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Effects of Storage Time on the Physicochemical Properties of Shortenings Produced from Tallow Tree (*Allanblackia floribunda*) Seed and African Pear (*Dacryodes edulis*) Pulp Oils

Akusu O.M[*], Wordu G.O, Obiesie C

[*]*Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria*

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[*]**Corresponding author**: Akusu O.M, Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria. Email: akusu.monday@yahoo.com

Abstract

The objective of this work was to evaluate the changes that occur in physicochemical characteristics of bakery shortenings produced from the oils of African pear pulp and tallow tree seed during storage, so as to ascertain its keeping quality. Edible oils were extracted from the pulp and seeds of African pear (*Dacryodes edulis*) and tallow tree (*Allanblackia floribunda*), respectively, using bulk extraction method. The oils were blended in the ratios of 80:20, 70:30, 60:40 and 50:50 (tallow tree seed oil: African pear pulp oil), emulsified, homogenized, pasteurized and crystalized to form bakery shortenings which were labelled as samples B1, B2, B3 and B4, respectively. The shortenings were stored in opaque sealed plastic cups at room temperature (28±2^{0}C) for 80 days. Changes in physicochemical characteristics were studied in intervals of 20 days till the end of the storage period. The result proved no significant (p>0.05) change in refractive index of the samples. Slip melting point (SMP) of all the products increased significantly (p<0.05) during the storage period. The SMP of samples B1, B2, and B4 increased from 35.36 – 36.38^{0}C, 35.30 – 36.30^{0}C and 35.46 – 36.90^{0}C, respectively. Samples B1, B2 and B3 did not show any significant change (P>0.05) in smoke point throughout the 80 days storage period. The smoke point of sample B4 reduced significantly from 205.20 – 203.77^{0}C. Iodine value (IV) of the shortenings for samples B1 and B2 reduced slightly from day zero to day 80. Though, these reductions were not significant (p>0.05) while that of samples B3 and B4 reduced significantly from 47.23 – 47.08g/100g and 49.23 – 48.01g/100g, respectively. There was no significant increase in peroxide value (PV) and percentage free fatty acids (FFA) of the shortenings. The FFA of sample B2 increased slightly from 0.106 – 0.110%, 0.094 – 0.101% for B3 and B4 0.081 – 0.090% during the 80 days storage period. This showed that shortenings can be formulated from the blends of *Allanblackia* seed and African pear pulp oils since the product recorded quality physicochemical characteristics and prolonged shelf stability.

Keywords: African Pear; Fat Blending; Keeping Quality; Modification; Physicochemical; Shortenings; Storage Time; Tallow Tree

Introduction

Modification of original fats by means of direct blending with other fats, fractionation, hydrogenation and inter-esterification has been attempted to improve the fat functionalities and thus optimize their application in food products **[1, 2].** Among the modification techniques, direct blending of fats is the method of choice as it has been considered to be a cheap and non-destructive technique. This technique has been used to modify several underutilised fats and oils **[3, 4].** There are basically three parameters to adjudge any oil as the healthiest cooking oil. That is, the ratio of saturated/mono unsaturated/polyunsaturated fatty acids, ratio of essential fatty acids (Omega 6/Omega 3) and presence of natural antioxidants **[5]**. Fat blending helps to derive protective advantage due to the presence of specific ingredients that offers protection against oxidation to improve frying recyclability **[6]**. Oxidative stability of oil can be improved by modification of fatty acid composition through blending **[7]**. Blending of oils modifies fatty acid composition without any chemical or biological process **[8]**. This modification processes affects the physicochemical characteristics of the fat blends, hence impacting desirable consistency and keeping quality on the end product **[1]**. However, solid shortening has good keeping quality due to its low water activity and do not require refrigeration during storage. However, they need to be stored away from odour-generating materials, cool and dry place **[2]**. Shortenings are tailored fat systems; properties have been modified in order to deliver specific functional needs **[9]**. Solid shortening produced from blends of *Allanblackia* seed and African pear pulp oils is expected to show better keeping quality. The quality of shortening is governed by five basic factors, these includes; processing conditions, triacylglycerols and emulsifier composition, tempering conditions, usage temperature and storage conditions **[10].** Attaining a stable crystal structure is an important consideration in the composition of solid shortening, to impact optimum creaming ability and for its ability to incorporate air into dough or cake batter. Shortening must be stable and in the best form and characterized as being smooth and creamy. These properties can be adversely affected by improper and non-uniform storage conditions. The low melting fat fractions in shortening might liquefy on prolonged storage at high temperatures and will further solidify on cooling to less functional crystal forms. Knowledge of the physicochemical changes that occur during fat storage is essential to ascertain it's shelve stability. The refractive index (RI) is the ratio of the speed of light in a vacuum to the speed of light in the fat sample **[11]**. It is related to the degree of saturation of the fat **[12]**. RI had been shown to provide hint on oxidative damage of fat during storage **[13]**. The temperature at which fat/oil gives off a steel bluish smoke when heated is termed smoke point. Fat decompose or breaks down into glycerol and its individual fatty acids when overheated. The glycerol further undergo hydrolyses to produce a thin-blue acrolein smoke **[14].** As reported by Thomas **[11]**, the smoke point serves as an indicator to the temperature limit which a particular fat can be used. It has a negative correlation with the percentage free fatty acid of the oil **[12]**. Decrease in smoke point occurs when the free fatty acid content increases. Percentage free fatty acid (FFA) content gives an indication of the extent of oxidation of fats and the degree of hydrolysis by lipolytic enzymes **[15]**. Peroxide value (PV) gives an indication of the degree of fat oxidized during storage **[16]** while iodine value is a simple chemical constant used to measure the degree of unsaturation or the average number of double bonds in an oil sample. It is the number of grams of iodine that could be used to halogenate 100g of oil **[16]**, reduction in iodine value during fat might occur due to auto oxidation reaction **[17]**.

Allanblackia seed oil is a vegetable fat, solid and stable at room temperature (28±2^{0}C) with slip melting point above 35^{0}C and will remain solid at 41^{0}C. Its high stearin content of over 49% makes it a ready source of hard stock for the blending and modification process. Thus, oil with a low melting point such as African pear pulp oil is needed to provide wide plasticity and spread ability in the blend. With a melting point of 25^{0}C and about 68% polyunsaturated fatty acid content, African pear pulp oil in the blend is expected to improve functionalities, nutrition and health value of the shortening. The storage properties of these related blends have not yet been investigated and reported. Hence, the objective of this work was to evaluate the changes in physicochemical properties of shortenings produced from blends of *Allanblackia* seed and African pear pulp oils during storage.

Materials and Methods

Mature and good quality fruits from the African pear (*Dacryodes edulis*) were purchased from the fruit market in Port Harcourt, Nigeria. The fruits were of optimum ripening as indicated in the complete bluish-black colour of the epicarp. Mature fruits of *Allanblackia floribunda* were obtained from Okehi and Igbodo in Eche Local Government Area of Rivers State, Nigeria. All chemicals used for this study were of analytical grade and were obtained from the Department of Food Science and Technology Laboratory, Rivers State University.

Processing and Oil Extraction of Raw Materials

African pear pulp was extracted from the fruit, oven dried at 60^{0}C for 24h in a hot air oven (model QUB 305010G, Gallenkamp, UK), milled using a laboratory mill (model MXAC2105, Panasonic, Japan) as described by Giami *et al*. **[18]**. Oil was extracted using bulk extraction process according to AOAC **[19]** standard method. The finely milled flour samples were soaked in excess n-Hexane at a ratio of 1:5 (1g flour sample/5ml solvent) and shaking vigorously for 6h using the laboratory shaker. The miscella layer (oil and hexane) was filtered using no.4 whatman filter paper, separation of hexane was done by distillation at 65^{0}C using the soxhlet distilling unit. The obtained oil was dried at 100^{0}C to eliminate all traces of hexane. The *Allanblackia* seeds were cracked, sorted and extracted using the rendering process described by Rosenthal *et al.* **[20]** with some modifications. The seeds were pulverized made into a paste and boiled for 6h; oil floated to the surface and was allowed to stand overnight. This was finally skimmed from the mixture with a sieve and heated to remove traces of moisture before storing in an air tight plastic container for further use.

Oil Refining

The extracted *Allanblackia* seed and African pear pulp oils were refined using the procedure described by O'Brien **[10]** with little modification. The crude oil was treated with 8% (v/v) of 0.1N $NaOH_{(aq)}$ at 65^{0}C for 10min with continuous stirring, using a laboratory stirrer (model JKL 2145, REMI Motors, India). The treated oil was then washed with warm distilled water and the aqueous phase was separated off using a separatory funnel. The washing process was repeated until the aqueous phase became neutral to phenolphthalein indicator. The separated oil was dried at 100^{0}C before bleaching with fuller's earth. To 100ml of the dried oil sample was added 3g of fuller's earth in a 250ml conical flask. The entire content was stirred continuously for 20min with a magnetic stirrer while heating at 80^{0}C. It was filtered at 50^{0}C using Whatman no.4 filter paper to obtain refined oil.

Formulation of Bakery Fat Blends

The different based stocks of *Allanblackia* seed and African pear pulp oils were blended in the following ratios: 80:20, 70:30, 60:40 and 50:50 (labelled as samples B1, B2, B3 and B4, respectively) in accordance with recommended blend of fats for bakery and all-purpose shortening formulation **[21]**. For a 100g bakery shortening (product), consisting of 98.28g vegetable fat phase plus 1.72g additives was made up of the earlier stated ratios (80:20, 70:30, 60:40 and 50:50) of the base stocks from *Allanblackia* seed and African pear pulp oils as shown in **(Table 1)[10]**.

Table 1: Production Blends for Bakery Shortenings

	Fat Phase			**Additives**					
Fat Blend	ASO (%)	APPO (%)	TOTAL FAT (g)	H20 (g)	DMG E471 (g)	CA E330 (g)	BHT E321 (g)	PS E201 (g)	SC (g)
B1	80	20	98.28	0.5	0.4	0.17	0.075	0.075	0.5
B2	70	30	98.28	0.5	0.4	0.17	0.075	0.075	0.5
B3	60	40	98.28	0.5	0.4	0.17	0.075	0.075	0.5
B4	50	50	98.28	0.5	0.4	0.17	0.075	0.075	0.5

ASO : *Allanblackia* Seed Oil,
APPO : African Pear Pulp Oil,
DMG : Distilled Monoglyceride,
CA : Citric acid,
BHT : Butylated Hydroxytoluene,
PS : Potassium Sorbate,
SC : Sodium Chloride,
H_2O : water

Bakery Shortening Production Process

For a batch of *Allanblackia* seed and African pear pulp oil bakery shortening, 98.28g each of the earlier fat blends were added to 1.72g of additives (0.4gDMG + 0.17gCA+ 0.075BHT+ 0.075gPS+ 0.5gNaCl+ 0.5gH_2O) at recommended levels by NIS:289 **[22]** and CODEX STAN 32 **[23]**. It was processed according to the method of O'Brien **[10]** with some modifications using the following procedures:

Emulsification: The fat blend (98.28g) were melted at 70^{0}C in a 500ml beaker, distilled monoglyceride (E471) emulsifier (0.4g) was added with continuous stirring.

Homogenization: The aqueous phase was prepared first by dissolving citric acid (0.17g), butylated hydroxyl toluene (0.075g), potassium sorbate (0.075g) and sodium chloride (0.5g) in 0.5ml of warm distilled water. The solution was added to the melted fat in the beaker and homogenized properly by continuous stirring with a laboratory stirrer (model JKL 2145, REMI Motors, India).

Pasteurization: The homogenized mixture was pasteurized at 85^{0}C for 2minutes. Heating was turned off and the content transferred to a mixing trough.

Crystallization: The homogenized and pasteurized solution was crystallized (plasticized) by cooling to 17^{0}C with continuous agitation using a laboratory stirrer (JKL 2145) at 300rpm and chilled in a mixing trough packed with ice cubes round its jacket.

Tempering and Storage: The mass of plasticized blend was tempered in a thermo regulated refrigerator (Model YDK 330, Express cool, Japan) at 22 – 25^{0}C for 48h to attain a stable polymorphic form.

Storage Studies

The shortening products were packed and sealed in an opaque plastic cups and stored at room temperature (28±2^{0}C) for 80 days storage period. Samples were collected in 20 days intervals (from day zero to 80) to determine the changes that occur in the physical and chemical properties of the shortening products during storage.

Physical properties studied included; refractive index, slip melting point and smoke point while that of the chemical properties determined were iodine value, peroxide value and free fatty acid of the formulated bakery shortening samples which were all done using primary indicators of fat quality with the aid of AOAC [19] standard methods.

Statistical Analysis

Data obtained were subjected to Analysis of Variance (ANOVA), differences between means were evaluated using Tukey's multiple comparison tests and significance accepted at $P \leq 0.05$ levels. The statistical package in Minitab 16 computer program was used and all the analysis carried out in duplicate.

Results and Discussion

Changes in Physical Properties

The changes that occur in physical characteristics such as refractive index, slip melting point and smoke point of bakery shortenings formulated with *Allanblackia* seed and African pear pulp oils during storage are presented in **(Tables 2, 3 and 4)**, respectively.

The result showed that there was no significant (p>0.05) change in refractive index (RI) of the samples throughout the 80 days storage period. This could be attributed to the relative stability of the iodine value of these products during storage. Agarwal *et al.* **[24]** Also reported consistency in RI of shortening after 12 months of storage. The stability of RI during storage is an indication that the unsaturated fats in the products did not reduce significantly during the period of storage **[25]**.

The slip melting point (SMP) of all the products increased significantly (p<0.05) during storage from 35.36 – 36.38^{0}C, 35.30 – 36.30^{0}C and 35.46 – 36.90^{0}C for samples B1, B2 and B4, respectively while sample B3 recorded no significant change throughout the storage period. The observed change in melting point of the shortening samples during storage is probably due to polymorphic changes, as the fat molecules realign in order to attain a stable crystalline form. This view was also supported by O'Brien **[10]** and Ghotra *et al.* **[26]**. There was no significant change (p>0.05) in smoke point of all the bakery shortening samples. This implies that the smoke points of the products were stable during the period of storage.

Table 2: Changes in Refractive Index of Bakery Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortenings Samples			
	B1	B2	B3	B4
0	1.4655a±0.000	1.4658a±0.001	1.4661a±0.001	1.4662a±0.001
20	1.4655a±0.000	1.4658a±0.000	1.4662a±0.000	1.4662a±0.001
40	1.4654a±0.000	1.4657a±0.001	1.4661a±0.000	1.4662a±0.001
60	1.4652a±0.000	1.4657a±0.000	1.4661a±0.000	1.4661a±0.000
80	1.4653a±0.000	1.4657a±0.000	1.4660a±0.000	1.4661a±0.000

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate determinations.

Table 3: Changes in Slip Melting Point (^{0}C) of Bakery Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortening Samples			
	B1	B2	B3	B4
0	35.36b±0.078	35.30b±0.134	35.23ab±0.629	35.46b±0.226
20	35.40b±0.141	35.31b±0.148	34.87b±0.035	35.50b±0.290
40	35.71ab±0.283	35.85ab±0.106	34.89ab±0.035	35.85b±0.064
60	35.86ab±0.198	35.85ab±0.071	35.69ab±0.375	36.15ab±0.007
80	36.38a±0.049	36.30a±0.424	36.52a±0.127	36.90a±0.007

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate determinations.

Table 4: Changes in Smoke Point (^{0}C) of Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortening Samples			
	B1	B2	B3	B4
0	214.22a±0.113	211.16a±0.014	208.16a±0.042	205.20a±0.000
20	214.22a±0.148	211.17a±0.049	208.17a±0.042	205.18a±0.035
40	213.97a±0.130	211.13a±0.028	208.16a±0.071	205.20a±0.000
60	214.04a±0.057	211.13a±0.000	208.02a±0.106	204.93a±0.106
80	213.95a±0.078	211.06a±0.078	208.02a±0.120	203.77b±0.339

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate samples.

Changes in the Chemical Properties

The changes in chemical characteristics such as iodine value, peroxide value and percentage free fatty acids of bakery shortening formulated with *Allanblackia* seed and African pear pulp oils during storage are shown in **(Tables 5, 6 and 7)**, respectively. The result showed that the iodine values (IV) of the shortening samples reduced slightly from day zero to 80, though these reductions were not significant (p>0.05). This is an indication that there was no significant reduction in unsaturated triacylglyceride content of the shortenings during storage. The peroxide values (PV) of the shortening products increased from 0.45 – 0.76mEq/kg, 0.44 – 0.46mEq/kg, 0.41 – 0.43mEq/kg and 0.32 – 0.34mEq/kg for samples B1, B2, B3 and B4, respectively during the storage period. Peroxide value (PV) gives an indication of the degree of fat oxidized **[16, 27]**. It is the milliequivalent (mEq) of oxygen per kg of fat. Oxidation of fat takes place through the formation of hydroperoxides. The hydroperoxides being the primary products of oxidation however, do not have any off-flavour **[15]**. The observed peroxide values in this study are below the maximum National acceptable PV of 2.00mEq/kg for shortenings **[25]**. Gulla and Waghray **[2]** equally reported increase in PV from 3.65 to 14.7mEqO2/kg for a (80:20) blend of sesame and rice bran oils stored for 12 months. Kiin-Kabari *et al*. **[28]** reported increase in peroxide value from 0.73 – 1.00mEq/kg, 0.70– 0.93mEq/kg and 0.57– 0.90mEq/kg, respectively for bakery shortening produced from 30:70, 40:60 and 50:50 blends of Shea stearin and fluted pumpkin seed oil after 90 days of storage at room temperature (28±2^{0}C).

Relatively significant increase was observed in samples B2, B3 and B4 in terms of the percentage free fatty acid (FFA) from 0.106 – 0.110%, 0.094 – 0.101% and 0.081 – 0.090%, respectively during the 80 days storage period while there was no significant increase (p>0.05) in that of sample B1. The FFA of all the samples were lower than the maximum acceptable value of 0.20mgKOH/g for margarine/shortenings **[22, 23, 25, 29]**. This indicates that all the formulated shortenings were shelf stable and chemically safe for culinary applications.

Table 5: Changes in Iodine Value (g/100g) of Bakery Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortening Samples			
	B1	**B2**	**B3**	**B4**
0	43.97a±0.163	45.87a±0.354	47.41a±0.007	49.23a±0.007
20	43.96a±0.057	45.67a±0.346	47.41a±0.000	49.23a±0.014
40	43.95a±0.212	45.85a±0.332	47.39a±0.000	49.19a±0.014
60	43.95a±0.305	45.85a±0.354	47.39a±0.014	49.05b±0.071
80	44.25a±0.034	45.70a±0.424	47.08b±0.106	48.01c±0.014

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate samples.

Table 6: Changes in Peroxide Value (mEq/kg) of Bakery Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortening Samples			
	B1	**B2**	**B3**	**B4**
0	0.45b±0.001	0.44b±0.007	0.41b±0.003	0.32b±0.003
20	0.46ab±0.001	0.45ab±0.001	0.41b±0.001	0.32b±0.002
40	0.46ab±0.001	0.45ab±0.000	0.42ab±0.000	0.32b±0.000
60	0.46ab±0.001	0.45ab±0.000	0.42ab±0.001	0.34a±0.001
80	0.47a±0.001	0.46a±0.001	0.43a±0.007	0.34a±0.000

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate samples.

Table 7: Changes in Free Fatty Acid (% FFA) of Bakery Shortenings Formulated with ASO and APPO during Storage

Storage Days	Bakery Shortening Samples			
	B1	**B2**	**B3**	**B4**
0	0.117a±0.002	0.106b±0.000	0.094b±0.001	0.081c±0.001
20	0.117a±0.001	0.106b±0.001	0.095ab±0.003	0.082bc±0.000
40	0.117a±0.002	0.108ab±0.001	0.099ab±0.000	0.083bc±0.001
60	0.118a±0.000	0.108ab±0.000	0.100ab±0.001	0.087ab±0.002
80	0.119a±0.002	0.110a±0.001	0.101a±0.001	0.090a±0.001

Mean values bearing different superscripts in the same column differ significantly (p<0.05). Values are means ± standard deviation of duplicate samples.

Abbreviations

ASO : *Allanblackia* seed oil,
APPO : African pear pulp oil,
B1 : Shortening formulated with 80:20 blend of ASO: APPO,
B2 : Shortening formulated with 70:30 blend of ASO: APPO,
B3 : Shortening formulated with 60:40 blend of ASO: APPO,
B4 : Shortening formulated with 50:50 blend of ASO: APPO

Conclusion

Relative stability of refractive index was observed which is an indication that the unsaturated fats in the products did not reduce significantly during the period of storage. Storage rendered no significant change in smoke point, iodine value, peroxide value and free fatty acid. The peroxide value and percentage free fatty acids of all the samples were lower than the maximum acceptable value, indicating that all the formulated shortenings were shelf stable and chemically safe for culinary applications. This study also proved that modification of two different vegetable fats with wide plasticity and spread ability such as *Allanblackia* seed and African pear pulp oils by means of blending to produce bakery shortening that is solid and stable at room temperature will give product with better keeping quality.

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