Full Length Research

Effect of different bakery shortenings on quality, storage and sensory properties of cake

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ABSTRACT: This study investigated the effect of African elemi, avocado, and sesame oils as vegetable bakery shortenings on cakes' quality and sensory properties. The emulsified bakery shortenings comprised of oil, water and egg yolk which were blended at high speed and incorporated into the cake batter to produce four cake samples coded as sample A (cake produced using commercial margarine), sample B (cake produced using African elemi shortening), sample C (cake produced using sesame shortening) and sample D (cake produced using avocado shortening). The samples were analysed for their proximate composition, physical, microbial and sensory properties. Proximate analysis of the cakes revealed moisture content of 24.63-26.84%, crude protein 7.82-10.02%, fat 7.38-9.89, ash 0.73-0.97%, crude fibre 0.39-0.79% and carbohydrate 52.84-58.80%. The result showed that the cakes produced using African elemi shortening contained higher crude protein and fat, while cakes produced using sesame shortening contained higher crude fibre and ash contents. The incorporation of the bakery shortenings had a significant ($p<0.05$) effect on the crude protein and carbohydrate contents of the cakes. On the other hand, the incorporation of the bakery shortenings had no significant ($p>0.05$) effect on the cake height and weight. The control sample was the most preferred sample by the panelists for all sensory parameters. This did not differ significantly ($p>0.05$) from the cakes produced using African elemi shortenings for all sensory attributes. Microbial analysis revealed that the cakes produced using commercial margarine and avocado shortenings had higher bacterial and mould counts. It was concluded that the cakes produced using sesame and African elemi shortenings were microbiologically safe for consumption up to a storage period of 9 days. Whereas, the control sample and cake produced using avocado should not exceed a storage period of 6 days.

Keywords: Bakery shortenings, quality, storage, cake, sensory properties.

INTRODUCTION

Shortening is generally a semisolid fat for use in food preparations, especially in baked goods. It is a word used to describe fats, oils and various processed versions of fats and oils that are used as ingredients in dough and batters (Kaur *et al.,* 2012). Shortening is a major ingredient in high-ration layer cakes; cakes in which there is much or more sugar than flour in the formula. According to Zhou *et al.* (2011), shortening performs three basic functions in cake products: it entraps air during the creaming process to aid

in the proper aeration or leavening of the batter and the finished cake; it coats the protein and starch particles, thereby disrupting the continuity of the gluten and starch to provide tenderization and lubrication to the texture and mouth-feel; it emulsifies large amounts of liquid thereby contributing to increased crumb moisture and softness in the product.

There is a growing trend in health with more and more people concerned about health problems and the Food

and Drug Administration's (FDA) finding that there is no safe level of trans fat consumption, other shortening sources have been tried such as olive oil (Matsakidou *et al.* 2010), a relatively expensive ingredient. Many companies began to use the relatively inexpensive palm oil instead of hydrogenated soybean oil to make zero trans-fat shortening. Ironically, the high levels of saturated fatty acids in palm oil result in the same cardiovascular problems as trans-fat (Zhou *et al.*, 2011). Liquid shortening has been developed for ease in bulk handling and metering at room temperature. Liquid cake shortenings function much like solid shortenings in baking systems, but they offer the user certain advantages. First, liquid shortening is fluid at room temperature, it is pumpable, which leads to great savings in labour costs. Second, it has no trans-fatty acids and much lower saturated fatty acids (Dunford, 2017).

According to Zhou *et al.* (2011), replacing more traditional solid plastic shortenings with a liquid version made from oils and emulsifiers may increase the structural quality and shelf life of bakery products whilst reducing the need for hydrogenated fats. The study also found that cakes made from liquid shortening containing zero trans-fats, and generally a healthier fat profile, showed more uniform grain, finer texture, higher volume, and better shelf-life than cakes made from solid plastic shortening.

Vegetable oils are generally excellent sources of poly-unsaturated fatty acids. Although general consumption of fats and oils has increased, recent trends in the baking industry are to reduce the usage of fats and oil and to replace plastic fats with liquid vegetable oils (Kaur *et al.*, 2011). African elemi, avocado, and sesame oils are promising oils which can be used as a replacement ingredient for solid plastic shortening. African elemi pulp oil is about 71 % palmitic acid and 18% oleic acid. They contain several fatty acids including oleic (36%), linoleic (28%), palmitic (26%), and 7% stearic (Maduelosi and Angaye, 2015). The oil derived from sesame seeds has a mild odour and pleasing taste and as such is a natural salad oil. The major unsaturated fatty acids are linoleic acid (46.9%) followed by oleic acid (37.4%), while the main saturated fatty acid is palmitic acid (9.1%) (Gharby *et al.,* 2017). Avocado oil has a high fatty acid profile in linoleic acid (48.77%) and linolenic acid (12.17%) (Flores *et al.,* 2019), thereby suggesting that the oil can be used to produce liquid shortening as a replacement in high-quality cakes. As a result, the use of avocado, African elemi, and sesame seed oils as liquid bakery shortenings needs to be explored. As industry moves away from the use of trans-fats in its formulations, it is important to look at the properties of replacement ingredients, in order to achieve the most effective yet healthy profile.

MATERIALS AND METHODS

The sesame seed and avocado pear oils used in the research were purchased from Spar Mall, Port Harcourt,
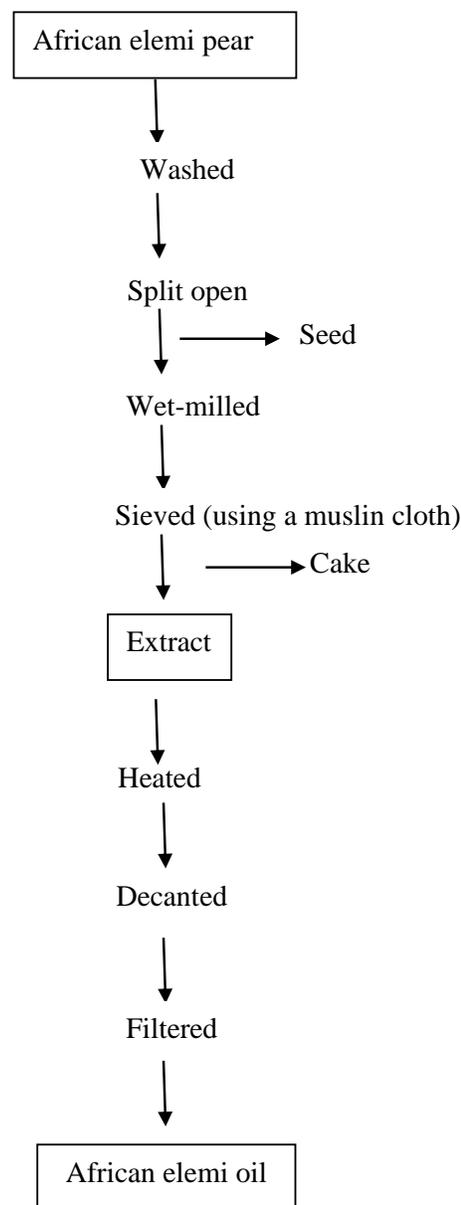
Figure 1. Production of cold press African elemi oil (Source: Kiin-Kabari *et al.,* 2020, with modification).

Rivers State and African elemi, refined wheat flour, sugar, baking fat, eggs, milk, salt and baking powder were purchased from Mile Three market in Diobu, Port Harcourt. Rivers State, Nigeria. All reagents and chemicals were of analytical grade and were obtained from the Food Science and Technology Laboratory, Rivers State University, Port Harcourt.

Extraction of African elemi oil

As shown in Figure 1, African elemi fruits were washed

thoroughly with distilled water and split open with a sharp stainless knife to remove the seed from the pulp. The pulp was milled using an attrition mill (MUNSON SK-24-MS) and then mixed with water. Thereafter, the mixture was sieved using a muslin cloth to obtain an extract containing the oil. The oil was heated in a pan until the water evaporated leaving the oil. The oil was then allowed to settle before it was decanted into a container. The oil was thereafter filtered using a muslin cloth. The oil was then stored in a plastic airtight container until required for further use.

Production of emulsified bakery shortening

The method described by Lawal *et al.* (2015) with slight modifications was used. A mixture which consisted of 75% shortening and 25% water was created. The ingredients which contained 280 mL of vegetable oil and 50 mL water were measured using a 3-to-1 fat-to-liquid ratio to ensure a proper mixture. The oil and water were placed into a large mixing bowl. In order to help the shortening, combine easily into the cake batter and also create lasting bonds between lipids and water (permanent emulsions), 8.5g of egg yolk was added. The mixture was blended at high speed for 1 min.

Preparation of cakes

The two-stage mixing method as described by Akubor and Ishiwu (2013) was used with slight modifications for the preparation of the cakes. The two-stage cake mixing method uses a high ratio shortening to create a very moist, soft texture, but firm structure cake. Firstly, all the dry ingredients (as shown in Table 1), which include flour, baking powder, sugar, and salt were mixed on low speed in a bowl. Then the shortening was added and mixed on low speed until the mixture resembled moist crumbs, with no dry flour. The other wet ingredients (eggs and milk) were added in two stages to the mixture and beat at medium speed for 2 minutes. The dough was cut out and baked in greased pans in the oven at 180°C for 20 minutes.

Determination of the proximate composition of the cake

The moisture, protein, crude fibre, fat and ash contents of samples were analyzed using the standard analytical method described by the Association of Official Analytical Chemists (AOAC, 2012). Moisture was obtained gravimetrically after drying to a constant weight at 70°C in a hot air oven (DHG 9140A). Fat was determined using the Soxhlet extraction method with ethyl ether. Kjeldahl method and a nitrogen conversion factor of 6.25 was used for crude protein determination. Ash content was determined gravimetrically after the incineration of the

Table 1. Recipe for the production of cakes.

Ingredient	Quantity (g)
Wheat Flour	100
Sugar	120
Shortening	40.00
Eggs	60.00
Milk	7.00
Salt	3.00
Baking powder	5.50

Source: Fu *et al.* (2018).

samples in a muffle furnace (Model SXL) at 550°C for 2 hours. The enzymatic gravimetric method was utilized in the determination of crude fibre. Carbohydrate was calculated by difference {100 - (Crude protein + crude fibre + ash + fat)}.

Determination of the physical properties of the cake

The physical properties of the cakes were determined by the AOAC (2012) method. The electronic weighing balance was used to take the weights of the cake samples. The diameter of the samples was determined by arranging six samples in a row and taking diameter measurements. The mean height (thickness) of cake samples was measured by taking three measurements from one sample and the average height was calculated.

Sensory evaluation of the cake

The cake samples were subjected to sensory evaluation within 24 hours after production. The following attributes: crust colour, crumb colour, taste, odour, flavour and softness were assessed on cake samples using a 9-point hedonic scale with 9 as like extremely and 1 as dislike extremely (Iwe, 2010) while overall acceptability was obtained as mean values of all the other sensory attributes assessed. Twenty panelists familiar with cake, who were neither sick nor allergic to baked products were involved in the assessment. The panelists were instructed to rinse their mouths with water after tasting each cake sample.

Microbial analysis determination of the cake

The analysis was carried out using the method described by Obinna-Echem (2024). Total viable bacteria count was determined using nutrient agar (NA) while Saboraud dextrose agar (SDA) was used for the enumeration of total mould count.

Statistical analysis

Data obtained from the analysis carried out was subjected to a one-way Analysis of Variance using IBM SPSS

Statistics (version 26). Statistical differences and relationships among variables were evaluated by analysis of variance under a general linear model and Tukey pairwise comparison at a 95% confidence level.

RESULTS AND DISCUSSION

Proximate Composition of Cakes produced using different bakery shortenings

The proximate composition of cakes produced using different bakery shortenings is shown in Table 2. The moisture content of the cakes ranged from 24.63-26.84% with sample A (cakes using King's margarine) recording the lowest value while sample C (cakes using sesame seed shortening) had the highest value. Sample A did not differ significantly (p>0.05) from samples B (cakes using African elemi shortening) and D (cakes using avocado shortening) but differed significantly (p<0.05) from sample C. Moisture content of the cake samples from this study is lower than the values of 36.48-38.90% for cake produced using chia gel as a fat substitute (Kadry et al., 2021). It is however slightly higher than the range (15.8-17.3%) reported by Osunrinade et al. (2020) for cake using shea butter shortening. The low moisture content indicates a good shelf life for the product since moisture content affects its stability and overall quality (Folake and Bolanle, 2006). The moisture content of any food is an index of its water activity and it is used as a measure of stability and susceptibility to microbial contamination.

The Ash content of the cake samples was 0.73- 0.97%. Sample D had the lowest value while sample C had the highest value. There was no significant (p>0.05) difference in the ash content of the samples. Ash content of the cakes from this study is lower than the range (2.90-3.90%) reported by Osunrinade et al. (2020) for cakes using shea butter as shortening. It is within the range (0.61-1.55%) reported by Seth and Kochhar (2018) for cakes developed using partially defatted peanut flour. The ash content of a food material could be used as an index of mineral constituents of the food (Orisa et al., 2023), because ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of an oxidizing agent (Sanni et al., 2009). The result therefore shows that cakes produced using sesame shortening would contain high minerals needed for physiological processes in the body.

The fat content of the samples ranged from 7.38-9.89% with sample A recording the lowest value while sample B recorded the highest value. Similarly, there was no significant (p>0.05) difference in the fat content of the samples. These values were higher compared to those (10.28-19.63%) reported by Kadry et al. (2021) for cakes using gia gel as a substitute. It is also higher than 29.27-30.52% reported by China et al. (2020) for cakes produced using fluted pumpkin seed. The low-fat content in the cake

samples is beneficial as it ensures long product shelf life by reducing susceptibility to oxidative rancidity. Fat is also important in the diets of infants and young children as it provides high energy density and facilitates the absorption of fat-soluble vitamins. It also provides essential fatty acids such as omega-3 and omega-6 polyunsaturated fatty acids (PUFA) needed for proper neural development in infants and young children (Igyor et al., 2011).

Crude protein content values ranged from 7.82-10.02%. The lowest value was recorded in sample A while sample B had the highest value. Cake samples using sesame seed and African elemi had significantly (p<0.05) higher crude protein content than other samples. The values are within the range (5.20-8.05%) reported by China et al. (2020) for cakes produced using fluted pumpkin seed. Kadry et al. (2021) also reported 12.01-14.55% for cakes using chia gel as a fat substitute which is higher than what was obtained (7.82-10.02%) from this study. Protein is essential for tissue replacement, growth and development in infants and young children (Okoye and Ene, 2018).

Crude fibre content ranged from 0.59-0.79% with sample D recording the lowest value while sample C had the highest value. Cakes produced using sesame shortening had significantly (p<0.05) higher fibre content than other samples. These values are comparable to those (0.24-1.11%) reported by Osunrinade et al. (2020) for cake using shea butter as a shortening. The higher fibre content of the cake produced using sesame shortening from this study has several health benefits, as it will aid in the digestion in the colon and reduce constipation. Crude fibre is the amount of indigestible sugars present in a food sample which has the physiological role of adding bulk to stool and thus contributes to the maintenance of internal distensions for a normal peristaltic movement, as reported by Akinyele and Oloruntoba (2013). In facilitating peristalsis, dietary fibre helps to reduce many gastrointestinal diseases, serum cholesterol, risk of coronary heart disease, colon and breast cancer and hypertension.

Carbohydrate content ranged from 52.84-58.80%. Sample B recorded the lowest value while sample A recorded the highest. The control sample was significantly (p<0.05) different from all other samples. These values are higher than those (29.82-35.02%) reported by Kadry et al. (2021) for cakes produced using chia gel as a fat substitute. It is also higher than the range (43.00-50.00%) reported by Osunrinade et al. (2020) for cakes using shea butter as shortening. The high carbohydrate content from this study is of nutritional benefit as it provides the energy needed to do work.

Physical properties of cakes produced using different bakery shortenings

The physical properties of the cake samples are shown in Table 3. Physical properties (weight, width and height) are very important quality criteria for cake samples, which

Table 2. Proximate composition (%) of cakes produced using different bakery shortenings.

Samples	Moisture	Crude protein	Fat	Ash	Crude fibre	Carbohydrate
A	24.63[b]±0.04	7.82[b]±0.00	7.38[a]±0.55	0.79[a]±0.13	0.59[b]±0.00	58.80[a]±0.64
B	26.31[ab]±0.19	10.02[a]±0.62	9.89[a]±1.10	0.79[a]±0.13	0.59[b]±0.00	52.84[c]±0.19
C	26.84[a]±0.04	9.78[a]±0.31	8.13[a]±0.00	0.97[a]±0.01	0.79[a]±0.00	53.39[bc]±0.51
D	26.18[ab]±0.90	8.91[ab]±0.31	7.94[a]±0.01	0.73[a]±0.08	0.39[c]±0.00	55.85[b]±1.12

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at (p <0.05).
Keys: A = Cake produced using Kings margarine; B = Cake produced using African elemi shortening; C = Cake produced using sesame shortening; D = Cake produced using avocado shortening.

Table 3. Physical properties of cakes produced with different shortenings.

Samples	Cake width (m)	Cake height (m)	Cake weight (g)
A	4.23[a]±0.25	3.70[a]±0.10	52.15[a]±5.14
B	3.43[b]±0.40	3.67[a]±0.15	53.77[a]±0.67
C	3.90[ab]±0.00	3.77[a]±0.21	42.32[a]±3.04
D	4.13[a]±0.12	3.77[a]±0.15	48.83[a]±6.81

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

strongly influence consumer preference and they are directly related to the type and amount of fat since fat promotes aeration of the batter and stabilizes the air bubbles formed during batter mixing (Felisberto *et al.,* 2015). Cake width values recorded ranged from 3.43 to 4.23 m. Sample B had the lowest cake width while sample A had the highest value. The control sample produced using conventional shortening had the highest width which was not significantly (p>0.05) different from cakes produced using sesame and avocado oils. Cake height ranged from 3.67-3.77 m with the lowest value recorded in sample B while samples C and D had the highest cake height. There was no significant (p>0.05) difference in the height of all the cake samples. Cake weight values recorded ranged from 42.32 to 52.15 g. Sample C recorded the lowest cake weight while sample B had the highest value. Similarly, no significant (p>0.05) difference was observed in the weight of the cake samples. This indicated that African elemi, sesame and avocado shortenings had no significant (p>0.05) effect on the weight and height of the cake samples. The weight of the cakes from this study was higher than the range (30.00-34.60 g) obtained by Alozie and Chinma (2015) for cakes prepared from wheat and cocoyam flour blends.

Sensory properties of cakes produced using different bakery shortenings

The sensory properties result of cakes produced using different bakery shortenings are shown in Table 4. Fat has a positive effect on bakery products' texture and colour and important to keep cake softer for a long period. Colour is one of the most important characteristics in the appearance of a cake, since this combined with the texture and flavour, contributes to the consumer's preference for the product (Felisberto *et al.*, 2015). Mean scores for crust colour ranged from 6.50-7.25 with sample B as the least preferred while sample D was the most preferred. Mean scores for crumb colour ranged from 7.10-7.75. Sample D was the least preferred while sample B was the most preferred. There was no significant (p>0.05) difference in the colour of the cake samples. This indicated that African elemi, sesame and avocado shortenings had no significant (p>0.05) effect on the crust colour and crumb of the cake samples. The low crust colour of the cake produced using African elemi was expected due to its colour making the crust colour slightly green. However, this change was not significant. Mean scores for taste ranged from 6.35-7.90 with sample D as the least preferred while sample A was the most preferred. The control sample was significantly (p<0.05) different from cakes produced using avocado and sesame shortenings. Mean scores for flavour ranged from 6.25-7.85. Sample C was the least preferred while sample A was the most preferred. The control cake sample was significantly (p<0.05) different from cakes produced using sesame shortening but not from cakes produced using African elemi and avocado shortenings. Mean scores for odour ranged from 6.00-8.05 with sample C as the least preferred while sample A was most preferred. Similarly, the odour of the control cake sample was significantly (p<0.05) different from cakes produced using sesame shortening but not from cakes produced using African elemi and avocado shortenings. Mean scores for softness ranged from 6.80-7.70. Sample C was the least preferred while sample A was the most preferred. There was no

Table 4. Sensory properties of cakes produced with different shortenings.

Samples	Crust colour	Crumb colour	Taste	Flavour	Odour	Softness	Overall Acceptability
A	7.25^a±1.59	7.10^a±1.25	7.90^a±1.02	7.85^a±1.04	8.05^a±1.47	7.70^a±1.13	7.63^a±0.94
B	6.50^a±1.57	7.75^a±1.86	7.45^{ab}±1.53	7.65^{ab}±1.46	7.75^a±1.12	6.90^a±1.48	7.33^a±1.05
C	7.60^a±1.39	7.55^a±1.10	6.45^b±1.70	6.25^b±2.20	6.00^b±2.34	6.80^a±1.77	6.78^a±1.36
D	7.65^a±1.09	7.05^a±1.36	6.35^b±1.95	7.20^{ab}±1.91	6.75^{ab}±1.74	7.15^a±1.14	7.03^a±1.18

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

Table 5. Total bacteria count (cfu/g) of cakes produced using different bakery shortenings.

Samples	Days				
	1	3	6	9	12
A	$5.00×10^3$	$1.45×10^4$	$3.35×10^4$	$4.40×10^4$	$5.45×10^4$
B	$1.50×10^3$	$1.20×10^4$	$1.80×10^4$	$2.50×10^4$	$3.00×10^4$
C	NG	$1.30×10^4$	$2.40×10^4$	$3.95×10^4$	$4.80×10^4$
D	$5.00×10^3$	$1.85×10^4$	$2.95×10^4$	$4.40×10^4$	$4.65×10^4$

Key: NG= No Growth.

Table 6. Total mould count (cfu/g) of cakes produced using different bakery shortenings.

Samples	Days				
	1	3	6	9	12
A	NG	$3.00×10^3$	$9.00×10^3$	$1.00×10^4$	$1.65×10^4$
B	NG	$1.50×10^3$	$2.00×10^3$	$3.50×10^3$	$6.50×10^3$
C	NG	$2.00×10^3$	$5.00×10^3$	$7.50×10^3$	$1.00×10^4$
D	NG	$4.50×10^3$	$7.50×10^3$	$1.10×10^4$	$1.15×10^4$

Key: NG= No Growth.

significant ($p>0.05$) difference in the softness of the cake samples indicating that the various shortenings had no significant ($p>0.05$) effect on the cake softness. Mean scores for overall acceptability ranged from 7.03-7.63 with sample D as the least preferred while sample A was the most preferred. Similarly, no significant ($p>0.05$) difference was observed in the overall acceptability of the cake samples. The result of the sensory analysis therefore showed that cakes produced using African elemi were highly liked with high ratings and compared favourably with the control sample for all sensory attributes.

Microbial properties of cakes produced using different bakery shortenings

The microbial properties of the cakes are shown in Tables 5 and 6. The initial total bacterial count of the cakes revealed that the cake produced using sesame shortening showed no growth of bacteria while total bacteria counts were the highest in the control sample and cake produced using avocado shortening. An increase in the total bacteria

count was observed during the storage period with the highest counts recorded in the control sample and for cake produced using avocado shortening. At the end of the storage period, the control cake had the highest total bacteria count. All the cake samples after 12 days of storage were within the microbial limit of $<10^5$cfu/g for ready-to-eat food products (ICMSF, 2002).

The initial mould count of the samples showed no growth for all samples. An increase in the mould count was observed during the storage period. Similarly, these increases were found to be higher in the cakes produced using avocado shortening and the control sample. At the end of the storage period, all the cake samples had a mould count of 10^4cfu/g. For food products, the number of moulds must not exceed 10^3cfu/g (Larissa *et al.*, 2018). Thus, the finding of this study showed that all the samples were above the acceptable limit and therefore, the products were not microbiologically safe during this period. Cakes produced using African elemi and sesame shortenings had total mould counts ($3.50×10^3$ cfu/g and $7.50×10^3$ cfu/g, respectively) within the requirement for moulds at day 9. This indicates that the cake samples

produced using these shortenings can be microbiologically safe for consumption up to 9 days of storage. Whereas, the control sample and cake produced using avocado should not exceed 6 days of storage. The presence of mould in the treated samples may be due to the presence of residual moisture which provides a conducive environment for their growth. Mould growth has been associated with the formation of heat-stable mycotoxins which are a major concern of food safety (Dalie *et al.,* 2010).

Conclusion

The incorporation of African elemi, sesame and avocado shortenings in the preparation of cakes demonstrated improved fat and protein content. The shortenings had a negligible effect on the ash, fat and crude fibre content of the cakes. Similarly, no negligible effects were observed for cake height and weight. The shortenings also had no significant effect on the crust colour, crumb colour, odour, softness and overall acceptability of the cakes. Cakes produced using African elemi shortening compared favourably with the cake produced using commercial shortening (King's margarine) for all sensory parameters including taste and flavour. Microbial analysis of the cakes revealed that the control cake and cake produced using avocado shortening had higher bacterial and mould counts during storage. At the end of the storage period, all the cake samples had total bacteria count within the recommended limit. However, the mould count of all the cakes after 12 days of storage period was above the recommended limit. The result also showed that the cakes produced using sesame and African elemi shortenings could be safe for consumption for up to 9 days of storage period while the control cake and cake produced using avocado shortening could be microbiologically safe for up to 6 days storage period.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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