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Research Article

Effect of Fermentation on Drying Characteristics of Three Varieties of Trifoliate Yam

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ABSTRACT

This study determined the effect of fermentation on drying characteristics of trifoliate yam varieties (white, yellow and deep-yellow trifoliate yam). Thin layer drying method was adopted using oven dry method at constant drying temperature of 70°C with air velocity of 2.35 m s^{-1} and relative humidity 35%. The unfermented samples shoed lower values of drying constant than the fermented samples. The drying constant of unfermented samples of *Trifoliate Yam* A, B and C (*A= Deep-Yellow, B= White, C= Yellow)* were -0.729, 1.3972 and 0.2787, respectively. While, the drying constant of fermented samples of *Trifoliate Yam* D, E and F (*D= Deep-Yellow, E= White, F= Yellow)* were -0.776,-0.763 and 1.5815, respectively. The drying rate of the samples solely dependent on the magnitude of drying constants sequel to this, fermented samples with larger magnitude of drying constant will dry faster than the unfermented samples with lower drying constant. Best fit equations and relationship between moisture content and drying time were developed with correlation coefficient (R^2) higher than 0.94. The sample A, B, C, D, E and F reached a constant moisture ratio of 0.021, 0.015, 0.021, 0.015, 0.014 and 0.016 at drying time of 540, 600, 600, 480, 540 and 540 minutes, respectively. Sample B and C had highest drying time followed by sample A, E and F while sample D had the lowest value of drying time. The fermentation had significant effect on the drying characteristics of trifoliate yam slices and drying of trifoliate yam samples occurred solely in the falling rate period which showed that internal moisture diffusion phenomenon is dominant and controlled the drying process.

RESEARCH ARTICLE

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- Fermentation,
- Drying characteristics,
- Trifoliate yam,
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- Yellow and white

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INTRODUCTION

Dioscorea dumetorum (Trifoliate Yam) has proven to be the most nutritious among the eight species of yam basically grown and consumed in the West and Central Africa (Sefa-Dedeh and Afoaka, 2002). According to Lape and Treche (1994), Trifoliate Yam demonstrated to be rich in protein, primarily balanced in essential amino acids with easily digested starch. According to Christian *et al.* (2018) and Lyonga and Ayu-Takem (1982), Trifoliate Yam species is a very high yielding yam species which requires no stalking like other yam species, consequently saving much labour during pre-harvest and post-harvest operations. Compared to other yam species, it has other common names such as African bitter yam, Wild Yellow and White-Colored trifoliate (three-leaved) yam and cluster yam (Ugwuanyi Nnadi *et al.*, 2020). In Ibo tribe mostly South-East Nigeria, bitter Trifoliate Yam is usually referred to as *ji una or jona* and food for the adult (Anthony *et al.*, 2016). It cannot be processed into fufu like other yam species due to its soft texture which favors old people with poor teeth structure as a result of old age, but they can be used as vegetable. It serves as raw material for formulations of new bio products upon it was found to be the cheapest and high yielding crop. Breweries and other similar companies explore the benefits of this underutilized yam species in preparation of beer (Anthony *et al.*, 2016). This underutilized yam species, when properly processed like other yam species can be used in making of yam flakes, instant flour for the bakery sector or starch in diverse pharmaceutical applications (Ukpabi and Ndimele, 2014). It has lots of medicine relevance as it has been proven to be a direct remedy for treatments of diabetes, malaria and other numerous aliments mostly in the South–East Nigeria, yet it remains an underutilized tropical tuber and probably it may be driven into extinction in no distant (Clifford *et al.*, 2013). In the modern world, handling and processing of agro based products are the most important aspect in food and nutritional security. Due to urbanization most food products are required to be produce in different forms in order to carter for daily nutritional requirements of a common man and also carter for the alarming pollution in the world (Nkhata *et al.*, 2018 and Omemu, 2011). Mostly, processing of agricultural products is done to improve consumer acceptability, palatability and transportability. They can also have adverse effect on the nutrient profile of food products by retaining its nutritional value Chaves-Lopez *et al.* (2014) and Omemu, (2011). There are some techniques implored in processing of Trifoliate Yam of which most of the methods are localized to certain areas while others are practiced globally. This research intends to adopt the most commonly used processing techniques (fermentation). Fermentations of food products are broadly used in processing of food products for production of numerous varieties of dishes in Africa. It is a prerequisite for development of acceptable texture, flavor food products. According to Buta and Emire (2015) and Chaves-Lopez *et al.* (2014) it improves the nutritional quality, digestibility and safety of foods. Fermentation can be used to minimize the antinutritional content in a food products and improve nutrient availability (Hotz and Gibson, 2007; Omemu, 2011; Nkhata *et al.*, 2018).

Drying characteristics is the commonest food process employed in improving food stability and security, as far as it noticeably declines the negative effect of water in the material, deterioration, microbiological activity, physical and chemical changes during its processing and storage (Mujumdar and Law 2010). It also, causes colour change, weight reduction, and enhances aesthetic and sensory effects of food (Brennan, 2006). Therefore, the basic goal is to limit moisture content to levels that halt or slow down the growth of spoilage microorganisms and incident of chemical reactions in order to extend the shelf-life of food (Oduro *et al.*, 2007). According to Maskan (2001) the high quality fast-dried foods have become necessary in the recent times which aggravated a renewed interest in drying operations. Furthermore, there is a high demand for convenient foods more especially ready to eat and instant products, which are desired to contain the less contents of additives and preservatives (Mujumdar and Law 2010). Therefore, the interest of the research was to determine the effect of fermentation on the drying characteristics of three varieties of Trifoliate Yam.

MATERIALS and METHODS

Source of sample

The Deep-Yellow, Yellow and White Trifoliate Yam (*Dioscorea dumentorum*) varieties used for this research work were harvested from Enugu State agricultural development programme, Enugu State, Nigeria at physiological maturity. They were immediately transported in a heap and stored in temperature and relative humidity rate of 28°C±3°C and 82±5% respectively.

Preparation of the Sample

The sourced Trifoliate Yam tubers from each variety (White Trifoliate Yam, Deep-Yellow Trifoliate Yam and Yellow Trifoilate Yam) were divided into two equal batches. The first batch which represent the raw (unfermented sample) were peeled, washed and then sliced into a rectangular shape of about 30x20x10 mm thickness using stainless kitchen knife and vernier caliper. The second batch were peeled, washed and soaked in a distilled water, the traditional fermentation method as reported by Oladele and Oshidi (2008) was used to ferment the sample. Both the fermented and unfermented processed samples were classified as A= Unfermented Deep-Yellow Trifoliate Yam, B= Unfermented White Trifoliate Yam, C= Unfermented Yellow Trifoliate Yam, D= Fermented Deep-Yellow Trifoliate Yam, E= Fermented White Trifoliate Yam and F= Fermented Yellow Trifoliate Yam. The micro-organisms involved in the traditional fermentation were naturel inoculants from the air. The samples were collected after 72 hours.

Figure 1. Pictorial showing procedures in preparing Trifoliate Yam flour sample.

Determination of Drying Charateristics of Trifoliate Yam

The samples were harvested and the research was carried out between November and December 2021 at Bioprocess laboratory, in Enugu State University of Science and Technology, Enugu State, Nigeria. The two prepared batches of Trifoliate Yam were introduced into the hot air oven dryer. The oven dryer was allowed to operate for 60 minutes without the sample in order to obtain the experimental design condition. The Samples were weighed before they were loaded in a drier and removed at interval of 60 minutes to record moisture loss until three consecutive constant weight and moisture content were obtain indicating equilibrium condition (John *et al.*, 2020). Thin layer drying method was adopted using oven dry method at constant drying temperature of 700°C (the temperature that retains the nutritive value of a biomaterial under drying process) with air velocity of 2.35 m s^{-1} and relative humidity 35%.

Moisture content at any time of drying

The moisture content of the sample at any given time and condition were determined using the Equation (1) reported by (Okeke *et al.*, 2020)

$$M_{ct} = \frac{W_t - W_d}{W_t} \quad (1)$$

M_{ct} = Moisture content (%wt) at time t;
W_t = Initial weight of the sample at any time
W_d = Weight of the dried sample

Drying rate at any time of drying

The drying rate of the sample were determined using the Equation (1) reported by (Dai *et al.*, 2017) with little modification.

$$D_R = \frac{M_{t1} - M_{t2}}{t_2 - t_1} \quad (2)$$

D_R = Drying rate (%/mins)
M_{t1} = Moisture content at t_1, (g g^{-1})
M_{t2} = Moisture content at t_2 (g g^{-1})
t_2 = Time of drying at M_{t2}
t_1 = Time of drying at M_{t1}

Moisture ratio of Trifoliate Yam

Moisture ration of the samples were determined using the Equation (3) reported by (Dai *et al.*, 2017) with little modification.

$$M_R = \frac{M_{t1}}{M_0} \quad (3)$$

M_R = Moisture ratio
M_{t1} = Moisture content (dry basis) at any time
M_0 = Initial moisture content (dry basis) of the sample.

Multiple Regression analysis

Regression analysis is a statistical technique that can test hypothesis that a variable is dependent upon one or more other variables. Version 2 was used to analyze data generated from the drying characteristics of Trifoliate Yam varieties.

RESULTS AND DISCUSSION

Drying curve and drying rate moisture relationship.

Drying curves may be represented graphically as averaged moisture content versus time, drying rate versus time, moisture ratio versus time or drying rate versus averaged moisture content (Coumans, 2000; Saeed *et al.*, 2008).

Table 1. Drying characteristics of fermented and unfermented Trifoliate Yam varieties dried at 700°C using oven drying method.

Drying time (mins)	Sample A		Sample B		Sample C		Sample D		Sample E		Sample F	
	Drying rate (mins)	MC (%)	Drying rate (mins)	MC (%)	Drying rate (mins)	MC (%)	Drying rate (mins)	MC (%)	Drying rate (mins)	MC (%)	Drying rate (mins)	MC (%)
0	-	49.80	-	62.61	-	49.42	-	65.05	-	76.42	-	63.74
60	0.46	22.0	0.62	25.30	0.25	34.51	0.67	24.82	0.75	31.56	0.63	26.14
120	0.28	15.91	0.34	19.70	0.21	24.53	0.41	16.27	0.48	19.24	0.42	13.04
180	0.22	10.30	0.30	13.20	0.19	15.50	0.32	8.12	0.38	7.67	0.32	5.6
240	0.18	6.38	0.22	8.94	0.16	9.96	0.25	4.82	0.30	3.56	0.26	2.05
300	0.16	2.56	0.19	4.45	0.14	6.26	0.21	1.26	0.25	1.31	0.21	1.06
360	0.14	1.18	0.17	2.00	0.13	2.52	0.18	1.04	0.21	1.15	0.17	1.05
420	0.11	1.07	0.15	1.56	0.11	1.29	0.15	1.04	0.18	1.13	0.15	1.05
480	0.10	1.07	0.13	1.25	0.10	1.05	0.13	1.04	0.16	1.13	0.13	1.05
540	0.09	1.07	0.11	1.14	0.09	1.04	0.00	0.00	0.14	1.13	0.00	0.00
600	0.00	0.00	0.10	1.14	0.08	1.04	0.00	0.00	0.00	0.00	0.00	0.00

Note: A= Unfermented Deep-Yellow Trifoliate Yam, B=Unfermented White Trifoliate Yam, C=Unfermented Yellow Trifoliate Yam, D= Fermented Deep-Yellow Trifoliate Yam E=Fermented White Trifoliate Yam and F=Fermented Yellow Trifoliate Yam.

It was observed from the Table 1 and from Figure 2 that the unfermented samples displayed a better drying curve properties with longer drying time while fermented samples had short drying time and this could be as a result of hardened surface of the unfermented samples which prevented free migration of water from the sample during drying (Minkah, 2007). The drying rate also indicates the quantity of moisture evaporated per unit time. It was found that at the beginning of drying, there was a higher rate of moisture loss in all the samples and this rate decreased as the drying time increased and this might be as a result of the nature of water present in the sample (Akpinar *et al.*, 2003) or due to internal pressure generated that forces the moisture in vapor form outside the Trifoliate Yam varieties (Nguyen and Price, 2007).

The drying rate and moisture content decreased steadily with drying time at all properties considered. The results revealed that the drying of Trifoliate Yam samples occurred solely in the falling rate period which showed that internal moisture diffusion phenomenon is dominant and controlled the drying process. The results were in agreement with Falada and Abbo (2007); Saeed *et al.* (2008); Singh *et al.* (2008); Doymaz (2011); Ju *et al.* (2016) reported for drying characteristics of different yam specie and potato. The average required drying time for fermented and unfermented Trifoliate Yam varieties were 500 mins and 580 mins respectively. It was observed that fermented samples had lower drying time due to that 72 hour fermentation has altered the internal structures of the samples loosen the sample pores which hastened the free movement of water both on the surface and internal portion in the sample. This result also indicated that the fermented sample had faster drying rate which reduces the risk of spoilage and improves quality of the biomaterials. The effect of moisture content and drying time were properly described by best fitting regression equation for unfermented and fermented samples as $MC=0.0002t^2- 0.2428t+61.317$, $R^2 = 0.9951$ and $MC = 696469t^{-2.136}$, $R^2 = 0.9438$ respectively while the effect of drying time on the drying rate were described with $Dr = 4E\text{-}07t^2 - 0.0006t + 0.2787$, $R^2 = 0.9958$ and

$Dr = 16.911t^{-0.77}$, $R^2 = 0.9917$ for unfermented and fermented samples respectively. These equations can also be used to model the drying characteristics of fermented and unfermented Trifoliate Yam samples. Generally, from Table 1, it was observed that sample E had the highest drying rate ranged from 0.75–1.13 mins with average drying rate and time of 0.32 and 260 mins respectively followed by sample D (0.67–0.13 mins with average drying rate and time of 0.29 and 225 mins respectively. The sample F which recorded 0.63–0.13 mins drying rate with average value of its drying rate and time as 0.28 and 225 mins respectively had the same average drying time with sample D. Sample B had 0.62–0.10 mins range of drying rate with mean value of 0.23 and 294 mins drying rate and time respectively while 0.46–0.09 range of drying rate with average drying rate and time of 0.19 and 260 mins respectively for sample A and drying rate range of 0.25-0.08 mins with mean value of 0.15 and average time of 294 mins for sample C respectively.

It can be concluded that the fermented sample had a better drying characteristic than unfermented samples and therefore, for the interest of processing of Trifoliate Yam species into various bio food products the 72 hours fermentation process should be adopted as it improves the mineral compositions, the health benefits and reduces the risk of spoilage and also improves quality of the products. This study was performed to facilitate the understanding of design, modeling and operation of a continuously oven dryer.

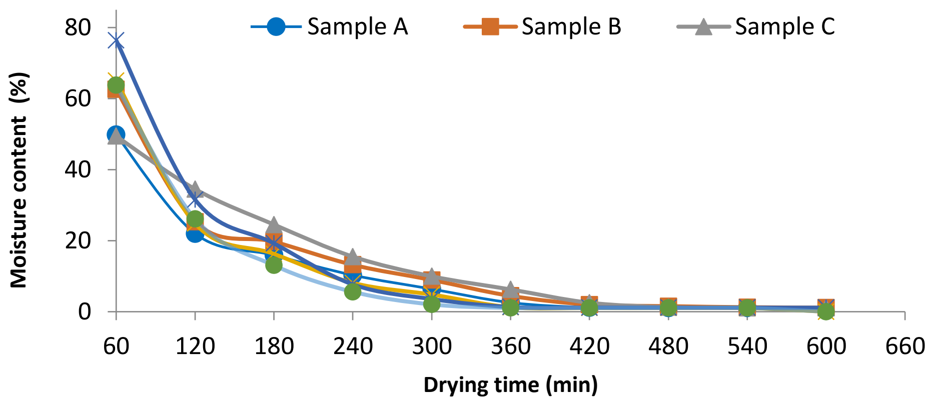

Figure 2. Drying curve of unfermented and fermented Trifoliate Yam varieties dried at 70°C using oven temperature.

Table 2. Best fit equations and relationship between moisture content and drying time of unfermented and fermented Trifoliate Yam varieties.

Samples	Best fitting regression equation	R^2 Values	(k)
A	$MC = 71.777e^{-0.009t}$	0.9647	4.273
B	$MC = 77.368e^{-0.008t}$	0.9712	4.348
C	$MC = 0.0002t^2 – 0.2428t + 61.317$	0.9951	-8.517
D	$MC = 0.0004t^2 – 0.3451t + 71.851$	0.8847	-7.824
E	$MC = 696469t^{-2.136}$	0.9438	13.453
F	$MC = 0.0004t^2 – 0.3543t + 71.469$	0.8825	-7.824

Note: A= Unfermented Deep-Yellow Trifoliate Yam, B=Unfermented White Trifoliate Yam, C=Unfermented Yellow Trifoliate Yam, D= Fermented Deep-Yellow Trifoliate Yam E=Fermented White Trifoliate Yam and F=Fermented Yellow Trifoliate Yam, MC = Moisture content, t= drying time, k = Drying constant.

From Figure 3 and Table 2 the relationship between change in moisture content and with time are presented. The correlation coefficient (R^2) of the samples which measures the relationship and variation between variables were 0.9647, 0.9712, 0.9951, 0.8847, 0.9438 and 0.8825 for sample A, B, C, D, E and F respectively. The best fit equations for sample A, B, C, D, E and F were $MC= 71.777e^{-0.009t}$, $MC= 77.368e^{-0.008t}$, $MC=0.0002t^2 - 0.2428t + 61.317$, $MC = 696469t^{-2.136}$ and $MC=0.0004t^2-0.3543t+71.469$. These values of mathematical equation and correlation coefficient are good prediction of the drying basis of moisture value at any time in the drying process and indicated that the mathematical equation fits the drying processes since their values are very close to 1.

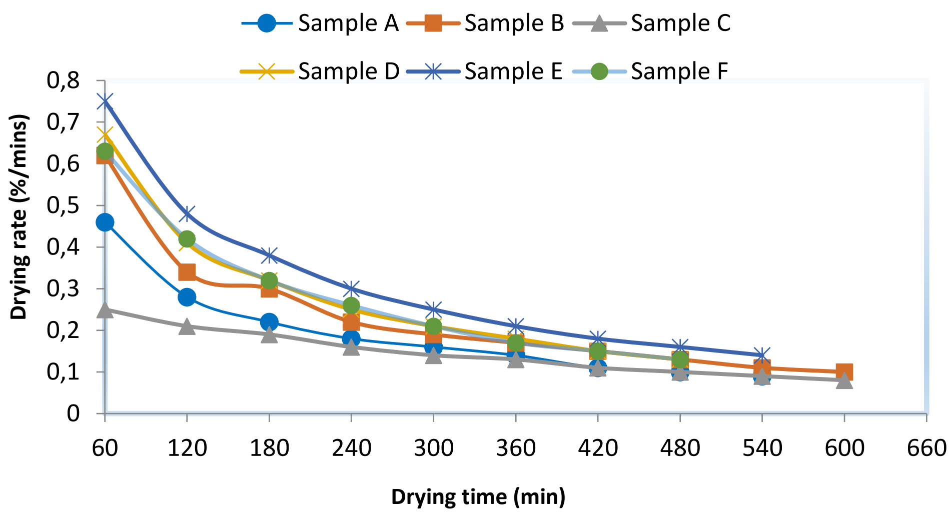

Figure 3. Drying rate of unfermented and fermented Trifoliate Yam varieties dried at 70°C using oven temperature.

Table 3. Best fits equation and relationship between drying rate and drying time of unfermented and fermented Trifoliate Yam varieties.

Samples	Best fitting regression equation	R^2 Values	(k)
A	$Dr = 9.4432t^{-0.729}$	0.9883	2.245
B	$Dr = -0.208\ln(t) + 1.3972$	0.9399	1.570
C	$Dr = 4E\text{-}07t^2 - 0.0006t + 0.2787$	0.9958	17.504
D	$Dr = 16.911t^{-0.776}$	0.9917	2.827
E	$Dr = 18.478t^{-0.763}$	0.9887	2.916
F	$Dr = -0.239\ln(t) + 1.5815$	0.988	1.431

Note: A= Unfermented Deep-Yellow Trifoliate Yam, B=Unfermented White Trifoliate Yam, C=Unfermented Yellow Trifoliate Yam, D= Fermented Deep-Yellow Trifoliate Yam E=Fermented White Trifoliate Yam and F=Fermented Yellow Trifoliate Yam, Dr = Drying rate, t= drying time, k = Drying constant.

From Figure 4, the drying rate of unfermented and fermented Trifoliate Yam varieties was presented, and Table 3 presented the best fit equations and relationship between drying rate and drying time of unfermented and fermented Trifoliate Yam varieties. The drying constant of sample A, B, C, D, E and F were -0.729, 1.3972, 0.2787, -0.776, -0.763 and 1.5815 respectively. It was observed that fermented sample (D, E, F) had -0.776, -0.763 and 1.5815 while unfermented samples (A, B, C) had -0.729, 1.3972 and 0.2787 respectively. The larger the magnitude of drying constants the faster the water is removed, therefore, fermented samples with larger magnitude of drying constant will dry faster than the unfermented samples with lower drying constant. The correlation coefficient (R^2) of the samples which measures the relationship and variation between variables were 0.9883, 0.9399, 0.9958, 0.9917, 0.9887 and 0.988 for sample A, B, C, D, E and F respectively. This indicated that the mathematical equation of the drying process suite the prediction extremely well since their R^2 values were very close to 1.00. It showed that, the drying model is extremely good prediction of the drying basis of moisture value at any time (t) in the drying process. The Figure 4, also showed that the first falling rate period of the samples ranged from 60 minutes to 120 minutes, which is the region where moisture on the surface of the sample are removed, the second falling rate period ranged from 180 minute to 360 minutes, this displayed the region where the internal moisture content of the sample are removed while the critical falling rate period ranged from 420 minutes to 600 minutes, it is the region where the drying rate falls to constant and this indicated the end of the drying process.

Moisture ratio and moisture loss relationship

The Table 3 presented the moisture ratio of fermented and unfermented Trifoliate Yam varieties dried at 70°C using oven dry method. The average moisture ratio and drying time of sample A, B, C, D, E and F are 0.135, 0.121, 0.190, 0.110, 0.098, 0.099 and 300 mins, 330 mins, 330 mins, 270 mins, 300 mins, 270 mins respectively. It was observed that sample C had the highest moisture ratio of 0.698 followed by sample A, E, F, B and D with values of 0.440, 0.412, 0.410, 0.404 and 0.381 respectively.

Table 4. Moisture ratio of fermented and unfermented Trifoliate Yam varieties dried at 70°C using oven drying method.

Drying time (mins)	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
0	0.00	0.00	0.00	0.00	0.00	0.00
60	0.440	0.404	0.698	0.381	0.412	0.410
120	0.321	0.306	0.496	0.250	0.251	0.204
180	0.206	0.208	0.313	0.124	0.100	0.087
240	0.128	0.139	0.201	0.074	0.046	0.032
300	0.051	0.068	0.126	0.019	0.017	0.017
360	0.023	0.027	0.050	0.015	0.015	0.016
420	0.021	0.025	0.026	0.015	0.014	0.016
480	0.021	0.006	0.021	0.015	0.014	0.016
540	0.021	0.015	0.021	0.000	0.014	0.000
600	0.000	0.015	0.021	0.000	0.000	0.000

Note: A= Unfermented Deep-Yellow Trifoliate Yam, B=Unfermented White Trifoliate Yam, C= Unfermented Yellow Trifoliate Yam,, D= Fermented Deep-Yellow Trifoliate Yam E=Fermented White Trifoliate Yam and F=Fermented Yellow Trifoliate Yam.

From the Table 4 and Figure 5, it was observed that from the theoretical moisture ratio plots, the moisture ratio was found to be zero at t=0, this is because the initial moisture content from which the moisture ratio at t=0 was calculated is as starting point of the drying. From the Figure 5, it was found that the unfermented samples (A, B and C) had highest average moisture ratio values. The moisture ratio of fermented and unfermented sample can be described with best fitting regression equation

Mr =3E-06t²–0.0026t +0.5875 with R^2 value of 0.9949 and *Mr = -0.189ln (t)+1.1348* with R^2 value of 0.9293, respectively. In comparison of Table 1 and 3 with Figure 3 and Figure 4, it was observed that as the drying time progresses the drying rate decreases with increase in moisture ratio. It is therefore believed that as the drying rate decreases the moisture ratio increases. The drying rate and the moisture ratio of trifoliate varieties are correlated with and solely dependent on the drying temperature. Moisture ratio with highest R^2 value indicated that the equation can be used to model the drying process. From all indications, it was observed that the sample A had highest value of correlation coefficient of 0.996 with best fits quadratic equation of $Mr = 3E\text{-}06t^2 - 0.0026t + 0.5875$. From the Table 3 above, it took sample A, B, C, D, E and F 540 mins, 600 mins, 600 mins, 480 mins, 540 mins and 540 mins to attain a constant moisture ratio of 0.021, 0.015, 0.021, 0.015, 0.014 and 0.016 respectively. Sample B and C had highest drying time followed by sample A, E and F while sample D had the lowest value of drying time.

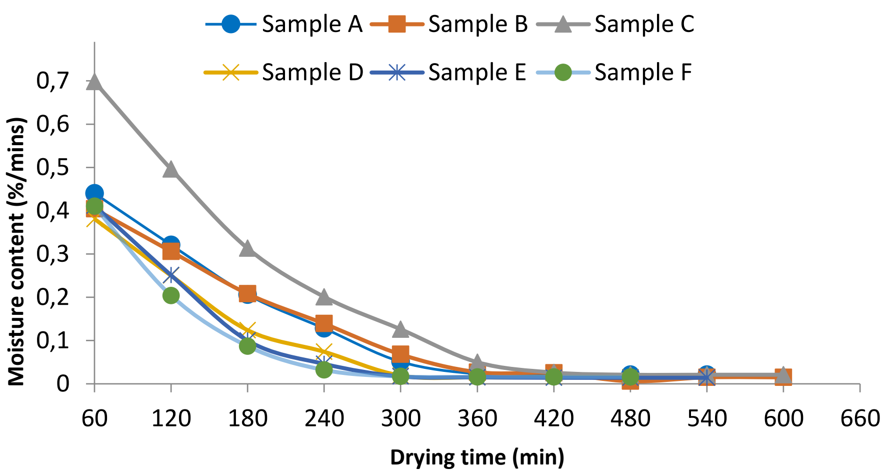

Figure 4. Moisture ratio of unfermented and fermented Trifoliate Yam varieties dried at 70°C using oven temperature.

From Figure1, the effect of adopted process parameters (72 hours fermentation and 70°C drying temperature) on the physical/sensory properties of the Trifoliate Yam varieties. It was observed that drying temperature and 72 hours fermentation altered the colour of the samples. Both white, deep-yellow and yellow trifiolate yam had similar colur (brown) of different intensities as finished products. Therefore, the process method adopted can not retain the colour of the Trifoliate Yam flour varieties.

Table 5. Drying kinetic equation and relationship between moisture ratio and drying time of unfermented and fermented Trifoliate Yam varieties.

Samples	Best fitting regression equations	R^2 Values	(k)
A	$Mr = 3E\text{-}06t^2 - 0.0026t + 0.5875$	0.996	14.914
B	$Mr = 2E\text{-}06t^2 - 0.0021t + 0.5248$	0.9959	14.508
C	$Mr = 4E\text{-}06t^2 - 0.0037t + 0.8824$	0.9928	15.201
D	$Mr = -0.189\ln(t) + 1.1348$	0.9504	1.666
E	$Mr = -0.185\ln(t) + 1.1206$	0.8922	1.687
F	$Mr = 773.5t^{-1.8}$	0.9453	6.650

Note: A= Unfermented Deep-Yellow Trifoliate Yam, B=Unfermented White Trifoliate Yam, C=Unfermented Yellow Trifoliate Yam, D= Fermented Deep-Yellow Trifoliate Yam E=Fermented White Trifoliate Yam and F=Fermented Yellow Trifoliate Yam, Mr = Moisture ratio, t= drying time, k = Drying constant.

CONCLUSION

The Trifoliate Yam slices were dried in a laboratory oven dryer at 70°C. The study reviewed that the moisture loss was subdued by diffusion mechanism. The drying temperature had significant effect on the drying characteristics of Trifoliate Yam slices. It was found that at the beginning of drying, there was a higher rate of moisture loss in all the samples and this rate decreased as the drying time increased. The drying of Trifoliate Yam samples occurred solely in the falling rate period which showed that internal moisture diffusion phenomenon are dominant and controlled the drying process. The average required drying time for fermented and unfermented Trifoliate Yam varieties were 500 mins and 580 mins respectively and this can useful in design drying equipment. The first falling rate period of the samples ranged from 60 minutes to 120 minutes, which is the region where moisture on the surface of the sample are removed, the second falling rate period ranged from 180 minutes to 360 minutes, this displayed the region where the internal moisture content of the sample are removed while the critical falling rate period ranged from 420 minutes to 600 minutes, it is the region where the drying rate falls to constant and this indicated the end of the drying process. It can be concluded that the fermented sample had a better drying characteristics than unfermented samples. Sample A, B, C, D, E and F attained constant moisture ratio of 0.021, 0.015, 0.021, 0.015, 0.014 and 0.016 at 540 mins, 600 mins, 600 mins, 480 mins, 540 mins and 540 mins respectively. Sample B and C had highest drying time followed by sample A, E and F while sample D had the lowest value of drying time.

DECLARATION OF COMPETING INTEREST

The authors declared that there is no conflict of interest during and after this research.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Obiageli Ugwuanyi-Nnadi: Investigation, writing-original draft, data curation,
Brendan Ekete Eje: Methodology, validation and review, and editing.
Patrick Ejike Ide: Investigation, formal analysis, writing-original draft, methodology, writing - original draft.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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