Effect of Drying Methods and Variety on the Chemical Composition, Functional and Microbial Properties of Date Flour

Ujong Anim Ekpo (anim.ujong@gmail.com)
Rivers State University
Emelike Nkechi Juliet Tamuno
Rivers State University
Ofiks Awajikatelem
Rivers State University

Research Article

Keywords: Date, Sun-drying, Cabinet-drying, Oven-drying, Amber, Sukkari

Posted Date: October 18th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2179762/v1

Abstract

The effect of three drying methods (sun, hot air oven and cabinet drier) on the chemical, functional and microbial properties of date flour was comparatively studied. The flesh of the two date varieties (amber and sukkari) were washed, dried at 65^{o}C, milled and sieved to obtain fine flour, and thereafter analyzed. Proximate analysis revealed that hot air oven-dried amber date powder exhibited significantly ($p < 0.05$) higher ash (2.64%), fat (5.35%), crude protein (10.50%), crude fibre (8.57%) while cabinet dried amber date exhibited the highest sugar (0.125%) and vitamin C (0.024mg/100g) content. Oven-dried amber date powder exhibited higher water absorption (1.10ml/g) and solubility (66.60%). Microbial analysis showed that hot air oven-dried amber and sukaari dates had the lowest total viable count (1.19×10^{5}g/CFU/ml and 9.45×10^{4}g/CFU/ml, respectively). Thus, the results suggest that hot air oven drying can be appropriately used to obtain date flour with good functionality, microbial property and chemical composition.

Introduction

Date palm (*Phoenix dactylifera* L.) is a perennial monocotyledon tree crop from the Aracaceae family (Uba et al., 2015). The fruit is very important in human nutrition because of its high concentration of key elements such as carbohydrate sugar, which varies from 65 to 80% by dry weight and is usually in the inverted form (glucose and fructose) (Alghamdi et al., 2019). Dates, in addition to sugars, include proteins, lipids, vitamins, dietary fiber, fatty acids, polyphenols, antioxidants, and amino acids (Chandrasekaran & Bahkali 2013). Dates are also high in vitamins A, B1, B2, B3, B5, and C. Dates include vitamin A, which has antioxidant characteristics that are beneficial for clear vision (Siddiq & Greiby, 2014). Shaba *et al*. (2015) reported that date palm (*P. dactylifera* L.) contains some percentage crude protein (1.21%), crude fat (1.73%), crude fibre (2.26%), ash (1.88%), moisture contents (1.16%), carbohydrate (91.76%), and calorific values (1621.50kg/100g) respectively. Date fruit is high in potassium, followed by calcium, zinc, phosphorus, magnesium, sodium, and iron. Date fruit is a high-energy food source with a sugar content ranging from 72 to 88 percent at maturity.

Date is widely used in traditional medicine to treat diabetes, obesity, cancer, and heart disease. The fruit has been shown to significantly improve diabetes patients' glycemic and lipid indices (Khalid *et al*., 2016). Dates also assist to prevent several chronic diseases, such as cancer and heart disease (Arshad et al., 2019). Many studies have found that date fruit extract can help lower blood cholesterol levels (Ali et al., 2012). Dates are a one-of-a-kind natural treasure that can be converted into a variety of date fruit derivatives or food products, as well as other byproducts from date waste. Date syrup, date juice, date bar, date jam, and butter are all high-value end products. Dates can thus play a part in industrializing economies by establishing date processing plants capable of producing products that meet the highest international quality and safety requirements (Ibrahim *et al*., 2020). Many date derivatives could be used as ingredients in food industries such as baked goods, beverages, confectionery, dairy, and sugar (Tang et al., 2013).

Drying is an energy-intensive procedure that requires removing moisture from a crop until the crop's moisture content is balanced with the surrounding air (Agoreyo et al., 2011). It involves the simultaneous transfer of heat and mass. The primary purpose of drying agricultural products is to minimize moisture content to a level that stops or controls bacterial activity and reduces deteriorative chemical reactions, hence extending food shelf life (Mujumdar and Law, 2010). Drying is also a key stage in preserving food quality, nutritional content, and shelf life (Emelike & Akusu, 2020). Large volumes of dried food goods extend shelf life, cut packaging costs, lower weights, improve appearance, retain original flavor, and, most significantly, maintain nutritional quality in most agricultural-based nations such as Nigeria (Demir et al., 2007; Ertekin & Yaldiz, 2004).

Agricultural crops are commonly dried using open sun, solar, and oven drying methods. Based on the intensity of the heat, duration of drying, and exposure to environmental pollution, each drying method has an effect on the vitamin content and other nutritional composition of the crop. The traditional method of drying dates in Nigeria, both on a local and large scale, is open sun drying. Some nutrients, such as vitamin C, are lost as a result of this procedure, as are food losses and contamination from dust, stones, and insects. Open sun drying is an unregulated method that exposes the produce to direct sunshine, rain, and dust. Food goods dried using open sun drying are undesirable since the drying method creates product quality unpredictability (Sagar & Kumar, 2010). According to Emelike (2020), sun drying changes the color of foods, resulting in shrinkage and an unappealing end product.

The solar drying technique has the benefits of minimalism and lower initial investments, but it requires lengthy drying durations (Andritsos et al., 2003), making it a time-consuming operation. To improve the excellence and value of dried dates, new industrial drying technologies such as hot-air drying should be used instead of the traditional open sun drying method. Convective hot-air drying is a popular industrial preservation technique. Traditional methods, such as oven drying, are used in industrial operations. Oven drying uses heat to reduce the moisture in food to a bare minimum by evaporation. This current drying process is used to dry plant materials at particular temperatures over a set amount of time. Oven drying is becoming more popular in the food processing industry due to lower manufacturing costs, resulting in more cheap products for customers. However, data on the influence of oven drying on date flour quality is scarce. Furthermore, the biochemical content of fruits varies according to variety and cultivar (Emelike & Akusu, 2020). Date varietals may thus have a substantial impact on the chemical makeup of dried date fruits. To enhance the usage of date flour in food products, it is vital to determine the appropriate drying method and variety for producing high-quality date flour. This study therefore seeks to study the effects of drying methods such as open sun drying, cabinet drying and hot-air oven on the quality of flour from two varieties of date fruit as this could serve as a basis for development and advice on proper postharvest handling and proper drying methods for date fruit.

Materials And Methods

Collection of Raw Materials: Two date varieties were used for this study namely: Amber and Sukkari. These varieties were obtained from Sangana Market, Port Harcourt, Nigeria. All chemicals used were of

analytical grade and obtained from the Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria.

Processing of date into date flour

Date fruit was processed into date flour using the method described by Nadeem et al. (2017). Fresh date fruit varieties were sorted and washed with portable water to remove adhering dirt followed by deseeding of the fruit manually. The fleshy pulp was cut into small pieces with the aid of a knife. The pulp with pericarp was then subjected to drying treatments as follows:

Cabinet drying

The sliced pulp with pericarp was evenly distributed in a thin layer onto stainless steel trays. The trays were then placed onto a cabinet drier fabricated locally by the Nigerian Stored Products Research Institute (NSPRI). This was dried at 65^{o}C overnight and subsequently milled using a nutri blender. In order to get fine and free flowing flour, 50% corn starch was added during the milling process. After milling, the date flour samples were sieved and packed in an air tight container and stored until required for further analysis.

Hot air Oven

The sliced pulp with pericarp was evenly distributed in a thin layer onto stainless steel trays. The trays were then placed onto a hot air oven and dried at 65^{o}C overnight and subsequently milled using a nutri blender. Corn starch was added during the milling process. After milling, the date flour samples were sieved and packed in an air tight container and stored until required for further analysis.

Sun drying

The sliced dates was poured on a clean tablecloth and laid out on a table at about 1.5 m from the ground and then placed under the sun for 6–8 days at the rate of 10 h per day. The dried dates were then milled using a nutri blender. Corn starch also added during milling as carried out during the oven drying process. After milling, the date flour samples were sieved and packed in an air tight container and stored until required for further analysis.

Chemical Analysis

Proximate analysis (moisture, ash, protein, fat and crude fibre) of the date flour samples was determined using the method of Association of Official Analytical Chemist (AOAC, 2012) while total available carbohydrate was calculated by difference using the formula:

100% - (% Moisture + % Ash + % Crude protein + % Fat + % Crude fibre)

Determination of Vitamin C

The method described by AOAC (2012) was used for determination of Vitamin C. Five (5.0) g of the sample was weighed into a clean beaker followed by the addition of 112.5 ml of distilled water and 12.5 ml of oxalic acid. This was allowed to shake for 30 min at room temperature, filtered after 30 min and made up to 50 ml. Ten (10 ml) milliliters of the sample was then pipetted into a 100 ml volumetric flask and titrated with the indophenol solution until a faint pink colour persisted for 15 sec. The concentration was expressed as mg ascorbic acid equivalent to V ml of the dye solution i.e. 10ml ascorbic acid solution = 0.002g ascorbic acid. If 0.002g ascorbic acid required 1ml dye solution to neutralize it,

then 1ml dye solution =,

Vit C = $\frac{V \times T}{W}$×100g mg ascorbic acid/100g sample

V = ml dye used for titrating of aliquot of sample

T = Ascorbic equivalent or dye solution expressed as ml/ml

W = gm of sample in aliquot titrated

Determination of Functional Properties

The water absorption capacity and solubility was carried out according to the method described by Omeire et al., 2014). The bulk density (ρ_b) of the date flour was determined by measuring the weight of the flour and the corresponding volume (Jinapong et al., 2008). Hygroscopicity of the date flours was determined using the method described by Koc et al. (2014). The degree of caking was carried out as described by Jaya & Das (2004).

Microbial Analysis

The analysis was carried out using the method described by Jidean and Jideani (2006). Total heterotrophic counts was determined using nutrient agar (NA), Saboraud dextrose agar (SDA) was used for the enumeration of total mould counts while was used for the enumeration of total yeast count. Twenty five gram (25 g) of samples each was weighed into 225 ml of prepared diluent and mixed to dissolve completely (10^{-1}). One millilitre (1 ml) was measured from 10^{-1} into the second tube (10^{-2}). Dilution will be continued to 10^{-7} which is the last dilution. Spread plate method was used for plating the samples. One millilitre from the dilution 10^{-7} was taken using sterile pipette and then it was introduced into sterile petri dish. This was done in duplicates for each one of the samples. The diluted culture (0.1 ml) was pipette into a petri dish containing the prepared media. The plates were then spread using a spreader. The NA plates were incubated at 37^{o}C for 18–24 hours while SDA plates were incubated at 30^{o}C for 4–7 days.

Statistical Analysis

All measurements were made in triplicates. Results were expressed as mean ± standard deviation. The analysis of variance (ANOVA) at a confidence level of 95% was performed. Duncan Multiple Range Test

(DMRT) was used to separate the mean. All the results that were obtained were analyzed SPSS version 20.0 software 2011.

Results

Chemical Composition of Date Flours

Table 1 shows the chemical composition of dried date flours of two varieties. Moisture of the dried date flours ranged from 7.32–12.94% with sample B (cabinet dried Amber date flour) recording the lowest value while sample F (sun dried Sukkari date flour) had the highest value. Ash content ranged from 1.59–2.67% with sample B (cabinet dried Amber date flour) having the lowest value and sample F as the highest.

Fat content of the dried date flours ranged from 0.49–5.35% with the lowest value recorded in sample C while sample A had the highest. Crude protein content ranged from 0.00-10.50% with the lowest value found in sample B while sample A had the highest. Crude fibre content of the date flours ranged from 0.04–8.57% with sample B recording the lowest value while sample A had the highest. Carbohydrate content of the date flours ranged from 65.46–85.63% with the lowest value found in sample A while sample B had the highest value. Vitamin C content of the date flours ranged from 0.007mg/100g to 0.024mg/100g with the lowest value found in sample F while sample E recorded the highest value.

Table 1
Chemical composition of dried date flours

Sample	Moisture (%)	Ash (%)	Fat (%)	Crude protein (%)	C. fibre (%)	CHO (%)	Vit. C (mg/100g)
A	7.47 ± 0.04^{d}	2.64 ± 0.07^{a}	5.35 ± 0.07^{a}	10.50 ± 0.00^{a}	8.57 ± 0.59^{a}	65.46 ± 0.64^{e}	0.020 ± 0.01^{ab}
B	7.32 ± 0.10^{d}	1.59 ± 0.07^{d}	0.90 ± 0.28^{c}	0.00 ± 0.00^{d}	0.04 ± 0.02^{d}	90.15 ± 0.47^{a}	0.018 ± 0.00^{ab}
C	8.64 ± 0.36^{c}	1.97 ± 0.10^{c}	0.49 ± 0.42^{c}	2.69 ± 1.32^{cc}	6.78 ± 0.57^{b}	79.44 ± 1.86^{c}	0.015 ± 0.00^{ab}
D	10.49 ± 0.51^{b}	2.25 ± 0.03^{b}	1.20 ± 0.42^{c}	3.50 ± 0.00^{bc}	5.45 ± 0.45^{b}	77.11 ± 0.50^{c}	0.020 ± 0.01^{ab}
E	8.69 ± 0.42^{c}	1.99 ± 0.15^{c}	0.70 ± 0.57^{c}	3.50 ± 0.00^{bc}	0.59 ± 0.00^{d}	84.53 ± 0.29^{b}	0.024 ± 0.00^{a}
F	12.94 ± 0.63^{a}	2.37 ± 0.03^{b}	3.16 ± 0.00^{b}	4.81 ± 0.62^{b}	3.57 ± 1.40^{c}	72.85 ± 3.04^{d}	0.007 ± 0.00^{b}

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

KEYS:

A = Hot air oven dried Amber date flour

B = Cabinet dried Amber date flour

C = Sun dried Amber date flour

D = Hot air oven dried Sukkari date flour

E = Cabinet dried Sukkari date flour

F = Sun dried Sukkari date flour

Functional Properties of Dried Date Flour

Table 2 shows the functional properties of date flours from two varieties. Hygroscopicity of the date flours ranged from 14.35–84.50% with the lowest value recorded in sample C while sample E had the highest. Dispersibility of the date flours ranged from 67.50–74.50% with sample A recording the lowest value while sample D had the highest. Degree of caking ranged from 30.50-81.85% with sample F recording the lowest value while the highest was found in sample E.

Water absorption capacity of the date flours ranged from 0.79-1.10ml/g with the lowest value recorded in sample B while samples A and D had the highest. Swelling power ranged from 1.45g to 2.94g with sample D having the lowest value while sample F as the highest. Solubility of the date flours ranged from 40.50% in sample F to 66.60% in sample A. Bulk density ranged from 1.54g/g to 1.70g/g with the lowest value found in sample A while sample D had the highest.

Table 2
Functional Properties of dried date flour

Samples	Hygroscopicity (kg/100g)	Dispersibility (%)	Degree of caking (%)	Water absorp. (ml/g)	Swelling power (g)	Solubility (%)	Bulk density (g/g)
A	28.50 ± 0.00^{e}	67.50 ± 0.71^{b}	50.75 ± 0.35^{c}	1.10 ± 0.14^{a}	2.83 ± 0.19^{a}	66.60 ± 2.82^{a}	1.54 ± 0.01^{e}
B	65.40 ± 0.14^{b}	70.50 ± 0.71^{ab}	62.50 ± 0.00^{b}	0.79 ± 0.00^{b}	2.26 ± 0.27^{b}	58.05 ± 5.16^{b}	1.63 ± 0.00^{b}
C	14.35 ± 0.21^{f}	71.00 ± 2.83^{ab}	45.40 ± 0.14^{d}	0.90 ± 0.14^{ab}	1.69 ± 0.31^{c}	55.30 ± 1.27^{b}	1.61 ± 0.00^{c}
D	56.80 ± 0.42^{c}	74.50 ± 0.71^{a}	33.30 ± 0.42^{f}	1.10 ± 0.00^{ab}	1.45 ± 0.03^{c}	59.45 ± 0.35^{ab}	1.70 ± 0.00^{a}
E	84.50 ± 0.00^{a}	73.50 ± 2.12^{a}	81.85 ± 0.21^{a}	0.99 ± 0.00^{ab}	2.53 ± 0.21^{ab}	61.00 ± 4.00^{ab}	1.69 ± 0.00^{a}
F	39.10 ± 0.14^{d}	72.50 ± 0.71^{a}	30.50 ± 0.00^{e}	0.80 ± 0.00^{b}	2.94 ± 0.20^{a}	40.50 ± 3.54^{c}	1.59 ± 0.00^{d}

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

KEYS:

A = Hot air oven dried Amber date flour

B = Cabinet dried Amber date flour

C = Sun dried Amber date flour

D = Hot air oven dried Sukkari date flour

E = Cabinet dried Sukkari date flour

F = Sun dried Sukkari date flour

Microbiological Analysis of Dried Date Flour

Table 3 shows the microbiological evaluation of date flours from two varieties. Total viable count of the date flours ranged from 9.45×10^4 CFU/g to 1.91×10^5 CFU/g with the lowest count found in sample D while sample F had the highest. Total mould count of the date flours ranged from 1.50×10^3 CFU/g to 1.05×10^4 cfu/g with sample B recording the lowest count while sample C had the highest. Total yeast count ranged from No growth in sample F to 1.00×10^4 CFU/g in sample C.

Table 3
Microbiological analysis (CFU/g) of dried date flours

Samples	Total viable count	Total mould count	Total yeast count
A	1.19×10^5	9.00×10^3	2.45×10^3
B	1.20×10^5	1.50×10^3	1.00×10^3
C	1.42×10^5	1.05×10^4	1.00×10^4
D	9.45×10^4	8.50×10^3	3.50×10^3
E	1.25×10^5	5.50×10^3	6.50×10^3
F	1.91×10^5	8.50×10^3	NG

KEYS:

NG = No growth

A = Hot air oven dried Amber date flour

B = Cabinet dried Amber date flour

C = Sun dried Amber date flour

D = Hot air oven dried Sukkari date flour

E = Cabinet dried Sukkari date flour

F = Sun dried Sukkari date flour

Discussions

Effect of Drying Methods and Variety on the Chemical Composition of Date flour

The high moisture content in the sundried date flour samples implies that sun drying significantly ($p < 0.05$) increased the moisture content of the dried date flours. This could be due to the higher temperature

of the hot-air and cabinet drier leading to the lowest moisture content in the samples. The significantly high moisture content of the sun dried sukkari date could be attributed to its soft characteristics which might have slowed the drying process. This study's findings were consistent with those of Ohuoba et al. (2019), who discovered that sun-dried water yam peel had a higher moisture content (10.1%) than hot air oven-dried samples (8.91%). Emelike and Ebere (2016) also discovered that hot air oven dried moringa leaf flour has a lower moisture content (1.65%) than sundried flour (4.25%). A large drop in moisture content, as shown in this study for hot air and cabinet dried date flours, reduces perishability, enhances value, and extends shelf life, making these items available all year (Agoreyo et al., 2011).

The differences in ash content on drying could be attributed to varietal differences and hardness of the date varieties. Date fruits are divided into soft, semi-dry, and dry kinds based on the texture of its edible portions, according to Sami et al. (2016). The high ash content of the cabinet and hot air oven dried amber date flours could be related to the large loss of moisture, which tends to boost nutritional concentration (Morris et al., 2004). Wijewardana et al. (2016) made a similar observation, reporting that soursop dried in a hot air oven preserved greater ash content than sun dried samples. Ash is the inorganic residue left after food has eliminated the water and organic stuff, and it is a measure of the overall quantity of mineral present in a food.

Sun and cabinet drying resulted in significant reduction in fat content of the amber date flours while fat was observed to increase following drying of sukkari date. These effects observed in the two date varieties could also be attributed to varietal differences and the degree of hardness. The result of this study agrees with the finding of Ladi et al. (2017) who reported that hot air oven dried tomato flour had higher fat (0.82%) than sun dried sample (0.53%). The low fat content of the hot air oven and cabinet dried sukkari flour (< 1%) represent a good index of storability as they reduce the susceptibility of the samples to lipid oxidation (Abioye et al., 2014).

Cabinet drying resulted in a significant reduction in protein content of both date varieties. Sun drying resulted in an increase in protein content of sukkari date variety; however, the effect of drying methods was not significant ($p > 0.05$). On the other hand, protein content of amber date was significantly ($p < 0.05$) retained following hot air oven drying. This could also be attributed to the significant reduction of moisture which tends to increase the concentration of nutrients (Morris et al., 2004). Similar finding was also reported by Ladi et al. (2017) who found that oven dried tomato flour had higher protein (3.70%) than sun dried sample (2.60%%). Ohuoba et al. (2019) also reported significant losses in protein content of tuber peels following sun drying.

A significantly higher retention was observed in hot air oven dried date flours followed by sun drying while cabinet drier resulted in significant ($p < 0.05$) losses in the fibre content. This result correlates well with the finding of Ladi et al. (2017) who reported that crude fibre of tomato flour was better retained in oven dried sample (6.37%) than in the sun dried sample (5.15%). There was also a significant ($p < 0.05$) difference in the carbohydrate content of the two date varieties with the amber date having higher carbohydrate content than the sukkari date. The high crude fibre of the hot air oven dried amber date flour implies that

the sample will be of health benefits such as reduced constipation and ease in colon digestion. Foods with high fibre content are used for the treatment of obesity, diabetes, cancer, and gastrointestinal disorders (Ibironke & Olusola, 2013).

Carbohydrate of date flour subjected to cabinet drying were significantly ($p < 0.05$) retained for both date varieties. On the other hand, hot air oven drying resulted in losses for amber date variety (65.46%) while this was retained for the sukkari date (77.11%) as compared to sun dried sukkari date (72.85%). These effects observed in the two date varieties could also be attributed to varietal differences and the degree of hardness of the date varieties. Ladi et al. (2017) also reported that sun dried tomato had higher carbohydrate (77.21%) than oven dried sample (77.00%) while on the other hand, Emelike & Ebere (20160 reported that hot air oven dried moringa flour had higher carbohydrate (29.32%) than sun dried sample (24.09%). There was also a significant ($p < 0.05$) difference in the carbohydrate content of the two date varieties.

The results also revealed that sun drying reduced the vitamin C content of the sukkari date variety significantly ($p < 0.05$), however this effect was not significant ($p > 0.05$) for the amber date variety. This research supports the claim that sun drying promotes the loss of some nutrients, such as vitamin C, due to direct sunlight exposure (Papu et al., 2014). According to Wijewardana et al. (2016), fast drying preserves more ascorbic acid than delayed drying. This could also explain why sun drying reduced vitamin C concentration dramatically, as sun drying requires long drying durations.

Effect of Drying Methods and Variety on the Functional Properties of Date Flour

Sun dried amber date flour had the lowest hygroscopicity and this was followed closely by hot air oven dried amber date flours which are the most desirable. The low temperature in sun drying resulted in the highest moisture content thus reducing its capacity to absorb moisture from surrounding (Tonon et al., 2008). Cabinet dried date flours had the highest hygroscopicity because to their low moisture content, which enhanced the water concentration gradient between the product and the ambient air. As a result, it has a greater potential to absorb moisture from the environment (Sarabandi et al. 2014). All of the date flours were hygroscopic, with hygroscopicity ranging from 14.35 to 84.50 percent (Schuck et al., 2012). Date is heavy in low molecular weight carbohydrates, which contributes to its hygroscopic characteristic. As a result, the carrier agent, corn starch or maltodextrin, is suggested. The hygroscopicity of fruit flours ranges from 3.28–34.72%, which shows agreement with some of the samples from this study (Santhalakshmy et al., 2015).

Because of its high hygroscopicity, cabinet dried had the highest degree of caking (Goula & Adamopoulos, 2010). According to the GEA Niro Research Laboratory (2005), flour with a caking degree of 10.1 to 20% is classified as somewhat caking flour, whereas flour with a caking degree of 20.1 to 50% is classified as caking flour. As a result, all date flours produced are caking flour. The drying process had no effect on the dispersibility of the date flours ($p > 0.05$). The property of dispersibility determines flour's ability to separate from water molecules and displays its hydrophobic activity. Adebowale et al. (2008)

discovered that higher dispersibility flour easily reconstitutes to produce fine, uniform dough during mixing. The disparities observed in the water absorption capacities of the date flours could be attributed to varietal differences and drying method. The result obtained shows that hot air oven dried date flour has a good ability of bind water. This finding implies that date flour could be utilized in confectionery. Water absorption capacity is a product's ability to associate with water in settings where water is scarce. Water absorption capacity, according to Niba et al. (2001), is a significant processing characteristic with consequences for viscosity. Furthermore, water absorption capability is critical in product bulking and uniformity, as well as baking applications. A high water absorption capacity is related to the loose structure of starch polymers, whereas a low number shows the structure's compactness (Adebowale et al., 2005).

Sun and cabinet drying resulted in a significant ($p < 0.05$) reduction in the swelling power of the amber date while this was observed to increase for dried sukkari date flour. This could be attributed to varietal differences and difference in hardness of the date varieties. Because it is determined by the weight of swelled starch granules and their occluded water, swelling power is a measure of hydration capacity. Food eating quality is frequently associated with water retention in inflated starch granules (Rickard et al., 1992). Furthermore, swelling power determines how much a flour sample expands in volume when soaked in water compared to its starting volume. According to Moorthy and Ramanujam (1980), the swelling power of flour granules is a measure of the degree of associative forces within the granule.

Both sun and cabinet drying caused significant ($p < 0.05$) reduction in the solubility of the date flours. This study agrees with the statement of Tunde-Akintunde & Akintunde (2011) who reported that hot air oven dried tapioca had better functionality than sun dried samples indicating that hot air oven drying can be used to replace sun drying to obtain date flour of high quality. Solubility refers to a solid's capacity to dissolve or disperse in an aqueous solution, most commonly water (Falade & Okafor, 2015). Lower values of flour solubility in sun dried date flours indicate the presence of strong bonding forces within the flour granules, whereas higher values in hot air oven dried could be attributed to increased leaching of solubilized amylose molecules from swollen starch granules, thereby promoting starch destruction (Asaam et al., 2018). Variety had a significant ($p < 0.05$) on the bulk density of the date flours. Bulk density of flours is very important in determining packaging requirement and material handling (Orisa & Udofia, 2020). Low bulk density of the dried amber date flour is desired as it contributed to lower dietary bulk, ease of packaging and transportation (Aluge et al., 2016).

Effect of Drying Methods and Variety on the Microbiological Properties of Date Flour

The low viable count in the hot air oven dried date flours is due to the high temperature. The high count in sun dried sample is due to contamination by dust, stones and insect in the course of open sun drying. Ladi et al. (2017) also reported high viable count for sun dried tomato (7.7×10^5cfu/g) as compared to oven dried tomato (5.7×10^3cfu/g). Total viable counts of all the samples were within the microbial limit of $< 10^5$cfu/g for food products (ICMSF, 2002). Similarly, the low mould count in the hot air oven dried

date flours is due to the high temperature while high count in sun dried sample is due to contamination by dust, stones and insect in the course of open sun drying. The high moisture content of sundried date flours can have a detrimental impact on product keeping quality by promoting the establishment of mould colony forming units. Mold may be present in most foods due to the existence of leftover moisture, which provides a favorable environment for their growth. Mould and yeast growth has been linked to the production of heat stable mycotoxins, which are a major source of concern in the food industry (Dalie et al., 2010). The date flours were within the acceptable limit of 10^2 to 10^4cfu/g for mould counts (ICMSF, 2002) and therefore, the products are microbiologically safe.

Conclusion

The study shows that the values obtained differed significantly with date variety used, an indication that the variety used for flour production has an effect on its properties and thus variety is an important factor in the production of date flour. Generally, sun drying samples gave lower values for most of the properties (especially ash, crude fibre, vitamin C, hhygroscopicity, degree of caking, water absorption and solubility) than hot air oven which is probably due to the lower drying temperature involved. The results also showed that the effect of the variety and drying method on the quality parameters of the date flours was significant. Sun drying resulted in a significant reduction in the ash, fat, protein, crude fibre, carbohydrate and vitamin C contents of dried amber date while ash, fat and crude protein content was observed to increase for hot air oven dried sukkari date flour. In addition, sun drying resulted in a significant reduction in the dispersibility, bulk density, solubility, hygroscocpity and degree of caking of dried sukkari date while dispersibility and bulk density was observed to increase for hot air oven dried amber date flour. Hot air oven drying also resulted in a decreased total viable and mould count which could enhance the keeping quality of the products. The results obtained therefore shows that hot air oven drying can be used to replace sun drying for the production of date flour.

Declarations

Competing Interests Disclaimer

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

References

Abioye, V.F., Adejuyitan, J.A. & Idowu, C.F. (2014). Effect of drying methods on the nutritional and quality attributes of baobab leaves (*Adansonia digitata*). *Agriculture and Biology Journal of North America,* 5(3): 104-108.

Adebowale AA, Sanni LO, & Fadaunsi EL. (2008). Functional properties of cassava-sweet potato starch blend. Proceeding of the 32nd *Annual Conference of Nigerian Institute of Food Science and Tech*, 2008; pp 304-305.

Adebowale, K.O., Olu, Owolabi. & Olawumu EK, Lawal (2005). Functional properties of native, physically and chemically modified breadfruit (*Artocarpus artilis*). Starch, Ind, Crops products, 21: 343-351.

Agoreyo, R.O., Akpiroroh, O., Orukpr, O.A., Osaweren, O.R. & Owabor, C.N. (2011). The effects of various drying methods on the nutritional composition of *MMusa paradisiaca*, *Dioscorea rotundata* and *Colocasis esculenta*. *Asian Journal of Biochemistry*, 6(6): 458-454.

Alghamdi, A.A., Fawzi, M., Awadelkareem, A.M., Sharif Hossain, A.B.M & Ibrahim, N.A. (2019). Nutritional Assessment of different Date fruits (*Phoenix dactylifera* L.) varieties cultivated in Hail Province, Saudi Arabia. *Bioscience Biotechnology Research Communications*, 11(2): 263-269.

Ali, A., Waly, M., Essa, M.M. & Devarajan, S. (2012). 26 Nutritionaland medicinal value of date fruit. In: Mohamed Essa, M, Manick-avasagan, A & Sukumar, E (Eds.),Dates: the genus Phoenix: production, processing, food, and medicinal values. CRC Press, P. 361.

Aluge, O.O., Akinola, S.A. & Osundahunsi, O.F. (2016).“Effect of Malted Sorghum on Quality Characteristics of Wheat-Sorghum-Soybean Flour for Potential Use in Confectionaries,” *Food and Nutrition Sciences*, 7:1241-1252.

Andritsos, N., Dalampakis, P., & Kolios, N. (2003). Use of geothermal energy for tomato energy. GMC Bulletin (March), 9–13.

AOAC. (2012). Official Methods of Analysis of the Association of Official Analytical Chemists, 20th ed., 2012.

Arshad, M.S., Batool, S.M., Khan, M.K. (2019). Bio-evaluation of functional date bars using rats as model organism against hyper-cholesterolemia. *Lipids in Health and Disease*, 18: 148

Asaam, E., Adubofuor, J., Amoah, I. & Apeku, O. (2018). Functional and pasting properties of yellow maize-soya bean-pumpkin composite flours and acceptability study on their breakfast cereals. *Cogent Food and Agriculture*, 4:1501932. https://doi.org/10.1080/23311932.2018.1501932.

Chandrasekaran, M. and Bahkali, A.H. (2013) Valorization of Date Palm (*Phoenix dactylifera*) Fruit Processing By-Products and Wastes Using Bioprocess Technology—Review. *Saudi Journal of Biological Sciences*, 20, 105-120.
https://doi.org/10.1016/j.sjbs.2012.12.004.

Dalie, D.K.D., Deschamps, A.M. and Richard-Forget, F. (2010). Lactic acid bacteria e potential for control of mould growth and mycotoxins: a review. *Food Control,* 21(4): 370-380.

Demir,V., Gunhan, T. and Yagcioglu, A. K. (2007). Mathematical modeling of convection drying of green table olives. *Biosystems Engineering*, 98: 47-53.

Emelike, N.J.T. & Ebere, C.O. (2016). Effect of drying techniques of moringa leaf on the quality of chin-chin enriched with moringa leaf flour. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 10(4): 65-70.

Emelike, N.J.T. (2020). Functional and physicochemical properties of turmeric flour as affected by processing methods. *Asian Food Science Journal*, 19(2): 1-10.

Emelike, N.J.T. & Akusu, M.O. (2020). Comparative effects of drying on the drying characteristics, product quality and proximate composition of some selected vegetables. *European Journal of Food Science and Technology*, 8(2): 11-23.

Ertekin, C. & Yaldiz, O. (*2004).Drying of eggplant and selection of a suitable thin layer drying model. Journal of Food Engineering*, 63: 349-359.

Falade, K.O. & Okafor, C.A. (2015). Physical, functional, and pasting properties of flours from corms of two Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) cultivars," *Food Science and Technology*, 52:3440–3448.

GEA Niro Research Laboratory (2003). Analytical methods dry milk products (Niro Analytical Methods, No. 15a). Soeborg.

Goula, A. & Adamopoulos, K. (2010). A new technique for spray drying orange juice concentrate. *Innovative Food Science and Emerging Technologies*, 11(2): 342-351.

Ibironke, A.A. & Olusola, O.O. (2013). Phytochemical screening, Proximate Analysis and Antimicrobial Activity of aqueous extract of *Megaphrynium macrostachchyum* seeds. *Int. J. Engin. Res., Tech.*, 2: 2123-2131.

ICMSF (2002). International Commission o Microbiological Specifications for Foods. Microorganisms in Foods 7. Microbiological testing in food safety management. New York USA, Kluwer Academic/Plenum Publishers; 2002.

Jaya, S. & Das, H. (2004). Effect of maltodextrin, glycerol monsterarate and trialcium phosphate on vacuum dried mango flour properties. *Journal of Food Engineering*, 63: 125-134.

Jideani, V.A. & Jideani, I.A. (2006) Laboratory manual of Food Bacteriology. Amana Printing and Advertising Ltd, Kaduna, Nigeria, 10:196.

Jinapong, N., Suphantharika, M. & Jmnong, P. (2008). Production of instant soymilk flours by ultrafiltration, spray drying and fluidized bed agglomeration. *Journal of Food Engineering*, 84: 194-205.

Khalid, S., Khalid, N., Khan, R.S., Ahmed, H. & Ahmad, A.(2017). A review on chemistry and pharmacology of Ajwa date fruit and pit. *Trends in Food Science & Technology*, 63:60–69.

Koc, B., Sakin-Yilmazer, M., Kaymak-Ertekin, F. & Balkir, P. (2014). Physical properties of yoghurt flour produced by spray drying. *Journal of Food Science and Technology*, 51(7):1377-1383.

Ladi, O.J., Awod, Y.P., Obogeh, K.A. & Alfa, I.N. (2017). Effect of drying methods and storage conditions on nutritional value and sensory properties of dehydrated tomato flour (*Lycopersicon esculentum*). *International Journal of Biochemistry Research and Review,* 19(1): 1-7.

Moorthy, S. N. & Ramanujam, T. (1986). Variation in properties of starch in cassava varieties in Relation to age of the crop. *Starch starke*, 38: 58-61.

Morris, A., Barnett, A. & Burrows, O. (2004). Effect of processing on nutrient content of foods. *Cararticles*, 37(3): 160-164.

Mujumdar, A.S. & Law, C.L. (2010). Drying technology: Trends and applications in Postharvest processing. *Food Bioprocess Technology*, 3: 843-852.

Nadeem, M., Qureshi, T.M., Ahmad, M.M., Riaz, M.N., Ameer, A. & Qurat-ul-An. (2017). Development of free flowing date flour and its utilization in muffins to enhance nutritional value. *Journal of Agricultural Research*, 55(4): 671-677.

Niba, L.L., Bokanga, M., Jackson, F.L., Schlimme, D.S. & Li, B.W. (2001). Physicochemical properties and starch granular characteristics of flours from various Manihot esculenta (cassava) genotypes. *Journal of Food Science*, 67(5): 1701-1705.

Ohuoba, A.N., Onwuka, G.I. & Omodamiro, R.M. (2019). Effects of drying methods on physicochemical properties of hydrocolloids isolated from peel flour of some selected root and tuber crops. *International Journal of Biochemistry Research and Review*, 27(3): 1-8.

Omeire, G.C., Umeji, O.F. & Obasi, N.E. (2014). Acceptability of Noodles Produced from Blends of Wheat, Acha and Soybean Composite Flours. *Nigerian Food Journal*, 32(1): 31-37.

Orisa, C.A. & Udofia, S.U. (2020). Functional and pasting properties of composite flours from Triticum durum, Digitaria exilis, Vigna unguiculata and Moringa oleifera Powder. *Asian Food Science Journal*, 19(2): 40-49.

Papu, S., Singh, A., Jaivir, S., Sweta, S. & Arya, A.M. (2014) Effect of Drying Characteristics of Garlic-A Review. *Journal of Food Processing Technology*, 5: 318. doi:10.4172/2157-7110.1000318

Rickard, J. E, Blanshard, J. M. V. & Asaoka, M. (1992): Effects of cultivar and growth season on the gelatinization properties of cassava (*Manihot esculenta*) starch. *Journal Science Food and Agriculture,* (59): 53-58.

Sagar, V.R. & Kumar, S.P. (2010). Recent advances in drying and dehydration of fruits and vegetables. *Journal of Food Science and Technology*, 47(1): 15-26.

Sani, L.A., Aliyu M.D., Hamza, A., Adetunji, O.A., Gidado, R.M. & Solomon, B.O. (2010). Exploring the Nigerian Date Palm (*Phoenix Dactylifera* L.) Germplasm For In Vitro Callogenesis, ISHS Acta Horticuturae 882: IV International Date Palm Conference 2010.

Sarabandi, K., Peighambardoust, S.H. & Shirmohammadi, M. (2014). Physical properties of spray dried grape syrup as affected by drying temperature and drying aids. *International Journal of Agriculture and Crop Sciences*, 7(12): 928-934.

Santhalakshmy, S., Don Bosco, S.J., Francis, S. & Sabeena, M. (2015). Effect of inlet temperature on physicochemical properties of spray-dried jamun fruit juice powder. *Powder Technology*, 274: 37-43. https://doi.org/10.1016/j.powtec.2015.01.016.

Schuck, P., Dolivet, A. & Jeantet, R. (2012). Analytical methods for food and dairy powders. Wiley, West Sussex.

Siddiq, M. & Greiby, I. (2014). Overview of date fruit production, postharvest handling, processing, and nutrition. In: Dates: Postharvest Science, Processing Technology and Health Benefits, 1sted. (edited by M. Siddiq, S.M. Aleid & A.A. Kader). Pp. 1–28.Chichester, UK: John Wiley and Sons.

Tang, Z.X., Shi, L.E. & Aleid, S.M. (2013). Date fruit: chemicalcomposition, nutritional and medicinal values, products. *Journal of the Science of Food and Agriculture*, 93: 2351–2361

Tunde-Akintunde, T.Y. & Akintunde, B.O. (2011). Effect of Drying Method on Quality of Tapioca from Different Varieties of Cassava (*Manihot esculenta*). *Nigerian Food Journal*, 29(2): 1-10.

Tonon, R.V., Brabet, C. & Hubinger, M.D. (2008). Influence of process conditions on the physicochemical properties of acai (*Euterpe oleaceae Mart.*) powder produced by spray drying. *Journal of Food Engineering*, 88(3): 411-418. http://dx.doi.org/10.1016/jfooden.2008.02.09.

Uba, A., Abdullahi, M., Yusuf, A. & Ibrahim, Z.Y.Y. (2015). Mineral profile, proximate and amino acid composition of three dates varieties (Phoenix Dactylifera L.). *Der Pharma Chemica*, 7(5): 48-53.

Wijewardana, R.M.N.A., Nawarathne, S.B. & Wickramasinghe, I. (2016). Effect of various dehydration methods on proximate composition and retention of antioxidants in different fruit flours. *International Food Research Journal,* 2(5): 2016-2020.