0.14	0.024	13.596	0.006
	ΔE	74.21	76.41	71.18	1.770	2.385	0.457
Large	L*	66.36	69.41	61.87	2.35	3.55	0.61
	a*	12.34	14.40	9.24	1.86	15.09	0.48
	b*	22.52	24.81	19.17	1.65	7.33	0.43
	Kroma	67.53	70.27	63.34	2.08	3.08	0.54
	Hue açısı	0.18	0.22	0.14	0.03	17.38	0.01
	ΔE	71.20	73.97	66.29	2.344	3.292	0.606

L: Parlaklık, *a*: Kırmızılık, *b*: Sarılık, *ΔE:* Yumurta kabuk genel rengi

Çizelge 8. Farklı ağırlık gruplarına ait yumurta örneklerinin bazı renk karakteristiklerine ait istatistik hesaplamalar.

Ağırlık grubu	L^*	a^*	b^*	Kroma	Hue açısı	ΔE
Jumbo	67.72^b	13.87^a	21.81	69.14^b	0.20^a	72.508^b
XLarge	69.86^a	12.25^b	21.43	70.94^a	0.17^b	74.214^a
Large	66.36^b	12.34^b	22.52	67.53^c	0.18^{ab}	71.197^b
F değeri	**8.79****	**6.20****	**0.83^{ns}**	**10.09****	**4.68***	**10.580****

L: Parlaklık, *a*: Kırmızılık, *b*: Sarılık, *ΔE:* Yumurta kabuk genel rengi

Kabuk rengi, yumurtanın besin değeri üzerine etkili bir özellik değildir. Ancak tüketici tercihini etkilemesinden dolayı yemeklik yumurtalarda önem kazanmaya başlamıştır. Kahverengi yumurtacılarda, yumurta kabuk renginin koyu olması tüketiciler tarafından tercih edilen bir özelliktir (Sarıca ve Erensayın, 2009).

Altan (1993), yaptığı araştırmada dış kalite özelliği olarak kabuk renginin tüketici tercihinde öncelikli olduğunu belirtmiştir. Demirulus ve ark. (1996)'ya göre Van ilinde beyaz yumurta fazla tüketilirken Kahramanmaraş'ta kahverengi yumurta beyaz yumurtaya göre %4.17'lik fark ile daha fazla tüketilmektedir. Yapılan birçok çalışmada, muhafaza şartlarının yumurtanın fiziksel, kimyasal ve mikrobiyolojik kalitesi etkisinde rolü olduğunu ve tüketicilerin yumurta tüketiminde yumurtanın tazeliğine, kabuk rengine ve yumurta sarı renginin önemli parametreler olduğunu bildirmişlerdir (Demirulus ve ark., 1996; Uluocak ve ark., 1998; Avan ve ark., 2001).

Jumbo, XLarge, Large gruptaki yumurtalar için ortalama *ΔE* değeri sırasıyla 72.51, 74.21, 71.20 belirlenmiştir (Çizelge 3). XLarge ve Jumbo yumurtaların kabuk rengi parlaklığının Large grup yumurtalardan daha yüksek olduğu; Kırmızılık (*a**) değeri bakımından Jumbo ve Large'nin, XLarge'den daha yüksek olduğu; Sarılık (*b** değeri) bakımından *L** ve Jumbo yumurtaların XLarge'den daha yüksek olduğu belirlenmiştir (Çizelge 7). *L*, a*,* Kroma ve ΔE değerleri bakımından gruplar arasındaki farklılığın önemli olduğu belirlenmiş ($P<0.01$), gruplar arasında *b** değeri bakımından önemli fark bulunmamıştır. Buna karşın hue açısının gruplar arasında $P<0.05$ düzeyinde önemli olduğu tespit edilmiştir (Çizelge 8).

Durmuş ve ark. (2010), kahverengi yumurtacı saf hat yumurtalarının kabuk rengi özelliklerinden *L*, a** ve *b** değerlerini; Barred Rock-1 için sırası ile 67.77, 7.22, 22.73; Rhode Island Red-2 için 64.95, 8.08, 4.30; Colombian için sırasıyla 67.81, 4.30, 19.31 olarak bildirmiştir. Duman ve ark. (2016), *ΔE* değerinin 70.07-71.03 aralığında değiştiğini belirlemişlerdir. Araştırmada incelenen gruplardaki renk karakteristik değerlerinin literatürler ile benzerlik gösterdiği belirlenmiştir.

4. SONUÇ

Çalışmada bulunan sonuçlar aşağıda sıralanmıştır.

-Yumurta ağırlığı arttıkça, yumurtaların dış kalite özelliklerinden uzunluk, genişlik ve geometrik ortalama çap, değerleri artmıştır.

-Galvanizli sac, PVC, kontrplak, laminant ve lastik gibi çeşitli yüzeylerdeki statik sürtünme katsayıları yumurta ağırlığının artmasıyla doğrusal olarak artmıştır. Lastik yüzeyde maksimum sürtünme katsayısı belirlenmiştir.

- Yumurta ağırlığı arttıkça, yumurtaların dış kalite özelliklerinden ağırlık ve yüzey alanı değerleri artmıştır.

-XLarge ve Jumbo yumurtaların kabuk rengi parlaklığının Large grubu yumurtalardan daha yüksek olduğu; kırmızılık (*a**) değeri bakımından Jumbo ve Large'nin, XLarge'den daha yüksek olduğu; Sarılık (*b** değeri) bakımından *L** ve Jumbo yumurtaların XLarge'den daha yüksek olduğu belirlenmiştir.

Sonuç olarak, yumurtaların iç ve dış kalite özellikleri, yumurtaların toplanması, sınıflandırılması, nakliyesi, paketlenmesi ve depolanması açısından önemli olan özellikler olup, bu özelliklerin dikkate alınması gereklidir.

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Mass Prediction of Apple Fruit by Using Nondestructive Impact Technique

Hasarsız Çarpma Tekniği Kullanarak Elma Meyvesinin Kütle Tahmini

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ABSTRACT

In this study, it was aimed to estimate the mass of apples by using the nondestructive impact technique and to develop different model approaches. Starkrimson apple varieties were used in the experiments. In the prediction of apple mass, 10 nondestructive impact parameters were taken into consideration using impact force-time curves, and the number of impact parameters were reduced by stepwise regression analysis method to be used in the mathematical model (F_{max1}, t_{max}, t_{max1}, I_a and t_{P1-2}). Apple mass prediction was made by using these parameters in the multiple linear regression analysis method (MLR). According to the results of statistical analysis, developed mathematical model predicted the apple mass with 3.07 g and 3.35 g prediction error in the calibration and validation data set, respectively. In the calibration and validation data set, determination coefficients of the apple mass prediction (R^2) were calculated as 0.94 and 0.93, respectively. The success of the mass prediction model according to the mass groups classified according to the cluster analysis was also determined. According to the results of the data group analysis, the true accuracy of the model approach was calculated as 32. In addition, the success of the classification of apple samples was calculated as 94.11%.

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ÖZ

Bu çalışmada, hasarsız çarpma tekniğini kullanarak elma kütlesini tahmin etmek ve farklı model yaklaşımları geliştirmek amaçlanmıştır. Deneylerde Starkrimson elma çeşitleri kullanılmıştır. Elma kütlesinin tahmininde, 10 hasarsız çarpma parametresi, çarpma kuvveti-zaman eğrileri kullanılarak dikkate alınmış ve matematiksel modelde kullanılmak üzere stepwise regresyon analizi yöntemi ile çarpma parametrelerinin sayısı azaltılmıştır (F_{max1}, t_{max}, t_{max1}, I_a and t_{P1-2}). Elma kütle tahmini, bu parametreler kullanılarak çoklu doğrusal regresyon analizi yöntemiyle (MLR) yapılmıştır. İstatistiksel analiz sonuçlarına göre geliştirilen matematiksel model, elma kütlesini kalibrasyon ve doğrulama veri setinde sırasıyla 3.07 g ve 3.35 g tahmin hatası ile tahmin etmiştir. Kalibrasyon ve doğrulama veri setinde elma kütle tahmini belirleme katsayıları (R^2) sırasıyla 0,94 ve 0,93 olarak hesaplanmıştır. Kümeleme analizine göre sınıflandırılan kütle gruplarına göre kütle tahmin modelinin başarısı da belirlenmiştir. Veri grubu analizi sonuçlarına göre model yaklaşımının gerçek doğruluğu 32 olarak, ayrıca elma örneklerinin sınıflandırma başarısı da %94,11 olarak hesaplanmıştır.

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1. INTRODUCTION

The world market for fresh fruit exports was 70 billion dollars, Turkey's share of slightly over 1.95%. Here, the increase in exports to Turkey not adequately reflect the amount of production and exchange that will bring $ 3 billion a year leads to the conclusion can not assess the sector. The reasons for this include: lack of infrastructure in packaging house facilities (pre-cooling, grading machines, cold air and packaging etc.) and failure to implement appropriate technologies and innovations in the packaging house facilities (use of manual or mechanical classification technology), as well as initial investment costs due to the fact that the companies cannot offer standardized fruits and vegetables to the foreign market and the ideal classification and packaging technology for retail sales has not been developed. Therefore, our competitiveness with other countries remains weak (Anonymous, 2017).

In our country, many conditions for the production of fruits and vegetables are tried to be provided by the producers but the technological level cannot be achieved in the classification and packaging. As a result, the competitive power required by the market conditions cannot be achieved and the breakthroughs in automation of packaging technology are tried to be compensated by technology imports. For this reason, our country is paying millions of dollars for packaging technology and bringing the economy to foreign dependency and bringing about significant adversities in the development of domestic technologies.

Electronic sorting lines are now widely used in classifications based on fresh fruit and vegetable packaging technology. Image processing modules are widely used in electronic classification lines. Electronic classification lines, which are not common but have dynamic weighing modules which are based on mass measurement, are also used in the classification of fresh fruits and vegetables. The color and size sensitive classification are made with image processing modules, and the products can be classified into both color and size. In these systems, it is carried out using the camera. In the electronic classifiers with dynamic weighing module, it is made by taking into consideration only the mass and the load cells are used. In recent years, the awareness of consumers and the resulting demand have made the use of electronic classification lines with double modules mandatory. In the systems with double modulus, which have both image processing and dynamic weighing module, classification can be made by using color, size and mass parameters. For example, in the classification based on size measurements, the volume can be estimated using the dimensions measured with the camera and the density can be calculated by correlating with the measured mass in the dynamic weighing module.

Packaging house firms that export fresh fruits and vegetables take into account some classification criterias and are obliged to comply with these criteria. For example, although exporting companies comply with some classification standards, the recipient countries determine the content of the products to be classified. Especially in recent years, instead of regular packaging in fruit packages, fruit and vegetable requests with the same size, color and mass have made it necessary to use electronic classification machines that have both image processing module and dynamic weighing module. For instance, in apple classifications using image processing technique, the difference between the dimensions of the fruit dimensions in width and height makes it difficult to classify the desired standard. This shows that the image processing technique is not sufficient in the classification of products of the desired dimensions.

In addition, it is not possible to select fruit varieties with dimensional trapezoidal geometry. Geometric scale classification of the fruit in various sizes according to the geometric size is grouped according to the size parameters that vary and in the three categories determined by the equivalent of large grams (mass) differences between the sizes are clearly seen. As a result, even the fruits of the same size (apple, tomato and citrus) have different weights due to their density difference. This situation can cause large fluctuations in packaging made only by size and quantity. When weight sensitive (dynamic weighing) classification systems are used, the standardization rate in the fruits classified will increase. This will provide significant gains in the economic sense.

Many researchers have investigated the relationship between size and mass of fresh fruits and vegetables by using image processing technique. These researchers have developed model equations for the prediction of volume and mass by using size parameters of some fruits such as apple, orange, tomato, pomegranate and fig (Tabatabaeefar and Rajabipour, 2005; Khosnam et al. 2007; Vursavuş ve Özgüven, 2008; Spreer and Müller, 2011; Shahbazi and Rahmati, 2012; Ghazavi et al. 2013; Sabzi et al. 2013; Izadi et al. 2014; Schulze et al. 2015). As stated above, in the measurements using image processing technique, even if the fruits are of the same size, their masses may be different due to the density difference. Especially apples, tomatoes and citrus fruits are also evident. Instead of real-time measurements, the calculation of the mass will be a more accurate approach. The classification with dynamic weighing module is carried over the load cells on the fruits and vegetables carrier system and the measurements are taken and the masses are predicted using different mathematical calculation methods (Elbeltagi, 2011). In addition, mass prediction of fruits and vegetables can be made by using the method of dropping onto the force sensor from the heights that will not damage the product. McGlone et al. (1997), Qarallah et al. (2008) and Vursavus and Kesilmiş (2016) have predicted the kiwi, onion and tomato mass, respectively with the mass-moment relationship by using the nondestructive impact technique. Furthermore, nondestructive impact technique was also used for sensing of fruit firmness (Delwiche ve ark., 1987; Gutierrez ve ark., 2007; Lien ve ark., 2009; Ragni ve ark., 2010 ve Vursavuş ve ark., 2017).

To develop a mass prediction model which will be used in the prediction of the mass of apple fruit by the nondestructive impact technique was aimed in this study. In the development of mass prediction model, multiple linear regression (MLR) analysis method was used.

2. MATERIALS AND METHODS

2.1. Materials

The apple samples were purchased from the same batch in a local market of Adana, Turkey, and stored at room temperature. Starkrimson apple variety was used in this study. The apples were chosen in different sizes to create different mass groups. A total of 120 apple samples, which are free from mechanical damage were measured in the experiments. The size and mass of the apples used were measured and recorded.

The dynamic impact test device was used to perform the impact test (Figure 1). Impact reaction of apple fruit falling onto a force transducer was investigated and nondestructive impact parameters were measured by the dynamic impact test device. The test device consists of (1) silent compressor, (2) vacuum pump, (3) on-off valve, (4) suction cup, (5) connection hoses, (6) impact plate, (7) force transducer, (8) charge amplifier, (9) data acquisition card and (10) software.

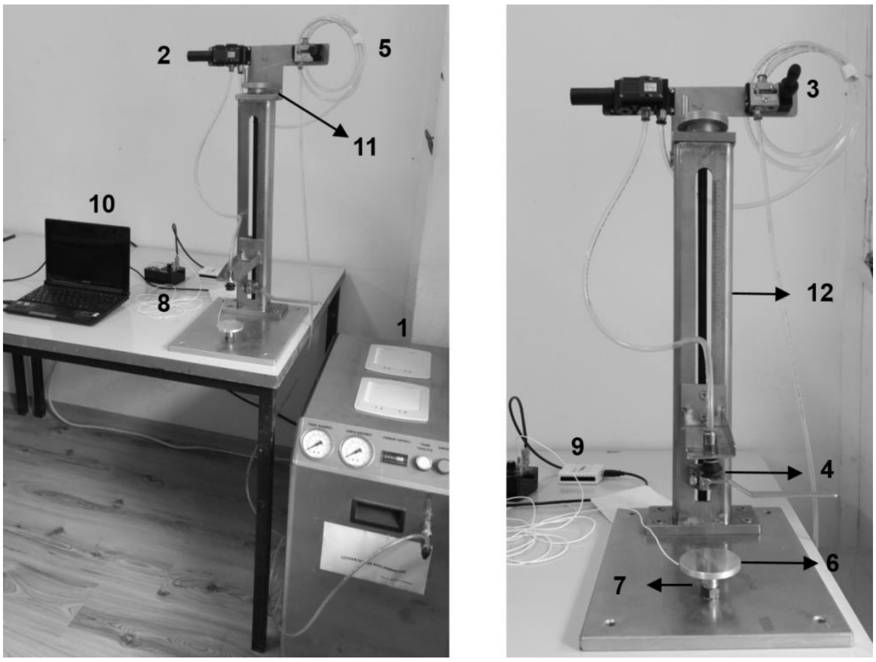

Figure 1. General view and components of the dynamic impact test device (Tüdeş, 2019)

The dropping height of the fruits can be adjusted by the help of the height adjustment lever on the test device (11). On the side of the test device there is a scale ruler that allows adjustment of falling heights (12). Vacuum effected apple samples by means of suction cups are dropped onto the impact plate by removing the vacuum effect with the help of the on-off valve.

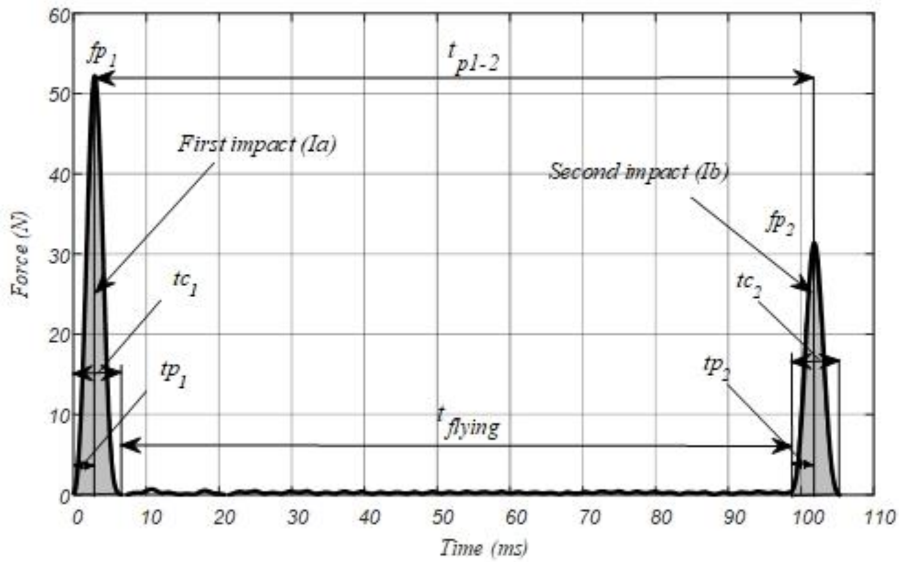

Figure 2. Sample graph for impact force-time and measured nondestructive impact parameters

In the drop test, the distance between the apple and the impact plate was set to 15 mm as suggested by Stropek and Golacki (2007) and Vursavus and Ince (2007), and this distance was checked before each drop. Under the impact plate, the force transducer was screwed. The signals detected by the force sensor were taken using the NI USB-6009 data acquisition card (DAQ). The signals obtained were amplified by means of a single channel amplifier (Model 4102C, DYTRAN) and digitized using an analog-to-digital converter of a 14 bit precision data acquisition card. The signals of the force sensor were selected at a sampling rate of 100 kHz. Measured force data were processed using MATLAB software. The MATLAB software interface allows simultaneous display of single and binary multiplication force-time graphs. The sample graph of the impact force-time and measured impact parameters displayed during the drop tests were given in Figure 2.

2.2. Methods

In the drop tests performed onto force sensor, apple samples were dropped on the impact plate from the cheek region along the flower-stem axis. Symbols, definitions and units of nondestructive impact parameters measured after the impact were given in Table 1. During the experiments, 120 apple samples with different mass groups were studied. In order to predict the mass of apple samples, nondestructive impact parameters given in Table 1 were used.

The impulse values of the first and second impacts ($I_{a,b}$) refer to the area under the impact force-contact time curve. These impact parameters were calculated using the equation given below (Qarallah ve ark., 2008).

$$I_{a,b} = \int_0^{t_c} f(t)dt = \frac{1}{f_s}\sum_{i=1}^{t_c f_s} f_i \tag{1}$$

Where; $I_{a,b}$ is the impulse value of the first and second impacts (Nms), t_c is the contact times of the first and second impacts (ms), f is the maximum force of the first and second impact (N) and f_s is the sample number of the first and second impact zones.

Table 1. Nondestructive impact parameters

Symbol	***Definitions***	***Measurement unit***
f_{P1}	Maximum impact force of the first impact	N
f_{P2}	Maximum impact force of the second impact	N
I_a	Impulse value of the first impact	Nms
I_b	Impulse value of the second impact	Nms
t_{C1}	Contact time of the first impact	ms
t_{C2}	Contact time of the second impact	ms
t_{flying}	Required duration between two impacts	ms
t_{P1}	Maximum duration of the first impact	ms
t_{P2}	Maximum duration of the second impact	ms
t_{P1-2}	Duration between the maximum times of the first and second impacts	ms

Mathematical model equations were developed by using MLR analysis method for mass prediction of Starkrimson apples. 10 nondestructive impact parameters were used as independent variables in the statistical evaluations (Table 1). The use of 10 impact parameters in mathematical model developments can cause numerical and logical complexity in real time applications. Therefore, stepwise regression analysis method was used to reduce the number of impact parameters. In this research, the following model equation was used for MLR analysis.

$$M_W = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n \tag{2}$$

Where: M_W is the apple mass , X_1, X_2 ... X_n are the the independent variables described in Table 1, and β_0, β_1, β_2... β_n are the regression coefficients of the model.

A total of 120 data of different mass and size levels, which were used for the mass classification of Starkrimson apple varieties were first subjected to cluster analysis (CA). Thus, it was decided that what should be the mass class intervals statistically. The aim was to measure the success of the classification prediction in the mass class ranges of the mass prediction model.

The mean mass values obtained for 120 apples used in the mass prediction model were firstly divided into two groups. 70% of the mass data were used for calibration and 30% for validation. Mathematical model equation of the mass prediction was created by using 70% data set. 30% data set was used to verify the developed model equation. SPSS 20.0 package program was used in all statistical evaluations. The root mean square error (RMSE), the mean absolute error (MAE) and the mean absolute error percentage (MAPE) of the calibration and validation data sets were used in the performance evaluations of the developed model equations by the following equations.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y_i^{act} - Y_i^{pred})^2} \quad (3)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i^{act} - Y_i^{pred}\right| \quad (4)$$

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\frac{\left|Y_i^{act} - Y_i^{pred}\right|}{Y_i^{act}}\right).100 \quad (5)$$

Where: RMSE is the root meansquare square error, MAE is the mean absolute error, MAPE is the average absolute error percentage, Y_i^{act} is the i. measured value, Y_i^{pred} is the i. the predicted value and n: the total number of measurements.

For the whole model evaluation, the coefficient of determination (R^2) was also calculated and given in equation 6.

$$R^2 = \left[\frac{\sum_{i=1}^{n}(Y_i^{act} - Y_{ort}^{act})(Y_i^{est} - Y_{ort}^{pred})}{\sqrt{\sum_{i=1}^{n}(Y_i^{act} - Y_{ort}^{act})^2}\sqrt{\sum_{i=1}^{n}(Y_i^{pred} - Y_{ort}^{pred})^2}}\right] \quad (6)$$

Where: Y_i^{act} is the i. measured value, Y_i^{pred} is the i. predicted value, Y_{ort}^{act} is the mean of the measured value, Y_{ort}^{est} is the the mean of the predicted value, R^2 is the the coefficient of determination, and n is the number of total measurements. The R^2 value ranges from 0 to 1.

According to these criterias, the model that gives a higher value of R^2 and lower values of RMSE, MAE and MAPE were determined as the optimal model.

3. RESULTS AND DISCUSSION

Some physical properties of 120 apple samples at different mass and size levels used for mass classification of Starkrimson apple varieties were given in Table 2

Table 2. Some physical properties of Starkrimson apple varieties used in experiments

Properties	***Mean***
Mass (g)	143.90±38.71
Equatoral fruit diameter (mm)	66,77±6.12
Geometric mean diameter (mm)	60.76±5.20
Sphericity (%)	91.09±2.28
Surface area (cm2)	116.77±20.11
Volume (cm3)	135.96±35.74
Density (g/cm3)	1.06±0.06

Pearson correlation matrix results related to nondestructive impact parameters given in Table 1 and used as independent variables were given in Table 3. As shown in Table 3, all nondestructive impact parameters were statistically significant at 1% (P <0.01) level. Therefore, all impact parameters were used in MLR analysis. A stepwise regression analysis was performed using the apple mass as dependent variable and all the other ten variables in Table 1 as independent variables, and statistical data summaries of model equations developed according to the results were given in Table 4.

Table 3. Correlation coefficients between nondestructive impact parameters and apple mass

Mass	***Nondestructive impact parameters***									
	I_a	I_b	f_{P1}	f_{P2}	t_{P1}	t_{P2}	t_{c1}	t_{c2}	t_{flying}	t_{P1-2}
M_W	0.70**	0.65**	0.86**	0.69**	0.63**	0.62**	0.46**	0.64**	-0.43**	-0.44**

** Correlation is significant at 1% (P<0.01). M_W is the measured apple mass

9 models were developed according to stepwise regression analysis and the nondestructive impact parameters (independent variables), correlation coefficients (R), coefficients of determination (R^2) and adjusted coefficients of determination (R^2), were given in Table 4. The number of parameters is kept to a minimum in order to avoid numerical and

logical complexity in multi parameter relationships. When an evaluation is made from this point, using the model equation with five parameters and making the apple mass prediction accordingly will be a correct approach. Although the coefficients of determination were higher in the model equations with 6 and above parameters, it was determined that RMSE does not change much or even higher. For this reason, it was concluded that it was more accurate to make five parameter selection in the development of the mass prediction model equation.

Table 4. Statistical data summaries of model equations developed according to stepwise regression analysis

Model No	***R***	***R^2***	***Adjusted R^2***
1	0.862[a]	0.743	0.740
2	0.947[b]	0.896	0.894
3	0.958[c]	0.918	0.915
4	0.966[d]	0.932	0.929
5	**0.970[e]**	**0.941**	**0.937**
6	0.973[f]	0.946	0.942
7	0.976[g]	0.952	0.948
8	0.979[h]	0.959	0.955
9	0.981[i]	0.962	0.957

[a] f_{P1},
[b] f_{P1}, t_{flying}
[c] f_{P1}, t_{flying}, t_{P1}
[d] f_{P1}, t_{flying}, t_{P1}, I_a
[e] f_{P1}, t_{flying}, t_{P1}, I_a, t_{P1-2}
[f] f_{P1}, t_{flying}, t_{P1}, I_a, t_{P1-2}, I_b
[g] f_{P1}, t_{flying}, t_{P1}, I_a, t_{P1-2}, I_b, f_{P2}
[h] f_{P1}, t_{flying}, t_{P1}, I_a, t_{P1-2}, I_b, f_{P2}, t_{c2}
[i] f_{P1}, t_{flying}, t_{P1}, I_a, t_{P1-2}, I_b, f_{P2}, t_{c2}, t_{P2}

Table 5. Performance Assessment Criterias for Measured and Predicted Values of Model Approach Used for Apple Mass Prediction.

Calibration (n=84)	***RMSE***	***MAE***	***MAPE***	***R^2***
Model 1	12,86	0,14	24,32	0,74
Model 2	5,98	0,03	5,24	0,89
Model 3	4,66	0,08	3,98	0,91
Model 4	3,73	0,94	3,47	0,93
Model 5	3,07	0,14	4,98	0,94
Model 6	2,97	0,35	1,98	0,95
Model 7	2,20	0,99	0,63	0,95
Model 8	2,55	0,41	0,26	0,96
Model 9	2,27	0,22	0,14	0,96
Validation (n=36)	**RMSE**	**MAE**	**MAPE**	**R^2**
Model 1	7,56	0,14	28,35	0,75
Model 2	4,42	1,18	18,19	0,88
Model 3	4,05	1,40	20,67	0,93
Model 4	3,75	0,32	5,34	0,94
Model 5	3,35	0,64	3,34	0,93
Model 6	2,93	0,66	2,80	0,92
Model 7	2,13	0,06	2,81	0,91
Model 8	2,96	0,56	2,68	0,93
Model 9	2,48	0,67	2,89	0,93

Performance evaluation measurements were made using calibration and validation data sets and given in Table 5. RMSE performance parameters were calculated as 3.07 g and 3.35 g in the calibration and validation datasets, respectively. The RMSE values of the model equation were found lower in the calibration data group compared to the validation data group. The root mean square error (RMSE) value obtained by using model equation indicates that the apple fruit mass is measured as ± 3.07 g in the calibration data group and ± 3.35 g in the validation data group. The mean absolute error (MAE) of the calibration data groups was lower than the MAE values (0.64 g) with a value of 0.14 g. In addition, the mean absolute error percentage (MAPE) of the calibration data groups was found to be slightly higher than the MAPE values of the validation data groups with a value of 4.98%.

When an evaluation is made through the model approach performance parameters given in Table 5 the mass prediction model equation for both the calibration (R^2 = 0.94) and the validation (R^2 =0.93) datasets has given a good prediction results. Vursavus and Kesilmis (2016) calculated the coefficients of determination (R^2) of tomato mass prediction model that they developed for calibration and validation data sets as 0.94 and 0.92, respectively. Similar results were also determined for mass estimation of apple fruits in our study. In addition, the coefficients of the model equations based on the nondestructive impact parameters determined by stepwise regression analysis for calibration datasets were given in Table 6.

Table 6. Statistical coefficients of model equation for apple mass prediction model based on parameters determined by stepwise regression analysis using the calibration data sets.

Model	***Non-Standardized Coefficients***	
	Coefficient	***Standard error***
Constant	102.61	24.23
f_{P1}	2.12	0.13
t_{flying}	-1.26	0.17
t_{max1}	14.72	2.95
I_a	0.15	0.03
t_{P1-2}	-0.51	0.15

Table 7. The statistical results of the calibration and validation data sets estimated from the developed model approach and containing the actual measurement values.

	Measured	*Estimated*
		M_w=102.61+2.12*f_{P1}-1.26*t_{flying}+14.72*t_{P1}+0.15*I_a-0.51*t_{P1-2}
Calibration (n=84)		
Mean (g)	142.56	142.42
Standard deviation (±)	37.45	36.40
Minimum (g)	70.61	76.00
Maximum (g)	239.82	232.66
Median (g)	132.13	135.09
Validation (n=36)		
Mean (g)	147.02	145.51
Standard deviation (±)	41.91	38.02
Minimum (g)	80.57	78.00
Maximum (g)	210.91	230.90
Median (g)	153.29	158.79

The statistical results of the calibration and validation datasets were examined in Table 7. According to the statistical results of the measured data groups given, the median value of the validation datasets (132.13 g) was higher than the median value of the calibration datasets (153.29 g). However, the results of U-test (Mann-Whitney) showed that the difference between the calibration and validation data sets was statistically insignificant (p> 0.05). The measured and predicted mean and median mass values were also statistically insignificant according to the results of the t-test conducted with the measured and estimated apple mass values with 5 parameters (P> 0.05). The model developed for apple mass prediction using multiple linear regression analysis method (MLR) was given in equation 7.

$$M_W = 102.61 + 2.12 f_{P1} - 1.26 t_{flying} + 14.72 t_{P1} + 0.15 I_a - 0.51 t_{P1-2} \quad (7)$$

Table 8. Apple mass groups according to cluster analysis results

Mass groups	***Number***	***Apple mass (g)***	
		Mean	***Standard deviation ±***
Small (S)	28	100.32	11.00
Medium (M)	58	153.39	18.55
Large (L)	34	197.72	22.22

The 120 samples of apple mass data were primarily subjected to cluster analysis (CA). According to the CA results, 120 apple samples were divided into 3 mass groups. The aim was to measure the success of the classification prediction in the mass class ranges of the mass prediction model. CA results of three different mass groups are given in Table 8. As shown in Table 8, 28 apple samples in small apple group with an average value of 100.32 ± 11.00 g, 58 apple samples with 153.39 ± 18.55 g mean apple group and 34 apple samples with an average value of 197.72 ± 22.22 g group. Class ranges with CA were determined as M_W <112.16 g for the small apple group, 112.16 için M_W for the medium apple group, and M_W≥166.93 g in the large apple group. 120 samples of Starkrimson apples were classified by taking into consideration these mass sizes.

When the results of the calibration datasets given in Table 9 are examined, it is seen that the real accuracy of the model approach developed for mass prediction was 72. True positive tells us that 72 of the 84 apple samples were in the actual groups. For validation datasets, true positive was found to be 32. The data on the classification success of the calibration and validation model approaches used in the mass prediction of apple samples of mass groups were given in Table 9. In addition, the classification success rate of the mass prediction model was calculated as 85.71%. The 85.71% classification success is also based on the actual groups of about 86 of us means that it is classified. Similarly, calculations were made within the validation datasets and the true accuracy of the model approach was calculated as 32. In addition, the success of the classification of the apple samples belonging to the validation data group was found to be higher than the classification success rate in the calibration data groups with 94.11%.

The relationship between the measured and predicted mass of the calibration (84) and validation (36) datasets was given in Figure 3 and 4. In addition, the model equation for the measured and estimated mass and the coefficient of determination (R^2) were calculated and shown in the Figures. As seen from the Figures, the measured and predicted apple mass relation of the calibration datasets was 94% and this relation was determined as 93% for the validation datasets.

Table 9. The classification success of the calibration and validation model approaches used in the mass prediction of apple samples of mass groups.

Data set		***S_M***	***M_M***	***L_M***	***True positive***	***Success rate***
Calibration (n=84)		n= 20	n= 40	n= 24		(%)
	S_E	15	5	0		
MLR	M_E	3	35	2	72	85.71
	L_E	0	2	22		
Validation (n=36)		n= 8	n= 18	n= 10		(%)
	S_E	8	0	0		
MLR	M_E	1	16	1	32	94.11
	L_E	0	2	8		

K = Small (MW <112.16 g), O = Medium (112.16≤ MW <166.93 g) and B = Large (MW ≥166.93 g) and KE, OE and BE = Estimated apple sizes; IR, OÖ and BÖ = Measured mass sizes.

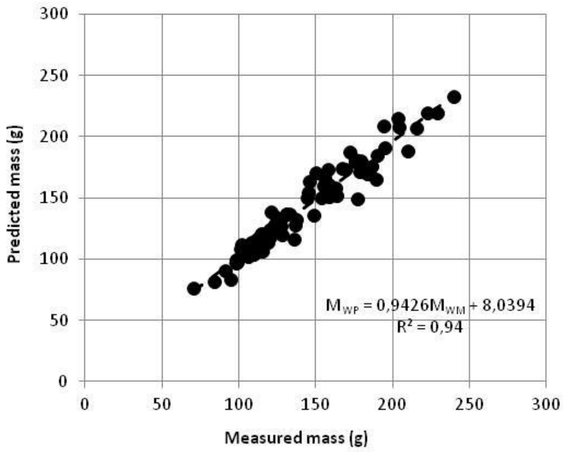

Figure 3. Relationship between measured and estimated mass for calibration datasets

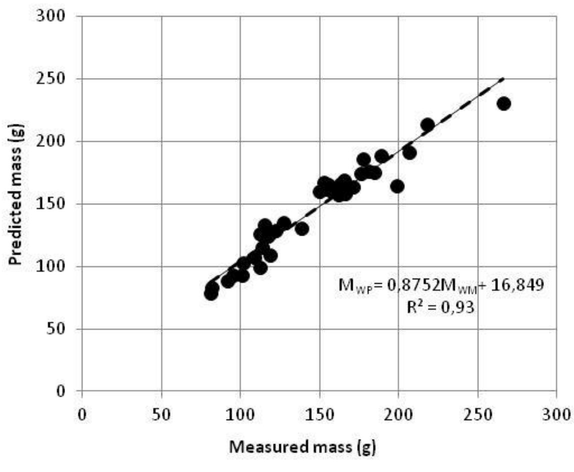

Figure 4. Relationship between measured and estimated mass for validation datasets

4. CONCLUSION

As a result of the measurements made with the apple mass prediction model, which was developed by using multiple linear regression analysis method, it was determined that the most suitable model was the model with five parameters by using the nondestructive impact technique and stepwise regression analysis method. In the mass prediction model, Fmax1, tmax, tmax1, Ia, and tP1-2, parameters as impact parameters were chosen according to stepwise regression analysis. It was concluded that the MLR model developed using these parameters could be used for the mass prediction of apples. As a result of the performance evaluation measurements obtained for the apple mass prediction model, the square root (RMSE) values of the calibration and verification error squares mean were calculated as 3.07 g and 3.35 g, respectively. These results show us that an approximate ± 3 g deviation occurs in the calibration and validation datasets in an apple sample. In electronic fruit sorting lines, load cells are used in dynamic weighing and real time mass measurements and their classification sensitivities are ± 1.50-2.00 g. Using the developed model equation, the deviation values were slightly higher when the apple mass RMSE values obtained by the impact technique on the force sensor were compared. By using mechanical, software and hardware arrangements and apple samples in wider mass ranges, the apple mass prediction to be performed by using the non-destructive technique in electronic classification lines may be an alternative to the method of measurement based on dynamic weighing method.

In the mass measurements performed by the drop technique on the force sensor, the apple multiplies twice as described in the method section. Depending on the mechanical property of the fruit and the height of the fall, a time of approximately 100 ms is needed. Depending on the software to be used, approximately 200 ms of apple mass prediction can be made. Measuring time of 200 ms means that approximately 5 fruits can be classified per second. As a result, it is concluded that the apple mass prediction to be made by using the undamaged impact technique at low altitude can be used in real-time electronic fruit classification lines, and additional studies that are mentioned above for some software and hardware improvements are needed. The described method of mass prediction does not require the tested object to stop on the surface. That is why it can be used at fruits/vegetables sorting lines. There is a certain disadvantage of this method that a fruit has to bounce twice. It is related to specified duration of the measurement time depending on fruit elasticity and drop height. The use of this method in modern sorting lines would require a design of a suitable measure position in order to reduce the transport time of a single fruit.

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Review of Wear on Tillage Tools: Constraints in Transferring of the Research Findings to the Agricultural Sector and Solution Proposals

Toprak İşleme Araçlarında Aşınma Konusunun Değerlendirilmesi: Araştırma Bulgularının Tarım Sektörüne Aktarılmasındaki Kısıtlamalar ve Çözüm Önerileri

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ABSTRACT

The aim of the study is to present the course of scientific developments of wear studies in soil tillage tools and to evaluate basic constraints in transferring the research results to the farm systems and the solution proposals. In this study, the studies conducted to analyze and reduce the wear losses in soil tillage tools in the last century are presented chronologically. Hereby, in the first stage of the study, it is aimed to present the course of scientific developments in this field. In the second phase, the reflection of the scientific research results in the agricultural sector was evaluated for Turkey. As a result of the investigation, it is observed that the developments in the field of materials science have been reflected in research aiming to improve the wear resistance of agricultural tillage tools and studies generally have focused on heat treatments and coatings. It is understood that the level of the economic prosperity of small-medium-sized farms, and the poor financial structures of small-medium-sized machinery manufacturers are the most important constraints in transferring the research results to the farm systems. As a result of the study; development of policies to strengthen the weak economic purchasing power of small-medium scale farms, and the weak financial structures of small-medium scale machinery manufacturers, and to reduce costs using new production technologies suitable to automation can be suggested.

Makale Bilgisi

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Toprak İşleme Makineleri
Aşınma

ÖZ

Çalışmanın amacı, toprak işleme makineleri konusunda yapılan aşınma çalışmalarının bilimsel seyrini sunmak ve araştırma sonuçlarını çiftlik sistemlerine aktarılmasında karşılaşılan temel kısıtlamaları ve çözüm önerilerini değerlendirmektir. Bu çalışmada, son yüzyılda toprak işleme makinelerindeki aşınma kayıplarını analiz etmek ve azaltmak için yapılan çalışmalar kronolojik olarak sunulmuştur. Çalışmanın ilk aşamasında bu alandaki bilimsel gelişmelerin seyrinin sunulması amaçlanmıştır. İkinci aşamada, bilimsel araştırma sonuçlarının tarım sektörüne yansıması Türkiye açısından değerlendirilmiştir. Yapılan incelemeler sonucunda, malzeme bilimi alanındaki gelişmelerin toprak işleme araçlarının aşınma direncini geliştirmeye yönelik araştırma çalışmalarına yansıdığı ve çalışmaların genellikle ısıl işlemler ve kaplamalar konuları üzerinde yoğunlaştığı görülmektedir. Küçük-orta ölçekli çiftliklerin ekonomik refah düzeyi ve küçük-orta ölçekli makine üretici firmaların zayıf finansal yapılarının araştırma sonuçlarının çiftlik sistemlerine aktarılmasındaki en önemli kısıtlar olduğu görülmektedir. Sonuç olarak; küçük-orta ölçekli çiftliklerin zayıf ekonomik satın alma gücünü, ve küçük-orta ölçekli makine üreticilerinin zayıf finansal yapılarını güçlendirmeye yönelik politikaların geliştirilmesi ve makine üretim maliyetleri azaltmak için otomasyona uygun yeni üretim teknolojileri kullanımı önerilebilir.

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1. INTRODUCTION

The development of tillage dates back to ancient times when agriculture began. During those times, sticks and stones were used for the tillage works. There are also pieces of evidence indicating that plough was used in Mesopotamia and the Egyptian Nile Delta 3-4 thousand years before Christ (Rehkugler, 2011). The emergence of the modern plough in the early 1800s (Kendall, 1959; Gilbert, 2010; Rehkugler, 2011) and the introduction of the first steel plough in 1837 (Kendall, 1959; Rehkugler, 2011) made a breakthrough in tillage. The explanation of interactions between the soil and the tillage tools and the wear losses in the tillage tools that cause the economic loss of millions of dollars each year has been an issue attracting the interest of researchers. The first Ph.D. thesis entitled "A study of the Plow-bottom and Its Action on The Furrow Slice" on tillage in Agricultural Engineering was written by White in 1917 (Rehkugler, 2011). The first studies on the wear of tillage tools date back to the early 1920s (Hoffman, 1922). The wear that occurs in the tillage implements varies depending on many parameters such as chemical composition of the material used, mechanical and microstructure properties of the used material, surface roughness, soil type, particle shape, size, soil strength and compactness, soil density, moisture content of soil, rock and gravel content, tillage speed and depth, geometry of the tool, and impact angle between the soil and the tool (Yu and Bhole 1990; Owsiak, 1997; Natsis et al., 1999). According to the study conducted by Schulze (1969), to examine breakdown and repair expenses in agricultural machinery, the most important factor causing a depreciation in agricultural machinery is wear. Among the types of damage determined in agricultural tools and machinery, wear is ranked first with a 42.5% share (Önal et al., 1994). Wear losses in tillage tools do not only result in economic losses caused by material, energy and labour losses. One of the most important problems caused by wear in tillage tools is that the tillage cannot be done in accordance with agrotechnical demands. The ploughshares, which are worn but insisted on being used without being replaced, speed up the formation of the plough pan since they cannot cut the soil and do only pushing. The blunted cutting edges of tillage tools are one of the factors that cause compaction in the soil. It is known that plough pan formation leads to a decrease in plant production efficiency by negatively affecting the plant root development, soil ventilation, water movement in soil and microbiological activities in soil (Soane, 1970; Barnes, 1971; Ulusoy, 1981).

The force needed to cut the soil, soil properties (e.g., humidity, density, adhesion, cohesion, and internal friction angle of the soil), interaction characteristics between the tool and soil (e.g., rake angle and friction angle), geometry of the tool, and tillage parameters (e.g., work width, tillage depth, and tillage speed) are known to change as a function. The worn tillage tools and increasing cutting edge thickness increase the need for draft force (Gavrilov and Koruschkin, 1954; Fielke 1996; Natsis et al., 1999) and fuel consumption (Karatish, 1955; Natsis et al., 1999; Derafshpour and Mogaddam, 2013). With the wear of ploughshare, the need for draft force increases by as much as 30% (Gavrilov and Koruschkin, 1954). Fielke (1996) reports that the ploughshare, whose sharp edge is blunted, can increase the draft force by up to 80%. It also becomes difficult for the worn ploughshare to hold on the groove.

Wear can be described as removing of materials from the surface due to interaction with another surface. The basic and most important types of wear are abrasive wear, adhesive wear, fatigue wear, and corrosive wear (Burwell, 1957/58). In a tribosystem, wear varies depending on dynamic, environmental, and material parameters. During wear, the interaction between the metal material and the soil can be said to be quite complex. The soil generally cannot be characterized as a rigid body, and the evidence of cutting and scratching indicates that the forces within even small areas are highly complex and of varying magnitude. During a tillage process, dynamic parameters of an abrading system contain the stresses on the sliding surface and the duration, and rate of sliding so far as it affects the temperature and stability of the sliding surface (Gill and Berg, 1967). The material parameters of the tillage tools that affect the abrasive wear are the hardness, strength, toughness, and surface roughness of the material. There are also parameters that are related to the environmental-soil and that affect wear. These are soil grain-related parameters (size, amount, and sharpness), the water content of the soil, compactness, and pressure of the soil, and presence of some materials (e.g. plant roots, trashes, and rocks) in the soil. Abrasive wear losses constitute the highest cost among the other types of wear. Adhesive wear is influenced by surface tension, surface characteristics of the tool material, and environmental-soil parameters such as soil type, soil moisture. The corrosive wear is affected by the properties of the material (chemical content, grain size, hardness, microstructure, and phases), residual stresses occurring in the material as a result of heat treatments and other production processes, and environmental conditions such as soil temperature, soil moisture, acidic-basic properties.

This study aims to present the course of wear studies related to tillage tools and to evaluate the difficulties and constraints in transferring the research findings to the agricultural sector.

2. HISTORICAL BACKGROUND AND THE CURRENT STATUS OF THE WEAR RESEARCH FOR TILLAGE TOOLS

The main studies carried out in the last century to determine and improve the life of the tillage tools are presented in chronological order, together with the topic of research, in the Table 1. It is observed that the developments in material science have been reflected in research aiming to improve the wear resistance of agricultural tillage tools. As can be seen from the Table 1, studies have focused on heat treatments and coatings aimed at improving the microstructure and surface characteristics of the material. Generally, as can be seen from the research results, improved the microstructure and surface characteristics increase the wear resistance of tillage tools. However, today, conventional heat treatment (quenching) is still the most widely used technique for improving the mechanical properties of tillage tools.

It is understood that studies focusing on determining the impact of the geometry and manufacturing forms of tillage tools on wear remains more limited (Table 1). Tillage tools are generally manufactured by the cutting from steel sheets and sometimes casting. In the manufacturing of the tillage tool, many process steps such as cutting of the part in the desired dimensions, opening holes for countersunk bolt and screws, heat treatment, giving the final shape to the part, hardening and tempering follow each other. As a result of this, traditional manufacturing processes are labour-intensive and take a long time. While Yazici (2011b) examined the wear behaviour of ploughshare produced through hot stamping from the filled steel mile, Yazıcı and Çavdar (2017) investigated the wear behaviour of the test samples produced through sintering from powder metals and boronized. Although such techniques may already seem more expensive, the transfer of the developments in production technologies to the agricultural sector will allow the modernization and automation of the production systems. This, in turn, will reduce costs in the long run. In recent years, studies focusing on interactions of the tillage tools and the modelling of wear are also conducted (Singh et al., 2011; Goel 2013; Skirkus and Jankauskas, 2015; Bedollaa et al., 2018; Zhang et al., 2018; Cucinotta et al., 2019). Realistic wear models will shed light on the technical, economic, and design optimization.

Table 1. Research carried out in the last century to determine and improve the life and performance of the soil tillage tools

Name of researchers and year of study	*Name of paper*	*Topic of research*
Hoffman, 1922	"Wearing Tests of Plowshares"	Material - Wear
Gallwitz, 1930	"Werkstoffe und abnutzung von pflugscharen"	Speed, Type of abrasive, Moisture content, Operating angle and depth, Composition and hardness of the material -Wear
Nichols, 1930	"Dynamic properties of soil affecting implement design"	Dynamic properties of soil -Design
Nichols, 1931	"The dynamic properties of soils, II. soil and metal friction"	Friction; metal-soil, Friction coefficient
Kühne, 1931	"Vergleichende untersuchungen an schar-werkstoffen"	Tillage speed - Wear
Zink et al, 1936	"Results of studies of the cutting edges of tillage implements"	Cutting Edges, Heat treatments, Soils conditions, Hardness -Wear
Kummer, 1938	"The dynamic properties of soil: A study of the nature of physical forces governing the adhesion between soil and metal surfaces",	Adhesion
Carleton and Martin, 1945	"Sharpening and hard surfacing plow and lister shares"	Types of plowshares, Share treatments, Hard-surfacing materials - Wear
Mitsuhasi et al, 1950	"Study of wear of steel against soils"	Soil moisture, Velocity, Cutting angle, Load - Wear
Gavrilov and Koruschkin, 1954	"The underside chamfer of plough shares"	Draught force - Wear
Mohsenin, 1956	"Development of an accelerated wear test for tillage tool materials and its application to ordinary cast iron and nodular iron"	Material (Carbon content), Suitable Shape and Size - Wear
Tribble, 1958	The teflon covered mouldboard plow	Teflon covered plough ear -Wear
Cooper and McCreery, 1961	"Plastic surface for tillage tools"	Teflon coating- Wear
Stroppal, 1961	"Über die Güte, den verschleiss und die schneiden form fabrikneuer pflugschare"	Cutting edge properties - Wear
Koszeghy, G. 1964	"Some questions of investigations on rotary cultivators"	Blade wear -Operating speed
Fox and Bockhop, 1965	"Characteristics of a teflon-covered simple tillage tool"	Teflon coating - Wear

Name of researchers and year of study	*Name of paper*	*Topic of research*
Richardson, 1967	"The wear of metallic materials by soil-practical phenomena"	Soil conditions - Wear
Marin and Tomescu, 1972	"Increasing the wear resistance of working member of the rotary tillers"	Overlay welding - Wear
Silveira, 1973	"Desgastes em cultivadores"	Soil moisture - Wear
Mutaf and Ulusoy, 1977	"Toprak işleme aletlerinin iş organlarında kullanılan bazı çeliklerin farklı ısıl işlemlere göre laboratuar ve tarla şartlarında aşınma dirençleri"	Material, Hardness - Wear
Quick et al., 1979	"Effects of speed and other parameters on lineal share wear"	Tillage parameters - Wear
Ulusoy, 1981	"Bazı Toprak işleme alet ve makinelerinde iş ooorganının aşınması üzerinde araştırmalar"	Tillage tools - Wear
Foley et al., 1984	"The use of alumina ceramic to reduce wear of soil-engaging components"	Alumina ceramic coating - Wear
Karamış, 1985	"Investigation on the wear of workpiece in soil tillage tools"	Tillage parameter, Soil moisture, Hardfacing, Tempering temperature, Surface roughness - Wear
Murthy, 1988	"Abrasive wear of cultivator shovel in soils"	Soil type, Soil moisture, Heat treatment, Material (carbon content)- Wear
Foley et al., 1988	"Wear of ceramic protected agricultural subsoilers"	Alumina ceramic coating- Wear
Quirke et al., 1988	"An evaluation of the wear behaviour of metallic materials subjected to soil abrasion"	Medium-carbon and high-carbon heat treated steels - Wear
Gupta et al, 1989	"Performance evaluation of wide cutting tillage tools of different geometry for dryland farming"	Geometry of tillage tools, Rake angles, Tillage depths - Draught
Kushwaha et al., 1990	"Investigation of agricultural tools with plasma sprayed coatings"	Metallic-glass coatings, Friction coefficient - Soil forces
Kushwaha and Shen, 1991	"Investigation of wear of agricultural tillage tools"	Materials- Abrasive medium (sand and soil) - Wear
Fielke et al., 1993	"Comparison of tillage forces and wear rates of pressed and cast cultivator shares"	Soil type and condition- Wear - Draft forces.
Milos et al, 1993	"Abrasive wear of agricultural machinery parts"	Soil conditions - Wear
Ali and Ezzat, 1994	"Wear of tillage tools coated by thermoplastic coatings"	Polyamide and polyethylene coatings- Wear
Zhang and Kushwaha, 1995	"Wear and draft of cultivator sweeps with hardened edges"	Coating - Wear
Fielke, 1996.	"Interactions of the cutting edge of tillage implements with soil"	Cutting edge geometry -Tillage forces - Soil movement
Zheng et al., 1996	"Wear resistance of cultivator tine (part 2) - Effects of tine parameters on wear resistance"	Tine parameters (hardness, shapes, coating materials, coating locations and shank types) - Wear
Kurchania, 1997	"Abrasive wear of cultivator shovels affected by soil, tool and operating parameter"	Soil, Tool and tillage parameter - Wear
Owsiak, 1997	"Wear of symmetrical wedge-shaped tillage tools"	Material, Heat treatment (quenching + tempering) - Wear
Ferguson et al., 1998	"Wear of cultivator shares in abrasive South Australian soils"	Heat treatment, Soil conditions - Wear
Owsiak, 1999	"Wear of spring tine cultivator points in sandy loam and light clay soils in southern Poland"	Soil type, Spring tine point -Wear
Salokhe et al., 1999	"Effect of Enamel Coating on the Performance of a Tractor Drawn Rotavator"	Enamel coating - Wear
Banaj et al, 2000	"Material wear of cultivator shovels"	Material - Wear
Bhakat, et al., 2004	"Metallurgical life cycle assessment through prediction of wear for agricultural grade steel"	Material, Hardness - Wear
Gupta et al., 2004	"Performance evaluation of different types of steel for duck foot sweep application"	Material, Heat treatment -Wear

Name of researchers and year of study	*Name of paper*	*Topic of research*
Jia and Ling, 2005	"Reduction of soil resistance through the use of a composite coating"	Material, Composite coating - Wear
Mohsenin and Womochel, 2005	"Wear tests of plough share materials"	Material - Wear
Bayhan, 2006	"Reduction of wear via hardfacing of chisel ploughshare"	Hardfacing (shielded metal arc welding) - Wear
Er and Par, 2006	"Wear of plowshare components in SAE 950C steel surface hardened by powder boriding"	Boronizing- Wear
Chahar, 2006	"Studies on wear characteristics of cultivator shovels"	Material (C content), Hardfacing, Tillage speed and depth, Soil moisture - Wear
Bhakat et al., 2007	"Characterization of wear and metallurgical properties for development of agricultural grade steel suitable in specific soil conditions"	Material, Heat treatment - Wear
Bobobee et al., 2007	"Wear rate of animal-drawn ploughshares in selected Ghanaian soils"	Material chemical composition, Share hardness, Soil physical factors- Wear
Bobobee and Gebresenbet, 2007	"Effect of cutting edge thickness and state of wear of ploughshare on draught force and heart rates of Sanga oxen in Ghana"	Cutting edge thickness, Draught force - Heart rates of oxen
Fouda and Tarhuny, 2007	"A Study on ploughshares wearing behavior under conditions of sandy loam soil"	Hardness, Share position, Soil moisture - Wear
Karoonboonyanan et al., 2007	"Wear resistance of thermally sprayed rotary tiller blades"	WC–Co and Al_2O_3/TiO_2 (+NiAl) coating - Wear
Kelly et al., 2007	"Pulsed DC titanium nitride coatings for improved tribological performance and tool life"	Titanium nitride coating - Wear
Mahapatra, 2007	"Wear characteristics of rotavator tynes for power tillers"	Materials (carbon contents), Abrasive particle size, Soil type, Rotovator tine type- Wear
Horvat et al., 2008	"Reduction of mouldboard plough share wear by a combination technique of hardfacing"	Hardfacing (shielded metal arc welding and high-frequency induction welding) - Wear
Natsis et al., 2008	"Influence of local soil conditions on mouldboard plougshare abrasive wear"	Soil conditions - Wear
Korucu and Arslan, 2008	"The effect of wear rate of cultivator shares and operating speed on draught force requirements"	Cultivator share types, Operating speeds- Draught
Kaur et al., 2011	"Studies on the wear performance of different materials of rotary blades"	Materials (low alloy steel, high carbon spring steel), Blade type, Soil type, Working period - Wear
Nalbant and Palalı, 2011	"Effects of different material coatings on the wearing of plowshares in soil tillage"	Chromium, nickel nitride and titanium plating coating - Wear
Yazıcı, 2011a	"Wear behavior of carbonitride-treated ploughshares produced from 30MnB5 steel for soil tillage applications"	Carbonitriding- Wear
Yazıcı, 2011b	"Investigation of the reduction of mouldboard ploughshare wear through hot stamping and hardfacing processes"	Hardfacing (shielded metal arc welding and gas metal arc welding) and Manufacturing form (Hot stamping)- Wear
Kang et al., 2012	"Wear Behavior of Thermal Spray Coatings on Rotavator Blades"	WC-Co-Cr, Cr3C2NiCr and Stellite-21 Coating- Wear
Yazıcı, 2012	"Investigation of the wear behavior of martempered 30MnB5 steel for soil tillage"	Martempering - Wear
Bednář, et al., 2013	"Suitability of technical materials for machinery subsoilers for soil tillage"	Material, Hardfacing - Wear
Derafshpour and Mogaddam, 2013	"Investigation of blade's wears of chisel plow in a silty clay soils"	Tillage depth, Operation area- Wear- Fuel consumption
González et al., 2013	"Wear of rotary plows operating in a tropical clay loam soil"	Tillage implements- Wear
Hrabe and Müller, 2013	"Research of overlays influence on plough-share lifetime"	Hardfacing (overlay welding)-Wear
Alwan and Hussan, 2014	"Study the effect of heat treatment on abrasive wear with silt clay loam soil texture"	Heat treatment- Wear
Kang et al., 2014	"Wear behavior of hardfacings on rotary tiller blades"	Hardfacing (gas tungsten arc welding) - Wear
Kolomeichenko and Titov, 2014	"Investigation of hardness of tillage tools being hardened by Carbo-Vibro-Arc method with paste application"	Hardfacing - Wear

Name of researchers and year of study	*Name of paper*	*Topic of research*
Jankauskas et al., 2014	"The method of hardening soil rippers by surfacing and technical-economic assessment"	Hardfacing - Wear
Chernoivanov et al., 2015	"Features of wear of agricultural machinery components strengthened by Fe_n B-Fe-B composite boride coatings"	FenB–Fe–B boride coatings - Wear
Hrabě, et al., 2015	"Evaluation of techniques for ploughshare lifetime increase"	Hardfacing (overlay welding) - Wear
Zhang et al., 2015	"Abrasive wear characteristics of subsoiler tines with bionic rib structure surface"	Materials, Bionic ridge structure, Sobsoiler tine - Wear
Vlăduţoiu et al., 2015	"Increasing agricultural machinery active parts durability by hardening"	Hardfacing - Wear
Arifa et al, 2015	"Improvements of harrows wear resistance"	Material, Sharpening angle, Hardfacing - Wear
Abd El-Hameid, 2016	"Development of a mathematical model to predict wearing and energy requirements of some treated tillage tools"	Heat treatment and coatings - Wear
Kostencki et al., 2016	"Durability and wear geometry of subsoiler shanks provided with sintered carbide plates"	Coatings (with sintered carbide plates and by pad welding) - Wear
Pyndak and Novikov, 2016	"Tribotechnical and energy assessment of parts of working members of cultivating machines after carburizing and laser hardening"	Carburizing, Hardfacing - Wear
Zein El-Din et al., 2016	"Effect of new hard facing materials of tillage tools on draft and roughness"	Carbon nanotube, Hard chromium composite, Surface roughness - Draft force requirements
Yazıcı et al., 2017	"Effect of carbonitriding on corrosion resistance of steel 30MnB5 in two acidic environments"	Carbonitriding, Quenching-Corrosive wear in soil condition
Yazıcı and Çavdar, 2017	"A study of soil tillage tools from boronized sintered iron"	Manufacturing form (Sintering), Boronizing, Quenching - Wear
Yazıcı et al., 2017	"Corrosion resistance and mechanical properties of quenched and tempered 28MnCrB5 steel in two acidic environments"	Quenching - Corrosive wear in soil condition
Tabrizi et al., 2017	"Analytical and experimental draft force evaluation of plastic coated chisel tines"	Ultra-high molecular weight polythene coating- Wear - Draft force
Stawicki et al., 2017	"Tribological properties of plough shares made of pearlitic and martensitic steels"	Material - Wear
Waheed and Ezzat, 2017	"Wear of tillage tools coated by thermoplastic coatings"	Polyamide and Polyethylene coatings - Wear
Březina et al, 2018	"Application of ductile iron in the manufacture of ploughshares"	Heat treatment - Wear
Stawicki et al., 2018	"Wear resistance of selected cultivator coulters reinforced with sintered-carbide plates"	Coatings - Wear
Singh et al., 2018	"Effect of heat treatment on wear rate of different agricultural grade steels and associated cost economics"	Materials, Austenization temperature, Tempering temperature - Wear
Singh et al., 2018	"Effect of hard-faced Cr-alloy on abrasive wear of low carbon rotavator blades using design of experiments"	Hardfacing - Wear
Novikov et al., 2018	"Composition and Tribological Properties of Hardened Cutting Blades of Tillage Machines under Abrasive Deterioration"	Carburizing and Laser hardening - Wear
Marani et al, 2019	"Effect of nano coating materials on reduction of soil adhesion and external friction"	Nano-coated material-Soil conditions - Friction and adhesion
Malvajerdia et al., 2019	"Protection of CK45 carbon steel tillage tools using TiN coating deposited by an arc-PVD method"	Titanium nitride (TiN) coating - Wear
Sukumaran et al., 2019	"From single asperity to real scale in the wear of agricultural tine"	Real-scale test in the field, in-lab macro-scale test, and micro-scale single asperity test - Simulation of wear
Singh et al., 2020	"Tribological Performance of Hardfaced and Heat Treated EN-47 Steel Used for Tillage Applications"	Hardfacing, Carburizing- Wear
Singh et al., 2020	"Abrasive wear behavior of newly developed weld overlaid tillage tools in laboratory and in actual field conditions"	Hardfacing- Wear

3. DIFFICULTIES IN REACHING THE RESEARCH FINDINGS TO THE AGRICULTURAL SECTOR AND SOLUTION PROPOSALS

Despite approaches such as conservation agriculture (conservation agriculture: CA; covers no or minimum mechanical soil disturbance, biomass mulch soil cover, and crop species diversification applications) that aims to reduce field traffic, carbon footprint, fuel, and machinery operating costs, tractor tillage-based systems continue to be the basis of the farm machinery industry. According to Kassam et al., (2019), in 2015-2016, CA applications were conducted in only 12.5% of the total cultivation areas worldwide. The choice and use of wear-resistant materials, and again the use of high-cost coatings, also necessitates an economic optimization. For economic reasons, it is not always possible to use the most durable materials or coatings. Constraints and solution proposals for the transfer of research results into practice for reducing wear in tillage machines can be gathered under three main headings in relation to the stakeholders of the subject; structural problems of farms, structural problems of firms producing tillage machines and policies regulating the sector.

3.1. Structural problems of the farms

There are many large and small scale farms operating in the agricultural sector around the world. Farm sizes vary from a few decares to thousands of hectares. In total farm numbers, there is a significant share of small and medium-sized farms. According to the FAO (2015) report, in the world, the rate of farms doing agriculture in less than 2 hectares of land is 98% in China, 90% in Egypt and Ethiopia, 80% in India, 50% in Mexico, and 20% in Brazil. 80.7% of agricultural enterprises in Turkey are in business-size-groups smaller than 100 decares, and the land that these businesses hold in their hands accounts for 29.1% of the total land (TARMAKBİR, 2019). The poor economic purchasing power of small medium-sized farms limits the purchase of relatively expensive tools and equipment.

3.2. Structural problems of manufacturers

Agricultural machinery manufacturers are of a variety of sizes, ranging from small and medium-sized enterprises to multinational corporations. When looking at the structures of the companies that produce tillage machines, it is seen that the companies operating in the sector have very different scales. Large-scale firms have R&D culture to increase competitiveness and market share in both national and international markets and they benefit from research findings, information, and technology more (many also have their own R&D department). However, this is mostly unlikely for small-medium-sized machine manufacturers which are in a large number. In agricultural tools and machinery industry, making production in large numbers and small-scale enterprises, which are financially inadequate, negatively affects the R&D process and innovation-based production at the sectoral level. There is no employment of technical personnel in small-medium-sized companies or it is insufficient (TARMAKBİR, 2019). On the other hand, companies that manufacture and sell machines are under pressure to provide both advanced-quality and affordable products to the market.

3.3. Policies regulating the sector

In order to promote, support, and subsidize the agricultural sector, policies are produced by the states and various international organizations. But the budgets of allotted resources are limited, and state support is also closely related to economic development levels of the states. According to "Agricultural Policy Monitoring and Evaluation 2018" report of the OECD, producer subsidies increased rapidly over the past 15 years, from $255 billion in 2000–02 to $484 billion in 2015–17 in the 10 non- OECD (a mix of developing and emerging) economies, and was driven by a 16-fold increase in producer support in China. In all nine other non-OECD countries examined by the report in question, this support increased from $ 11 billion to $ 24 billion (OECD, 2018). Particularly, support and subsidies are not at the desired level in low and middle-income countries. Additionally, subsidies are generally received by wealthier farmers.

3.4. Solution Proposals

The following solutions can be highlighted, particularly for improving the welfare levels of small-medium-sized farms and machine manufacturers;

- Policies for farms; in accordance with regional-geographical conditions, development of policies that will raise the level of socio-economic welfare of farmers (development of rural development policies, strengthening agricultural production and trade policies for small and partial enterprises, arrangements supporting cooperative and organization), machine-equipment supports, promoting the use of common machinery, development of machine parks (the use of machines through leasing will reduce costs), virtual removal of farm boundaries to enable the use of highly equipped high capacity machines, subsidized agricultural loans, providing effective agricultural advisory services to farmers, and farmer training policies are important (TAGEM 2018; TARMAKBİR 2019). It can be suggested to raise awareness of farmers about choosing of machine that has wear-resistant tillage tools by preparing geographical maps showing soil abrasiveness, and to provide technical consultancy support to farmers as well as financial support for purchasing the machine.

- Policies for machine manufacturers; encouraging the companies with instruments such as R&D, renovation of their technological-production infrastructure, and technical personnel employment support, forming policies supporting university-industry cooperation that may be an important complementary element for R&D (TARMAKBIR, 2019), development of projects for transferring the research findings to the sector, development of policies to encourage companies to cluster and specialize can be suggested. Information production and information transfer (nationally, regionally, and internationally) should be encouraged in cooperation between public-universities-private sectors. The fact that machine manufacturers expand through mergers and acquisitions, adopt export-oriented strategies, and have broad sales networks will increase their competitiveness in the market. Only the firms whose economic-financial indicators have improved can turn to R&D investments.

4. CONCLUSION

The following issues can be highlighted as a result of this study focusing on the review of the wear studies on tillage tools and evaluation of the difficulties-constraints of the transferring of the results of those studies to the agricultural sector in Turkey;

- Development of policies to strengthen the weak economic purchasing power of small-medium scale farms, and the weak financial structures of small-medium scale machine producers,
- Development of policies that reduce environmental harm, reduce costs, and encourage the transfer of simple and logical new information and technologies to the sector,
- Development of realistic wear models, implementing approaches that increase wear resistance in tillage tools, and that reduce fuel consumption, and the use of new production technologies suitable for automation that reduce costs can be suggested.

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