academicJournals

Vol. 7(6), pp. 113-119, June 2013
DOI: 10.5897/AJFS2012.0605
ISSN 1996-0794 ©2013 Academic Journals
http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Effect of substituting sugar with date palm pulp meal on the physicochemical, organoleptic and storage properties of bread

J. E. Obiegbuna[1]*, P. I. Akubor[2], C. N. Ishiwu[1] and J Ndife[3]

[1]Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[2]Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria
[3]Department of Food Science and Technology, Kaduna Polytechnic, Kaduna State, Nigeria.

Accepted 12, May 2013

The effect of substituting granulated sugar with date palm fruit pulp meal (DPFPM) in bread production was evaluated. Date palm fruit pulp was oven dried (46°C, 8 h) and milled. Granulated sugar was substituted at 0, 25, 50, 75 and 100% with DPFPM in bread recipe and bread produced using straight dough bulk fermentation method. Proofing ability of the dough, oven spring, bread loaf weight, volume and specific volume were evaluated. Proximate composition, incidence of mold growth on bread loaves and sensory properties of the loaves were also determined. On dry weight basis, crude fat, crude fiber, crude protein and ash contents significantly ($p < 0.05$) increased from 6.25 to 7.72, 1.52 to 4.45, 16.85 to 21.26, and 2.26 to 3.84%, respectively, whereas carbohydrate decreased from 73.12 to 62.73% with increasing substitution of sugar with DPFPM. The decrease in proofing ability of the dough (2.20 to 2.08) was insignificant ($p > 0.05$) while the decreases in oven spring (2.30 to 1.87 cm), loaf volume (848.3 to 762.3 cm^3) and specific volume (3.15 to 2.64 cm^3/g) were significant ($p < 0.05$). Loaf weight increased ($p < 0.05$) from 265.5 to 288.8 g. Visually observable colonies of mold on bread loaves during storage initially decreased but later increased with increasing DPFPM. Substituting sugar with DPFPM had no adverse overall effect on the acceptability of bread loaves; it however increased the nutritional value but decreased the physical quality of the bread loaves.

Key words: Bread, granulated sugar, date palm fruit pulp meal, substitution, physicochemical properties.

INTRODUCTION

Bread is one of the commonest staple food eaten world over. It is composed of dough from wheat, yeast, water and other ingredients, which has been fermented and subsequently baked. When the dough is made, the yeast starts to work on the fermentable sugars, transforming them into alcohol and carbon dioxide, thus increasing the dough volume. Sugar, though used as ingredient in bread, is not considered essential or indispensable in bread making. This is because flour contains a small amount of natural sugar and some starch is converted to sugar during fermentation process. The natural sugar content of the flour, however, is very limited in amount and for most forms of bread, sugary agent must be added to meet the usual yeast requirements throughout the fermentation process and also supply the necessary sweetness and other functions performed by sugar in bread baking

*Corresponding author. E-mail: jamesejyke@gmail.com. Tel: +2348063214410.

(Wihlfaht, 2007). Apart from providing substrate to yeast for CO_2 production and imparting sweetness to baked goods, other functions of sugar include the production of golden brown color of the crust, improvement of texture of the crumb, retention of moisture in the crumb and adding to the nutritional value of bread.

Many sugar substitutes are available for use in baking especially in a situation where low-calorie alternative may affect positively a medical condition such as diabetes where sugar consumption is severely limited. Some natural alternatives to white sugar for bakery products namely raw honey, maple syrup, molasses, corn syrup, stervia, xylitol, agava nectar, brown rice syrup, evaporated cane juice, black strap molasses, date sugar and organic sugar have been listed by Anon (2010), and Khan (2010). Khan (2010) reported that one cup of date sugar is equivalent to one cup of granulated or brown sugar. NHB and AIB (1990) and Ebiringa and Echebiri (2004) used honey as sugar substitute in bread production, Akubor and Yusuf (2007) used date palm syrup in cake production.

Date palm (*Phoenix dactylifera* L.) fruit, locally called 'debino' in Hausa language, is from the family of Arecaceae (Al-daihan and Bhat, 2012). It is cultivated for its edible sweet fruit. The fruit is a drupe in which an outer fleshy part (exocarp and mesocarp) referred to as pulp (Besbes et al., 2010) and pericarp (Duke 1981) surround a shell (the pit or stone) of hard endocarp with a seed inside. The fruit is available in different forms namely whole pitted and unpitted, dehydrated pieces, diced, extruded date pieces and macerated fruit (Berreveld, 1993; Glasner et al., 2002). Barreveld (1993) reported that a date palm fruit of 20% moisture content provides 3,000 kcal/ kg of date flesh.

Ahmed et al. (1995) and Vandercook et al. (1980) documented that date fruits are high energy food sources with 72 to 80% sugar content at maturity. At khalal stage, nearly all 80 to 85% of the sugar is sucrose. As ripening progresses, the sucrose is hydrolyzed into reduced sugars such as glucose and fructose. Al-Shahib and Marshal (2003) stated that the fruit of date palm contains a high percentage of carbohydrate (total sugar, 44 to 88%), fat (0.2 to 0.5%), 13 salts and minerals, protein (2.3 to 5.6%), vitamins and a high percentage of dietary fiber (6.4 to 11.5%). Ahmed et al. (1995) and Vandercook et al. (1980) reported that date fruit are good sources of iron and potassium, a fair source of calcium, chlorine, copper, magnesium and sulphur, and a minor source of 16 amino acids and vitamins A, B_1 and B_2.

Many products useful to humans are produced from date palm. The primary product is the fruit which is eaten fresh, dried or various processed forms (Glasner et al., 2002; Kader 1992). Dry or soft dates are eaten out of hand or may be seeded and stuffed, or chopped and used in great variety of ways on cereal pudding, bread, cakes, cookies, ice cream or candy bars (Barreveld 1993; Glasner et al., 2002); and can be made into juice, vinegar, wine, beer, sugar, syrup, honey, pickle, paste, dip and food flavor (Barreveld 1993; Glasner et al., 2002).

Date fruit pulp has been used more as a sugar source than as a fruit (Barreveld 1993). Date sugar is manufactured by processing dried dates into powder form and is great for sprinkling on breakfast cereal and baked goods (Khan 2010). In this study, date pulp meal was used as replacement for granulated sugar in bread production with the aim of evaluating the physicochemical, organoleptic and storage properties of the bread.

MATERIALS AND METHODS

Raw material procurement

The ripe date palm fruit used in this work was purchased from a hawker in Kaduna, Nigeria. Wheat flour (Golden Penny), granulated sugar (Dangote, Nigeria), margarine (Blue Band), yeast (Angel), iodized salt (Dangote), ascorbic acid, Edlen Dough Conditioner (EDC-95) and powdered milk (Cowbell) were purchased from Ega Market in Idah, Kogi State, Nigeria.

Processing of date palm fruit into meal

The seeds of the date palm fruits were removed and discarded. The pulp (pericarp) was oven dried at 45°C for 8 h (VMR Scientific, Model 1370, Oregon, USA) and subsequently milled using hand milling machine.

Production of bread

The bread was produced using the recipe shown in Table 1. Date palm fruit pulp meal (DPFPM) was used as replacement for granulated sugar at the following ratios: 80:0, 60:20, 40:40, 20:60 and 0:80 (sugar: DPFPM), which culminated to 0, 25, 50, 75 and 100% substitution levels of sugar. The dry ingredients were weighed or measured in the required quantities and mixed. Then, 500 ml of water was added to form the dough and mixed thoroughly. The dough was then kneaded to smooth consistency. During the kneading, margarine mixed with vegetable oil was added. When kneading was completed, the resulting dough was cut in weights of 350 g, molded into oblong shape and put into baking pans already greased with vegetable oil. The dough was proofed at room temperature (32 ± 2°C) for 1 h 40 min. It was then transferred to baking oven (Animex, Enugu, Nigeria) preheated to 230°C and baked for 40 min, removed from the oven and left to cool to room temperature (32 ± 2°C) before packaging in polyethene films.

Methods of analyses

Proximate analyses

Moisture (air oven method), crude fat (Soxhlet extraction method), protein (microKjeldhal method, Nx6.25), ash and crude fiber of granulated sugar, DPFPM and bread loaf samples were determined as described by AOAC (1990) methods. Carbohydrate content was estimated by difference {100- (%moisture + % Crude fat + % crude protein + % ash + % Crude fiber)}.

Table 1. Recipe for bread production.

Ingredient	Quantity
Wheat flour	1000 g
Yeast	80 g
Salt	50 g
Sugar/ date pulp meal	80 g
Margarine	30 g
Improver (ascorbic acid)	2 g
Edlen dough conditioner (EDC-95)	2 ml
Powdered milk	8 g
Water	500 ml

Proofing ability

This was carried out by measuring the height of the dough in the pan before and after proofing. The difference in height was the proofing ability (Rakkar 2007).

Oven spring

This was determined from the difference in the height of proofed dough before and after baking (Idowu et al., 1996).

Loaf weight, volume and specific volume determinations

The weight of bread loaf was measured using an analytical weighing balance. The volume of the loaf was determined by rape seed displacement method (AACC, 2000) with slight modification. Sesame seed was used in place of rape seed. The seeds were layered in the box of known dimension. Bread loaf was inserted and the seed poured to fill the remaining space till the seeds were running over. A straight edge rule was used to level the seed. The volume of the seeds was measured using a measuring cylinder and the volume of bread loaf calculated as the volume of the rectangular box less the volume of sesame seed. Loaf specific volume was calculated as the ratio of loaf volume to its weight.

Fermentation/ baking loss determination

This was determined as the difference in weight of the dough before proofing and the average weight of bread loaves.

Assessment of incidence of mold growth on bread loaf surfaces

This was carried out by counting the number of mold colonies visually observed on bread loaf surfaces during storage. The bread loaves were stored (unwrapped and wrapped in transparent polyethylene) on clean laboratory benches at room temperature (32 ± 2°C).

Sensory evaluation of bread loaves

A twenty-man panel consisting of equal numbers of male and female of 15 years and above evaluated the bread samples. The samples were served simultaneously in white plastic plates in a sensory evaluation laboratory illuminated by white fluorescent tube. The panelists evaluated the preference for the samples on the following characteristics: crumb color, crust color, flavor, texture and overall acceptability. The evaluation was carried out on a seven point Hedonic scale with 1= disliked very much and 7 = liked very much. Tap water was provided for rinsing of mouth to remove after taste.

Table 2. Proximate composition of granulated sugar (table sugar) and pitted date palm fruit pulp meal (DPFPM)

Parameter	Granulated sugar	DPFPM
Moisture (%)	3.11	6.56
Fat (%)	0	1.88
Crude fiber (%)	0	3.66
Crude protein (%)	0	5.51
Ash (%)	1.01	2.95
Carbohydrate (%)	95.88	79.44

Statistical analysis

Data were subjected to analysis of variance (ANOVA) and significant means discriminated by Tukey's LSD test (Gomez and Gomez 1984). Significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Proximate composition of granulated sugar, DPFPM and bread loaves

The proximate composition of granulated sugar and date palm fruit pulp meal (DPFPM) are presented in Table 2. The table reveals that apart from carbohydrate, ash (1.01%) was the only solid identified in the granulated sugar. This was unlike DPFPM which contained fat (1.88%), crude fiber (3.66%), crude protein (5.51%) and ash (2.95%) in addition to carbohydrate (79.44%). As expected, the granulated sugar is in a purer form than DPFPM.

The proximate composition of bread loaves, shown in Table 3, indicates that crude protein, fat, ash and crude fiber contents significantly ($p < 0.05$) increased with increasing replacement of granulated sugar with DPFPM whereas the carbohydrate content significantly ($p < 0.05$) decreased. The significance was recorded at 50% replacement with DPFPM for carbohydrate, 75% replacement for crude protein, ash and crude fiber; and at 100% for crude fat. Significant ($P < 0.05$) differences also existed between full (100%) replacement of granulated sugar with DPFPM and 25% replacement of granulated sugar in protein, ash, crude fiber and carbohydrate contents.

Proofing ability and oven spring

The proofing ability and oven spring (Table 4) decreased

Table 3. Proximate composition (dry weight basis) of bread as affected by sugar substitution with date palm fruit pulp meal (DPFPM).

Parameter	Percentage (%) Sugar Substitution with DPFPM (w/w)					
	0	25	50	75	100	LSD
Moisture* (%)	26.12	25.98	25.76	26.36	26.44	-
Fat (%)	6.25[a]	6.68[ab]	7.01[ab]	7.38[ab]	7.72[b]	1.30
Crude fiber (%)	1.52[a]	2.30[ab]	2.98[abc]	3.76[bc]	4.45[c]	1.48
Crude protein (%)	16.85[a]	17.85[ab]	19.05[abc]	20.21[bc]	21.26[c]	2.41
Ash (%)	2.26[a]	2.65[ab]	3.14[abc]	3.42b[c]	3.84[c]	1.02
Carbohydrate (%)	73.12[a]	70.52[ab]	67.82[bc]	65.23[c]	62.73c	3.75

Values are means of duplicate determinations. Means with the same superscript within a row were not significantly ($p > 0.05$) different. LSD, Least significant different.

Table 4. Physical properties of dough and bread as affected by sugar substitution with date palm fruit pulp meal (DPFPM).

Parameter	Percentage (%) Sugar substitution with DPFPM (w/w)					
	0	25	50	75	100	LSD
Proofing ability (cm)	2.20[a]	2.18[a]	2.14[a]	2.10[a]	2.08[a]	-
Oven spring (cm)	2.30[a]	2.22[ab]	2.16[ab]	2.02[bc]	1.93[c]	0.21
Weight of bread loaf (g)	269.5[d]	272.4[cd]	275.5[c]	279.9[b]	288.8[a]	4.12
Volume of bread loaf (cm^3)	848.3[a]	817.6[b]	795.6[c]	771.6[d]	762.3[e]	5.75
Specific volume (cm^3/g)	3.15[a]	3.00[ab]	2.89[ab]	2.76[ab]	2.64[b]	0.43
Fermentation/ oven loss (%)	23.00[a]	22.17[a]	21.29[ab]	20.03[b]	17.49[c]	1.92

Values are means of quadruplicates determinations. Means with the same superscript within a row were not significantly ($p > 0.05$) different. LSD, least significant different.

from 2.20 to 2.08 cm and 2.30 to 1.87 cm, respectively, as granulated sugar was replaced with DPFPM. The decrease in proofing ability was insignificant ($p > 0.05$), whereas that of oven spring was significant ($p < 0.05$). Proofing is an expression for the step in creating yeast breads during which the yeast makes the bread to rise (Rakkar, 2007); and it is measured by dough height which depends to some extent on the volume of gas (CO_2) production during fermentation (proofing), as well as protein matrix with its level of gluten (Badifu et al., 2005). During proofing, the yeast metabolizes simple sugar derived by hydrolysis of wheat starch and sugar optionally added to dough, producing CO_2 that was trapped by gluten matrix of the dough. The consequence is the rising (leavening) of the dough as a result of the stretching of the gluten matrix. Simple sugar is more readily provided by the hydrolysis of granulated sugar which is mainly sucrose than the wheat flour starch as the latter is more complex and may be more difficult to hydrolyze by yeast enzymes. This sucrose was also likely more abundant for yeast activity in granulated sugar than in DPFPM as evidenced in the higher carbohydrate contents of granulated sugar (Table 2). The decrease in proofing ability of the dough as the level of DPFPM increased may be as a result of the decrease in the amount of readily available fermentable sugar.

Oven spring is the ability of the dough to rise during baking. It is an important baking quality that measures the dough strength against heat related changes (Idowu et al., 2010). It is an indication of the proper strength of gas cell walls that entraps the gas and their elasticity by which they expand without collapsing due to increased yeast activity during initial phase of baking (Rakkar 2007). It is also a common knowledge that one of the main reasons for oven spring (rising in the hot oven) is the formation of bubbles in the dough and the formation of steam expanding the bubbles. Hence, increased yeast activity during initial phase of baking and/ or the formation of bubbles in the dough and the formation of steam expanding the bubbles may have caused the oven spring. Extra protein and fiber introduced by increasing amount of DPFPM may have bound some water making it unavailable for bubble and steam formation thereby reducing the consequent expansion.

Table 5. Mean sensory scores of bread as affected by replacement of sugar with date palm fruit pulp meal (DPFPM).

Parameter	%Sugar substitution with DPFPM					
	0	25	50	75	100	LSD
Crust color	6.3^{a}	5.7^{ab}	5.4^{ab}	5.5^{ab}	5.1^{b}	1.15
Crumb color	2.5^{b}	5.6^{a}	5.3^{a}	5.3^{a}	5.3^{a}	1.39
Flavor	5.2^{a}	4.1^{a}	3.8^{a}	4.5^{a}	4.4^{a}	1.53
Texture	5.6^{a}	4.8^{a}	5.0^{a}	5.0^{a}	5.4^{a}	0.96
General acceptability	4.7^{a}	3.7^{a}	4.0^{a}	4.2^{a}	4.2^{a}	1.32

Means with the same superscript within a row were not significantly ($p > 0.05$) different. LSD, least significant different.

Weight, volume, specific volume and processing loss of bread loaves

The weight of bread loaves significantly ($p < 0.05$) increased from 283.3 to 299.5 g with increasing replacement of granulated sugar with DPFPM. Shittu et al. (2007) reported the basic determinant of loaf weight to be the quantity of dough baked and the amount of moisture and carbon dioxide diffused out of the loaf during baking. Badifu et al. (2005) also attributed the increase in loaf weight to the relative high moisture content, the nature of carbohydrate and high bulk density of flour. In this study, this could be a result of increase in crude fiber, protein, fat and ash that could not be easily fermented by yeast and which have probably absorbed and immobilized water, making it not easily vaporized during baking.

The volume and specific volume of bread loaves significantly ($p < 0.05$) decreased from 848.3 to 762.3 cm^3 and 3.15 to 2.64 cm^3/g, respectively, as granulated sugar was replaced with DPFPM (Table 4). The decrease in volume could be a cumulative effect of lower proofing ability and oven spring which are functions of gas evolution. Shittu et al. (2007) attributed the variation in loaf volume of the bread samples produced from the same formulation, proofing time and dough size to different rate of gas evolution. The sugar available for yeast activity and consequently for evolution of gas could be lower in granulated sugar/ DPFPM blends due to the contents of protein and crude fiber (Table 2). Specific volume is the volume per unit weight of loaf. It is the integral of weight and volume of the loaf related to the rising power of the loaf during baking (Ayo et al., 2008) and has been generally adopted in the literature as a more reliable measure of loaf size (Shittu et al., 2007). The reduced specific volume with increasing DPFPM signified that the decrease in volume of loaves was not proportional to increase in weight. The rate at which the volume decreased outweighed the rate at which the weight increased. The specific volume of 2.64 to 3.15 cm^3/g for bread samples in this study is low. According to Lin et al. (2009), China Grain Products Research and Development Institute (CGPRDI) in 1983 documented that the specific volume of standard bread should be 6 cm^3/g and should not be less than 3.5 cm^3/g. Specific loaf volume is a function of hydration. The low specific loaf volume in this study could be as a result of minimal hydration of 50%, having used 500 ml of water for 1000 g of flour to form the dough. Ocheme et al. (2010) used hydration of 56% (56 ml of water for 100 g of wheat flour) and obtained specific loaf volume of 3.86 cm^3/g.

Table 4 shows that processing loss decreased significantly ($p < 0.05$) with increasing replacement of granulated sugar with DPFPM. The loss, deduced as the difference of the dough weight before proofing and the weight of baked loaf, could be a cumulative effect of fermentation loss during proofing and water evaporated during baking. Rakkar (2007) made a similar deduction of the weight of baked bread from the initial weight of the dough and attributed the difference to the moisture loss alone. It is likely that the fiber and protein introduced into the dough by DPFPM held some moisture, preventing them from evaporation.

Sensory properties of bread loaves

The mean sensory scores on preference for bread loaves are shown in Table 5. Whereas the preferences for crust and crumb colors were significantly ($p < 0.05$) affected by replacement of granulated sugar with DPFPM, those of texture, flavor and overall acceptability of the loaves was not. Only the preferences for crust and crumb color of loaves with 100% granulated sugar were different ($p < 0.05$) from those of 100% DPFPM. The preferences for the color of both the crust and the crumb of the blends were not different ($p > 0.05$). However, whereas the preference for crumb color increased with increasing replacement of granulated sugar with DPFPM, that of crust color decreased. The non-difference in preference

Table 6. Incidence of mold growth as affected by replacement of sugar with date palm fruit pulp meal (DPFPM).

Storage period (day)	Number of observable mold colonies on bread loaves				
	Percentage (%) Sugar substitution with DPFPM				
	0	25	50	75	100
Wrapped bread loaf samples					
1.	0	0	0	0	0
2.	0	0	0	0	0
3.	0	0	0	0	0
4.	15	12	0	0	0
5.	35	21	12	17	29
6.	64	48	46	60	72
Unwrapped bread loaf samples					
1.	0	0	0	0	0
2.	0	0	0	0	0
3.	0	0	0	0	0
4.	1	0	0	0	0
5.	8	2	2	3	6
6.	15	4	3	5	10

for flavor of bread may be expected if the sweetness of the same mass of date sugar and granulated or brown sugar is equivalent (Khan, 2010) unless contributions of phytochemical found in date meal, as impure substance, could come into play. The inverse preference for color of the bread crust and crumb may have affected its possible effect on the overall acceptability.

Incidence of mold growth on bread loaf surfaces

The number of mold colonies visually observed on bread loaves during six days of storage is presented in Table 6. Wrapped bread samples baked with 100% granulated sugar and 25% (20 g) replacement with DPFPM had 15 and 12 colonies, respectively, at the fourth day of storage whereas unwrapped bread sample baked with only granulated sugar had one visually observed colony. On the fifth and sixth days, highest numbers were observed on the loaves baked with granulated sugar alone for both wrapped and unwrapped loaves. The number of colonies were, however, higher on the wrapped bread loaves. The visually observed colonies seemed to increase with increasing replacement of granulated sugar with DPFPM. The initial delay of mold growth on bread loaves baked with DPFPM and its blends with granulated sugar could have suggested the possession of antifungal properties by DPFPM. However, the increasing number of mold colonies with increasing amount of DPFPM has proved otherwise. Mold growth is a function of water activity of a product or relative humidity of an environment. As bread stales, water is emitted as a result of retrogradation of gelatinized starch molecules. This water migrates to the surface of loaf where it is vaporized. The vapor saturated the microenvironment of wrapped loaves and increased the relative humidity which now favors the growth of mold. The vapor is not held back as much for unwrapped loaves leading to lesser number of colonies. Non-sugar components of DPFPM such as protein and ash may have enriched the bread loaves, making it more favorable substrate for mold growth. Higher moisture content of bread with higher DPFPM may have also favored the mold growth.

Conclusion

The use of date palm fruit pulp meal as sugary agent to replace granulated sugar in bread production improved the nutritional value of bread. The overall organoleptic quality was not affected even at 100% replacement. The physical property of the bread, judged majorly by the loaf specific volume that relates loaf weight to its volume, decreased with increasing replacement of granulated sugar. As the decrease was not significant at 75% replacement with date fruit pulp meal but was at 100% replacement, replacement of granulated sugar with a proportion of the date fruit pulp should be encouraged. Using high proportion may delay the incident of mold growth on the loaves but may encourage greater growth at prolonged storage. Antimycotic may be incorporated in the bread to suppress this activity.

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