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EFFECT OF DIFFERENT DRYING TECHNIQUES ON THE RESISTANT STARCH, BIOACTIVE COMPONENTS, PHYSICOCHEMICAL AND PASTING PROPERTIES OF CARDABA BANANA FLOUR

– Research paper –

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Abstract: This study investigated the effect of different drying techniques on Cardaba banana flour. Cardaba banana was processed using sun, cabinet and freeze drying methods. The proximate, pasting, functional, starch profile and antioxidant properties of Cardaba banana flour were evaluated. The drying methods significantly ($p \leq 0.05$) affected the chemical, functional, pasting and antioxidant properties of the Cardaba banana flour. Freeze dried (FD) flour sample had highest (6.69%) protein value, while sun dried (SD) flour sample had the lowest (6.13%). The crude fat of FD sample (2.38%) was not significantly different ($p > 0.05$) from cabinet dried (CD) flour (2.38%) sample. However, sun dried sample crude fibre content was the highest (0.84%). In addition, drying methods significantly ($p \leq 0.05$) affected the pasting characteristics of Cardaba banana flours. Results of functional properties showed that the drying methods had no effect on the least gelation properties of the flour. The resistant and total starch was highest in CD, and least in SD. Freeze drying produced flour high in indigestible carbohydrate compared to the other methods. Cardaba banana flour samples from all the drying methods showed substantive total phenolic, flavonoid, ABTS and DPPH contents. The drying methods employed significantly ($p \leq 0.05$) affected the functional, chemical, pasting and antioxidants properties of Cardaba banana flours. However, the study indicated that freeze drying and cabinet drying produce flours with better properties.
Keywords: Cardaba banana, Antioxidants, Cabinet drying, Freeze drying, Sun drying.

INTRODUCTION

Globally, the demand for wheat flour has been on increase as the population utilizing it is increasing (Ayo-Omogie and Odekunle, 2017). Only few countries like China, India, USA, Russia and France produce and supply wheat in large quantities (Nebraska Wheat Board, 2009; FAO, 2013), while developing countries like Nigeria imports wheat to meet her demands for bread, biscuit and cake production. Flours from some locally available crops, especially cereals, are being incorporated into wheat flours in the formulation of composite flours. These composite flours are either totally gluten-free or reduced gluten contents, with enhanced nutritional contents. In addition, utilization of these cereals fully or partially were meant to promote their utilization in baked products. The use of non-wheat crops (cereals and tubers) promotes economic strength of several developing countries.

Wheat flour can be totally or partially replaced by blending with other non-wheat crop flours for production of baked products (Awolu et al., 2018; Awolu et al., 2016). In developing countries where importation of wheat flour is costly, composite flour serves as a viable alternative to wheat flour and also promotes the use of indigenous crops as flour (Awolu and Oseyemi, 2016; Hasmadi et al., 2014). Researches into alternative crops (cereals and tubers) being used for the preparation of composite flours for the production of baked food products (Awolu and Olokunsusi, 2017; Noor-Aziah and Komathi, 2009; Abdelghafor et al., 2011). These crops include cassava, plantain, barley, rice, tigernut, and corn have been studied for making baked products from composite flour (Ali et al., 2000). Legume crops are supplemented with some cereals and tubers in order to improve the protein contents, minerals and rheological characteristics of composite flours (Awolu et al., 2018; Awolu and Olokunsusi, 2017; Awolu et al., 2016; Mohammed et al., 2012; Noorfarahzilah et al., 2014).

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In tropical and sub-tropical regions, banana serves as a source of food for millions of people and a good source of income for farmers, thereby boosting the economic power of the countries in the regions. While ripe bananas are consumed raw, or blended to make juice, the unripe banana can be processed into flour for making bread, dough and pasta (Aparicio-Saguilan et al., 2007; Rungsinee and Natcharee, 2007). Findings have shown that unripe banana is very rich in fibre, vitamins, micro and macro nutrients, which makes incorporation of its flours into wheat flour a perfect supplement for eventual production of baked products rich in nutients (Ovando-Martinez et al., 2009). Apart from this, banana is rich in resistant starch and indigestible carbohydrate leading to improved benefits such as improved insulin sensitivity, lower blood sugar levels and also reduce appetite (Gaurav and Manoj, 2014).

Drying is critical to the production of banana flour. Drying removes moisture from materials and thereby, increases its shelf-life (Demirel and Turhan, 2003). According to Krokida et al. (1998), density, texture, colour, porosity and sorption of the flour depend on drying methods used and this may as well affect quality of bread produced. Hence, this study examines the effect of different drying techniques on nutritional, functional and pasting characteristics of Cardaba banana flour.

MATERIALS AND METHODS

Collection of materials

Green mature, freshly harvested Cardaba banana was obtained from the Teaching and Research Farm of the Federal University of Technology Akure, Ondo State. After harvest banana of uniform quality were used for the study. All reagents used were of analytical grade.

Banana flour processing

Banana flour was produced using the method of Ayo-Omogie et al. (2010) (Figure 1).

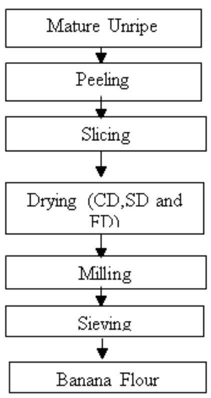

Figure 1. Flow chart for the production of banana flour

Sufficient banana were washed, peeled and sliced to about 5 mm width using a slicer. Three drying techniques were used in the production of Cardaba banana flour: cabinet, freeze and sun drying techniques. For freeze drying, samples were first kept in a freezer at -40ºC until frozen, then transferred into the freeze dryer which operated at -50ºC and 0.1m Pa. The cabinet drier, on the other hand, was operated at 60°C for 24 h while the sun dried samples exposed to tropical sun temperature between 30ºC and 35ºC (Nigeria) in August/September, 2018 for about 5days. It was afterwards milled into flour and were screened through a 0.25 mm sieve.

Determination of proximate composition

The determination of the moisture, ash, crude fibre, fat and protein content of the samples were carried out using the method of AOAC (2005). Carbohydrate content was evaluated by difference.

Evaluation of resistant starch, total starch and antioxidative properties

The analysis of resistant starch (RS) was carried out using the method of Goňi *et al.* (1996). Incubation of the samples was done at 40 °C, 60 min, pH 1.5 with pepsin (0.1 mL (10 mg/mL), Sigma P-7012) for protein removal, α-amylase (1 mL: 40 mg/mL) and incubated at (37 °C, 16h, pH 6.9). Sigma A-3176 was used to hydrolyze digestible starch and the residue was treated with 2M KOH to solubilize the resistant starch and was afterwards incubated (60°C, 45 min, pH 4.75) with amyloglucosidase (80 mL: 140 U/mL), to hydrolysis of the solubilized resistant starch. The resistant starch concentration of the test sample was calculated as mg of glucose × 0.9. The difference between TS and RS gave the value for digestible starch DS.

Phenol and flavonoid were determined as described by (Bushra et al., 2009), While ABTS and DPPH were determined as modified by Saura-Calixto (2003).

Determination of functional properties

Functional properties such as least gelation concentration, swelling capacity, swelling index, foaming capacity and bulky density were determined. The swelling capacity and index of the flours were determined according to Dossou et al. (2014), while the foaming capacity was determined by the method of Yellavila et al, (2015). The swelling capacity, swelling index and least gelation were determined by the method of Dossou *et al.* (2014) and the bulk density by the method used by Awolu, (2018).

Determination pasting properties

Pasting properties of banana samples such as peak, trough, breakdown, final and setback viscosities were evaluated using Rapid Visco Analyzer, as described in (Awolu, 2018).

Determination of antioxidants properties

Phenol and flavonoid was determined as described by (Bushra et al., 2009). While ABTS and DPPH was determined as modified by (Saura-Calixto, 2003).

Statistical analysis

All analytical determinations were conducted in triplicates. Means and standard error were calculated. Data obtained was subjected to analysis of variance (ANOVA) at 0.05 level of significant using Statistical package for social sciences (SPSS) version 22s, separation of means were done using Tukey's Test.

RESULT AND DISCUSSION

Effects of variation in drying technique on the proximate composition of banana flour

The proximate composition of banana flour subjected to different drying techniques was presented in Table 1. There was significant ($p \leq 0.05$) difference in moisture contents of the three methods with the highest moisture content in freeze-dried banana flour (FDI) (6.49%) while the lowest was in cabinet-dried banana (CDT) (4.43%). The moisture content of sun-dried banana flour recorded in this study was higher than value reported by Sunitha et al. (2017) for sun dried banana (4.43%), while that of cabinet-dried flour was lower than 6.92% reported by Sahoo *et al.* (2015). Nevertheless, the moisture content of all the banana flours obtained in this study were lower than 10.0% making them shelf stable (SON, 2007).

The crude fat of FDI (2.38%) was not significantly ($p > 0.05$) different from CDT sample (2.38%). The fat content would enhance the flavour retaining capacity of the flour samples, as well as making the samples appropriate for some fat soluble vitamins. The crude fibre of sun-dried Cardaba banana flour (SDN) (0.78%) was not significantly different from that of CDT (0.84%). Fibre is required for easy bowel transit of foods, reduced calorie consumption and reduced incidence of diabetics.

Highest crude protein value was recorded in FDI (6.69%) and lowest on SDN (6.13%). Freeze drying was observed to preserve the crude protein content of the banana than the other methods and this might be due to the fact that freeze drying applies low pressure and low temperature thereby leaving the cellular structure of the banana intact (Dincer, 2003; Kusakabe and Kamiguchi, 2004; Agnieszka and Andrzej, 2011).

Total ash was highest in SDN (1.59%), but not significantly ($p > 0.05$) different from CDT (1.55%). There was reduction in crude fat, protein and energy value of the banana flour processed by sun drying techniques when compared with other drying methods. The reduction might not be unconnected with unmoderated temperature of sun drying and the longer period of drying. This is contrary to Fadimu et al., (2018) where sun drying had more crude fat and protein content than cabinet drying. The carbohydrate content ranged from 82.59% to 83.88% while the highest energy value was recorded in CDT (382.74 kcal/100g) and lowest in SDN (374.81 kcal/100g). Reduction in moisture contents as a result of dehydration has been reported to have inverse relationship with carbohydrate, ash and fibre contents (Morris et al., 2004).

Table 1. Proximate Composition (% dry weight) of Banana flour Subjected to the Drying Methods

Samples	M.C. (%)	Crude fat (%)	Crude fibre (%)	Protein (%)	Total ash (%)	CHO (%)	Energy (kcal/100g)
FDI	6.49±0.14^{a}	2.38±0.20^{a}	0.19±0.01^{b}	6.69±0.26^{a}	0.95±0.02^{b}	89.79±0.35^{c}	381.41^{b}
SDN	6.19±0.15^{b}	1.93±0.10^{b}	0.79±0.01^{a}	6.13±0.22^{c}	1.59±0.04^{a}	89.56±0.11^{b}	375.37^{c}
CDT	4.43±0.10^{c}	2.38±0.22^{a}	0.84±0.04^{a}	6.45±0.09^{b}	1.55±0.02^{a}	88.78±0.11^{a}	384.62^{a}

Mean values in the same column which is not followed by the same letter are significantly different ($p \leq 0.05$). Keynotes: FDI= Freeze dried banana, SDN= Sun dried banana, CDT= Cabinet dried banana, M.C. = moisture content, CHO = Carbohydrate

Pasting properties of banana flour subjection to the different drying methods

The pasting properties of Cardaba banana flour as influenced by different drying methods are presented in Table 2. Peak viscosity ranged from 1445 to 3153 RVU for samples CDT and FDI while Trough was from 1162 RVU to 2270 RVU. Trough is a measure of the ability of paste to withstand breakdown during cooling; a higher trough indicating higher stability during cooling. While freeze dried sample had the overall best peak and trough viscosities, closely followed by sun dried sample, cabinet dried samples had least peak and trough viscosities but highest breakdown and setback viscosities. Cabinet-dried Cardaba banana flour would be more stable during cooking than other drying methods, having lowest breakdown viscosity. In addition, cabinet dried sample would also have the least retrogradation. It can be inferred that the better heat treatment used in cabinet drying was responsible for its better stability and lesser retrogradation of CDT to the freeze dried and sun dried samples. Han et al., (2015) reported that freeze drying leads to increased syneresis in gelatinized starches and accelerates retrogradation. The break down viscosity of SDN (285 RVU) and CDT (281 RVU) were not significantly (p >0.05) different.

Peak time of the three drying methods on banana flour varied from 5.40 min. (FDI) to 5.53 min. (SDN) while pasting temperatures were 81.5 °C for FDI, 83.1 °C for SDN and 84.7 °C for CDT. Significant difference in pasting properties of Cardaba banana flour processed through different drying methods agreed with the report of Arinola et al. (2016) where significant differences were observed in the pasting properties of the unripe plantain flour samples subjected to different drying methods. In addition to this, Arinola et al (2016) reported correlation between the variations in peak viscosity with the drying time. This variation may be due to the fact that the drying techniques used have different temperatures and the carbohydrate components of the flour need a proper heat to break it down, as pasting characteristic depend on the ratio of amylase to amylopectin in starch (Falola et al., 2015).

T able 2. Pasting properties of banana flour subjection to the different drying methods

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown Viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Pasting temperature (°c)
FDI	3153±0.57^a	2270±1.00^a	883±1.00^a	3473±1.00^a	1201±1.00^a	5.40±0.01^c	81.5±0.01^c
SDN	2087±1.52^b	1793±3.21^b	285±5.00^b	2721±2.08^b	925±3.21^b	5.53±0.10^a	83.1±0.01^b
CDT	1445±1.52^c	1162±3.51^c	281±2.08^b	1557±0.57^c	391±0.57^c	5.45±0.01^b	84.7±0.03^a

Mean values in the same column which is not followed by the same letter are significantly different (p<0.05).
Keynotes: FDI= Freeze dried banana, SDN= Sun dried banana, CDT= Cabinet dried banana.

Functional properties of banana flour subjected to the different drying methods

The functional properties of the samples were presented in Table 3. There was no significant (p >0.05) difference in the least gelation capacity (LGC) of the three methods, it was constant (2.0%) for the three methods. This might indicate that drying has no effect on the least gelation properties of the flours. This is in agreement with the observation of Fadimu et al., (2018) where there was no statistical difference in LGC recorded in respect to different drying techniques used. Swelling capacity (SC) was significantly (p ≤ 0.05) difference from 0.51% (SDN) to 10.59% (CDT). This was also observed by Arinola et al. (2016). Swelling index of FDI (469 ml/g) and SDN (460 ml/g) were not significantly different (p >0.05).

Table 3. Functional properties of banana flour subjected to the different drying methods

Sample	LGC (%)	SC (%)	SI (ml/g)	FC (%)	EC (%)	BD(g/ml)
FDI	2.00±0.00^a	4.08±0.01^b	469±6.44^a	9.33±0.05^c	48.05±0.05^a	0.86±0.04^a
SDN	2.00±0.00^a	0.51±0.03^c	460±36.31^a	15.67±0.59^b	42.31±0.01^c	0.85±0.05^a
CDT	2.00±0.00^a	10.59±0.05^a	387±1.05^b	17.85±0.01^a	46.16±0.02^b	0.83±0.01^a

Keynotes: FDI= Freeze dried banana, SDN= Sun dried banana, CDT= Cabinet dried banana, LGC= least gelation capacity, SC= swelling capacity, SI= swelling index, FC= foaming capacity, EC= emulsification capacity, BD= bulk density.

Foaming capacity was highest in CDT (17.85%) and lowest in FDI (9.33%).

Emulsification capacity was highest in FDI (48.05%) and lowest in SDN (42.31%). Protein is the major determinant for functional properties such as emulsification and foaming capacity, and these can be easily affected by heating and thereby influences the functional properties of the flour.

Freeze drying was more efficient in processing protein containing food (Dehnad et. al., 2016). The bulk density obtained on the banana flour did not significantly (p >0.05) vary with the drying methods; it ranged from 0.83 g/ml (CDT) to 0.86 g/ml (FDI) but higher than the value recorded by Falade and Olugbuyi (2010) and Fadimimu et al. (2018). According to Thakur et al. (2016) low bulk density is much better for infant meal. Dehnad et al. (2016) suggested that different drying techniques may cause variation in functional properties of food due to a compromise between temperature, humidity and drying time.

Starch profile (g/100g) of banana flour subjected to the different drying methods

Starch profile of Cardaba banana flour varied significantly (p ≤ 0.05) to variation in drying methods (Table 4). Resistant starch in SDN (16.83 g/100g) was the lowest while CDT (27.53 g/100g) was the highest. The highest total starch was in CDT (40.77 g/100g) and lowest in SDN (22.74 g/100g) The use of physical processing treatments such as cooking, drum drying resulted in increase in resistant starch content whereas other processing treatments resulted in decrease resistant starch (Rodrigez-Damian *et al*., 2012); this might have led to the increase resistant starch in cabinet dried banana flour (Tribess *et al.* 2009). The resistant starch values recorded in this study was lower than that values recorded by Ovando-Martinez *et al*. (2009) for banana flour (42.54g/100g) and Faisant *et al*., (1995) values of 57.2 and 47.3% obtained in unripe banana flour using two different methods. There was no significant (p >0.05) difference in soluble indigestible fraction of SDN (14.68 g/100g) and CDT (14.66 g/100g). Insoluble indigestible ranged from 49.88 g/100g (SDN) to 55.31 g/100g (FDI). The soluble and insoluble indigestible fractions of freeze dried banana flour were higher, thus, indicating that freeze drying significantly retained the dietary fibre of Cardaba banana flour. The indigestible fraction (IF) consists of those food constituents that are not digested in the small intestine, then passed into the colon, and the fermentative microflora process them, (Saura-Calixto *et al*., 2000).

Table 4. Starch profile (g/100g) of banana subjected to the different drying methods

Sample	Resistant Starch	Total Starch	Soluble Indigestible Fraction	Insoluble Indigestible Fraction
FDI	20.69±0.05^{b}	29.24±0.09^{b}	15.37±0.05^{a}	55.31±0.03^{a}
SDN	16.83±0.06^{c}	22.74±0.11^{c}	14.68±0.04^{b}	49.88±0.02^{c}
CDT	27.53±0.01^{a}	40.77±0.02^{a}	14.66±0.01^{b}	52.12±0.88^{b}

Mean values in the same column which is not followed by the same letter are significantly different (p<0.05). Keynotes: FDI= Freeze dried banana, SDN= Sun dried banana, CDT= Cabinet dried banana.

Antioxidant properties of banana flour subjection to the different drying methods

The antioxidant properties of Cardaba banana flour subjected to different drying methods are presented in (Table 5). Total phenolic contents of the freeze and cabinet dried sample ranged from 0.20 mg/g (SDN) to 0.71 mg/g (CDT), flavonoid was highest in SDN (0.05 mg/g) and lowest in FDI (0.01 mg/g). ABTS ranged from 0.024% (FDI) to 0.026% (SDN), while there was no significant (p >0.05) difference between the DPPH of FDI (34.8%) and SDN (33.64%). High temperature during flour processing might be responsible for reduction of antioxidants (Taha *et al*., 2015). In this study it was observed that sun drying method reduced phenol content than the freeze and cabinet-dried banana. Antioxidants like phenol and flavonoids are necessary in food, as they scavenge the free radicals such as hydrogen-perioxide, thereby alter the oxidative process that can lead to degenerative diseases (Emad, 2014).

Table 5. Antioxidative properties of banana flour subjection to the different drying methods

Sample	Phenol (mg/g)	Flavonoid (mg/g)	ABTS (%)	DPPH (%)
FDI	0.68±0.02[a]	0.01±0.000[c]	0.024±0.00[c]	34.80±0.32[b]
SDN	0.20±0.01[b]	0.05±0.001[a]	0.026±0.00[a]	33.64±0.09[b]
CDT	0.71±0.03[a]	0.02±0.001[b]	0.025±0.00[b]	45.61±1.35[a]

Mean values in the same column which is not followed by the same letter are significantly different ($p<0.05$). Keynotes**:** FDI= Freeze dried banana, SDN= Sun dried banana, CDT= Cabinet dried banana.

CONCLUSIONS

Freeze drying flour samples had the overall best physicochemical properties, followed by cabinet dried samples. Although sun-drying samples had the best crude fibre and total ash contents, cabinet dried samples had the best resistant starch and total starch contents. Freeze dried samples also had the best soluble and insoluble indigestible fractions. Sun dried samples had the best flavonoids and ABTS properties, freeze dried sample had the best phenolic content while cabinet dried sample had the best DPPH. Freeze dried samples also had the best pasting characteristics, followed by sun-dried samples. In addition to having best physicochemical properties, freeze drying produced samples with the best pasting and antioxidants properties.

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