# Production of Bakery Fat from Blends of *Allanblackia floribunda* (Vegetable Tallow) and Soybean *(glycine max)* Oil

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**Abstract**
*Allanblackia floribunda and soybean oil were blended in ratio 40:60 (Allanblackia: Soybean) and used in the formulation of bakery fat. Physicochemical properties of the individual oils and as well as the formulated bakery fat were evaluated and compared with a commercial counterpart. Result revealed that moisture content, smoke point, flash point, density and melting point of A. floribunda and soybean oil were, respectively, 0.49 and 0.25% , 194.0 and 189.0℃, 266.5 and 249.0℃, 0.888 and 0.915 g/cm$^3$, 36.5 and -20.50℃. Similarly, oil colour, viscosity and refractive index were, 20.2Y, 3.2R and 20.0Y, 4.2R, 35.0 and 25.0 Cst, 1.46 and 1.47°C. Solid fat content ranged from 0.00 to 84.5(40 - 10℃) in soybean and A. floribunda, respectively. Formulated bakery fat had melting point of 37.9℃, free fatty acid content (0.08%), water content (16.35%), salt (1.45%) and fat content (82.04%) while the control sample had melting point of 41.0℃, free fatty acid content (0.21%), water content (18.30%), salt (1.50%) and fat content (80.20%). Formulated bakery fat compared favorably with the commercial equivalent in terms of physicochemical properties; Allanblackia fat provided a solid fat base with sharp melting point crucial for creating bakery fat that maintain their shape and structure during baking while soybean oil rich in polyunsaturated fatty acids contributes to the nutritional profile of the bakery fat. Allanblackia and soybean oil in bakery fat is recommended to encourage utilization and value addition to indigenous crops.*

***Keyword:*** *Allanblackia fat, Soybean oil, Bakery Fat, Blends, Physicochemical*

## Introduction
Bakery fat is a minor but vital ingredient in baking; it is essential for improving tenderness by coating flour proteins and shortening gluten strands, making it easier for the gluten network to expand; it provides moisture and flavor, and aid leavening by trapping air. It also contributes to mouth feel and browning of baked goods (Iwe, Michael, Madu, Obasi, Onwuka, 2017). As one of the major food categories, fats are energy dense nutrients that contain many of the fatty acids essential for health, including omega-3 essential for many biological functions. Bakery fat like margarine is a water-in-oil emulsion with a fat blend of at least 80% vegetable oil or animal fat which is solid at room temperature and 20% water. Both phases contain components such as antioxidants and fat-soluble vitamins (e.g. vitamins A, D), flavour, emulsifiers, colorants (e.g. β-carotene), and preservatives (e.g. BHT, BHA). The water phase usually contains table salt and organic acids (e.g. citric acid). Bakery fat production includes the transformation of fats into an

emulsified arrangement with spreadable features in order to improve its physicochemical, sensory, and nutritional properties (Nasirpour-Tabrizi *et al.,* 2020). Developing bakery fat varies depending on raw materials and handling methods; however, the production consists of five main phases: (a) aqueous and oil phase preparation, Emulsification, crystallization and packaging/maturation.

**Aqueous phase**

It is characterized by water-soluble ingredients including sodium chloride (Nacl), antioxidants (e.g. buthylated hydroxyl toluene (BHT), buthylated hydroxyl Anisole BHA), citric acid (regulates acidity), milk, and preservatives (Fruehwirth *et al*., 2021). These ingredients are added to water for solubulization. The aqueous phase is conditioned and heated in a tank to a temperature of 60 °C; heating is needed to avoid temperature reduction during emulsification; which can affect the stability of the emulsion in early crystallization (Nguyen *et al*., 2020).

**Oil phase**

Oil phase is made up of blended, interesterified, fractionated or partially hydrogenated oils or fats with oil soluble ingredients such as emulsifiers (lecithin or mono-acylglycerols), oil soluble colour and vitamins (pre-mix) (Nasirpour-Tabrizi *et al*., 2020).

**Emulsification**

After heating and solubilization of ingredients in the aqueous and oil phases, the emulsion is shaken for 10 to15 min, before transferring to a tube cooler unit (votator and pin-walker); where the temperature is increased above the melting point to avoid the formation of microscopic crystals (Nguyen *et al*., 2020). Presence of finely dispersed water droplets in the oily phase indicates a suitable emulsion (Hwang and Winkler-Moser, 2020).

**Crystallization**

This is carried out in the votator and pin-walker. The main step in bakery fat processing is crystallization or plasticization, with formation and maturation of crystals (Hondoh and Ueno, 2016).Critical points of crystallization include: (i) insufficient crystallization may result in low gloss, low creaminess, lumps, low plasticity, and brittle appearance; (ii) excessive crystallization causes excessive gloss and creaminess, oily appearance, low consistency, and migration of oil to the surface (oil-out) (Silva *et al*., 2021).

**Packaging**

This is also termed maturation step (Hwang and Winkler-Moser, 2020). From the crystallizer, the bakery fat is packaged and brought to stabilization between 5 and 7 °C for approximately 24 h. Bakery fat is packed in containers with mechanical, light, and oxygen protection, however, most bakery fat are packaged in nylon as primary packaging then in carton as secondary pack (Hwang and Winkler-Moser, 2020).

**Storage stability of bakery fat**

Bakery fat with 80% fat logically has a shelf life of 6 to 12 months if refrigerated throughout the distribution and marketing chain. Bakery fat stability depends on: oil phase composition, emulsifiers, interaction between the ingredients, production process, and crystalline network (Detry*et al.,* 2021). Stability of bakery fat is related to changes in its texture, oxidative, and physical properties (Silva *et al.,* 2021). Antioxidants are usually added to retard the oxidation in bakery fat (Han Lyn *et al.,* 2021, Nadeem *et al*., 2017).

Most bakery fats are produced from partially hydrogenated fats which are the major sources of saturated fatty acids (SFA) and Tran's fatty acids (TFA); consumers who accumulate large amounts of TFAs in their bodies are at risk of coronary artery diseases, hypertension, as well as obesity. Considering the evidence, and findings of experts scientific panels, of increasing harmful effects of TFAs on human health, the Food and Drug Administration (FDA) of the USA in June 2018, decreed that partially hydrogenated vegetable oil (the major source of TFAs) be removed from the GRAS list and asked producers to replace with healthy fats. For this, bakery fat industries can no longer be sustained by the conventional palm oil, groundnut oil soybean oil etc. due to unavailable raw materials and high price, therefore, new approaches and solutions are needed to expand the range of baked products with cheap and available baking fat. *Allanblackia floribunda* oil is a cheap and readily available raw material that can be utilized in bakery fat production. The tree species is scattered in the moist tropical forest zone of Nigeria and some West African countries. In Rivers State, Nigeria, the trees can be found in the forest of Okehi, Igbodo, Rumuewhor, Ubimini, Elibrada, Ogbakiri, Oyigbo and Ndoki communities. The seeds are of value due to its oil content (58-62% oil) which are similar in physical and chemical properties of oil obtained from other edible vegetable oils (Okwechime *et al.,* 2017). The seed fat is solid at ambient temperature and fatty acid is composed of: stearic acid 45 -58% and oleic acid 40 - 51%; its profile compares favorably with those commonly found in other vegetable oils. The fatty acid profile results in melting point around 34-38°C, this means that the oil will remains solid at room temperature, but melts at body temperature which is essential for a fat-based spread (Epanda *et al.,* 2020). Hence, Allanblackia seed oil can be a better alternative as replacement for partially hydrogenated fat; although, the seed fat is less known in Nigeria it is also underutilized. Soybean oil is pressed from soybean seed (*Glycina maxima*). The oil is used in food products due to its nutritional and functional properties, cost, and availability. It contains predominantly unsaturated fatty acids (linoleic acid at 53% and linolenic acid at 8%) (Abdelghany *et al.,* 2020), Linoleic is an omega-6 fatty acid and linolenic is an omega-3 fatty acid. These two fatty acids are ‘essential fatty acids with no saturation causing soybean oil to be liquid at room temperature and .resulting in low melting points (Sung, 2021).

**Oil blending**

To improve fat functionalities and accordingly optimize their application in food products, several modifications of their natural form such as blending directly with other fats or oil, hydrogenation, fractionation or interesterification have been made (Hu *et al*., 2017). Direct blending method is considered to be a cheap and non-destructive technique (Kumar, 2018). Vegetable oils and fats blending is an economical way of altering the physicochemical besides enhancement in oxidative and thermal stability (Kaseke *et al*., 2021**)**.The blending process is simple; it involves adding different portions of desired base stocks into a vessel with heat and agitation. Vegetable oil blending allows a change in fatty acid profiles and gives higher contents of natural bioactive compounds, which can enhance the stability of oils and improve their nutritional value. Blending polyunsaturated oil with more saturated or monosaturated oils is an option to adjust fatty acid levels to optimal level, such as blending Allanblackia seed fat, rich in saturated fatty acids, and soybean oil rich in polyunsaturated fatty acid in bakery fats can result in bakery fat with desired physicochemical properties for good baking performance. While the use of hydrogenated bakery fat is full of challenges, numerous replacement options are available. The aim of this research is to produce bakery fat from blends of *Allanblackia floribunda* and soybean oil.

## Materials and Methods

### Plant Materials

*A.floribunda* seeds were obtained from Rivers State Allanblackia Project farm (RSSDA), located in Mgbu-Azuogu (near Ndoki) in Oyigbo Local Government Area of Rivers State, Nigeria, while soybean seeds were purchased from Mile 3 Market Diobu, Port Harcourt.

### Chemicals and Reagent

All chemicals and reagents used were of analytical grade (products of BDH Chemicals Ltd, Poole, England) supplied by Joechem Chemicals Choba, Port Harcourt, Rivers State.

### Ingredients used in the Bakery fat Production

Vanilla flavor; antioxidant (BHT), milk powder and table salt were purchased from De-Giant bakers, 403 Ikwerre Road, Port Harcourt Rivers State.

### Methods

### Oil Extraction

***Allanblackia floribunda* Oil:** Seed fat was extracted using the hot water flotation method as described by Okwechime *et al.* (2017); Obinna *et al.* (2023).

**Soybean Oil**: Seeds were cracked, milled in Panasonic mixer (MXAC2-105, Japan) and meat extracted using ethyl alcohol as solvent in a 3:1 ratio (ethyl alcohol: soybean meats) by a motorized stirrer for 2 h after which the mixture ("micelle") was filtered through a clean filter cloth into a stainless receiving vessel. The mixture of oil and solvent was dried in air oven (model QUB 305010G, Gallenkamp, UK) at a temperature of 60℃ for 3 h to remove residual ethyl alcohol as described by Obinna et al. (2023).

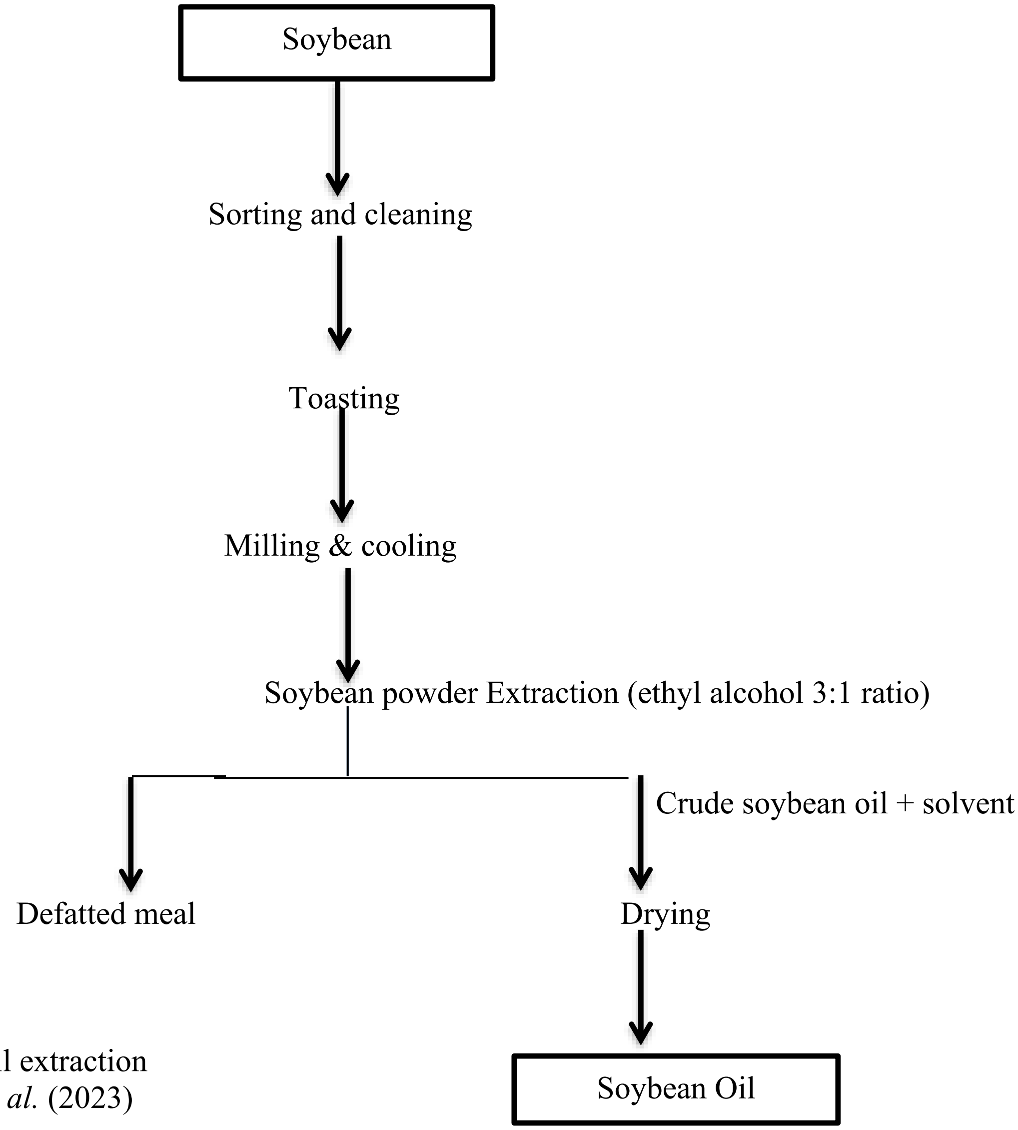


Fig. 1: Soybean oil extraction
Source: Obinna *et al.* (2023)

**Analysis**

**Physicochemical properties of *A. floribunda* and soybean oil**

**Physical properties**

Oil was oven dried at 105℃ for 2 h and loss in weight was taken as moisture content as described by AOAC, (2019). Smoke point was done by heating the oil rapidly; temperature of the oil was taken as the smoke point, when a continuous bluish stream of smoke sample was given off. Using the Penske-Martens closed cup apparatus; flash point was recorded at the temperature indicated by the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup. Melting point was determined as described by the American oil chemist society open capillary slips melt point (AOCs, 2017); capillary tubes were filled with the oil samples until 1 cm high column. The temperature at which the fat column rises was reported as SMP. Lovibond Tintometer (Model F, New Delhi, India) was used as described by AOCs, (2017) to determine oil colour in 5 ¼ inch cell (133.4 mm), the size of cell used and the red, yellow, blue or neutral readings forming the colour match was recorded as Y (yellow), R (red) and B (blue). Viscosity test was performed in a constant-temperature using Cannon-Fenske (Fisher Scientific, Pittsburgh, PAI glass capillary kinematic viscometers Hach), Kinematic viscosities ***v,*** expressed in centistokes was calculated from the measured flow time, t, and instrument constant, c as described by AOAC, (2019**).** To determine solid fat content, the method described by Obinna et al. (2023) and Onwuka, (2018) was followed with little adjustment, solid fat content (SFC) – temperature profile was measured using density bottle at various temperatures: 10°C, 20°C, 30°C, and 40°C. The solid fat content – temperature profile was calculated using the equation below:

$$\text{SFC (\%)} = \frac{\rho-\rho l}{\rho s-\rho l} \times \frac{100}{1} \qquad \text{Eq. (1)}$$

Where, $\rho$ = Density of the lipid at a particular temperature
$\rho l$ = Density of lipid when completely liquid
$\rho s$ = Density of lipid when completely solid
**Density** was calculated as:

$$\text{Density } (\rho g/g) = \frac{mass\ of\ sample}{Volume\ of\ sample} \qquad \text{Eq. (2)}$$

**Peroxide value**

This was determined by titrating oil sample previously dissolved in 30 mL of 3:2 Acetic acid—chloroform solution with 0.01M $Na_2S_2O_3$ (sodium thiosulphate) solution after the addition of 0.5 mL saturated KI solution.

$$\text{Peroxide value (Meq/kgoil)} = \frac{S-B \times N}{W} \times 1000 \qquad \text{Eq. (3)}$$

Where:
B = titration of blank, mL
S = titration of sample, mL
N = normality of sodium thiosulfate solution
W = weight of sample
Meq/kgoil = mill equivalents peroxide/1000g sample

**Iodine value**

Iodine value was determined by dissolving the oil sample in 20 mL carbon tetrachloride ($CCl_4$) and 25cm$^3$Wijs solution before titrating with 0.1M $Na_2S_2O_3$ on addition of 20 cm$^3$ of 10 % KI and 100 cm$^3$ distilled water.
The iodine value was calculated from the equation below:

$$\text{Iodine value (g/100g)} = \frac{B-S \times N \times 12.69}{Wt\ of\ sample} \qquad \text{Eq. (4)}$$

Where:
S= titre value of the oil
B = titre value of blank
M = molarity of $Na_2S_2O_3$

**Free fatty acid content**

Free fatty acid was measured following the test method described by AOAC, (2019), 5.0 g oil was introduced into a 250 cm$^3$ conical flask, to this was added 100 mL neutralized ethanol and few drops of phenolphthalein indicator. The mixture was titrated with 0.1 M NaOH solution until a pink color developed. Free fatty acid was calculated using the equation:

Free fatty acid (%) = $\frac{T \times M \times Mw}{w}$ Eq. (5)

Where,
T = titre value
M = molarity of the titrant
W = weight of oil used
Mw = molecular wt. of predominant fatty acid

**Saponification Value**

About 25 $cm^3$ of 10 % ethanolic KOH was added to 2.0 g of oil sample and refluxed for 30 min. The unreacted KOH was back titrated with 0.5 M HCl using three drops phenolphthalein as indicator. Saponification value was calculated using the equation shown below as described by AOAC, (2019). A blank titration was conducted similar to the above procedure but without the oil sample.

Saponification value, mg KOH per g of sample = $\frac{Va - Vb \times M}{W} \times 100$ Eq. (6)

*Where*,
Va = titre value of the blank used
Vb = titre value of the oil
M = molarity of the HCl
W = weight of the oil sample

**Unsaponifiable matter**

The resulting mixture from saponification analysis was transferred to an extraction cylinder using ethyl alcohol; warm and then cold distilled water was added until the total volume was 80 mL. The content of the cylinder was cooled to 25 ℃ and 50 mL petroleum ether added and extracted three times. The petroleum ether fractions from the extraction were combined in a separatory funnel and washed three times; using 25 mL portions of 10% ethyl alcohol in distilled water until wash solution no longer gives a pink color on addition of one drop of phenolphthalein solution. The petroleum ether extract was transferred to a tarred beaker and evaporated to dryness in a water bath, cool in a desiccator and weighed.

Unsaponifiable matter, % = $\frac{\text{weight gain}}{\text{weight of sample}} \times 100$ Eq. (7)

**Bakery fat formulation**

**Oil Blend**

Allanblackia oil was melted at 60 ºC in air oven and blended with soybean oil in a ratio 40:60 (Allanblackia: Soybean), then, bakery fat was formulated using: water 16 %, salt 0.8%, milk powder 1.0 %, flavor (vanilla) 0.2 %, beta carotene 0.05%, no emulsifier.

**Production procedure for bakery fat**

Oil soluble flavor and beta carotene were dissolved in the oil phase while salt and milk were dissolved in chilled water phase. The chilled water containing salt was added gradually to the oil blend and agitated for 10 min to form emulsion; the emulsion so formed was cooled (Tempered) in an ice bath containing 10 % calcium chloride ($Cacl_3$) to a temperature of 11℃. The resultant bakery fat was packaged and stored in a refrigerator at 4 ℃ until required for use.

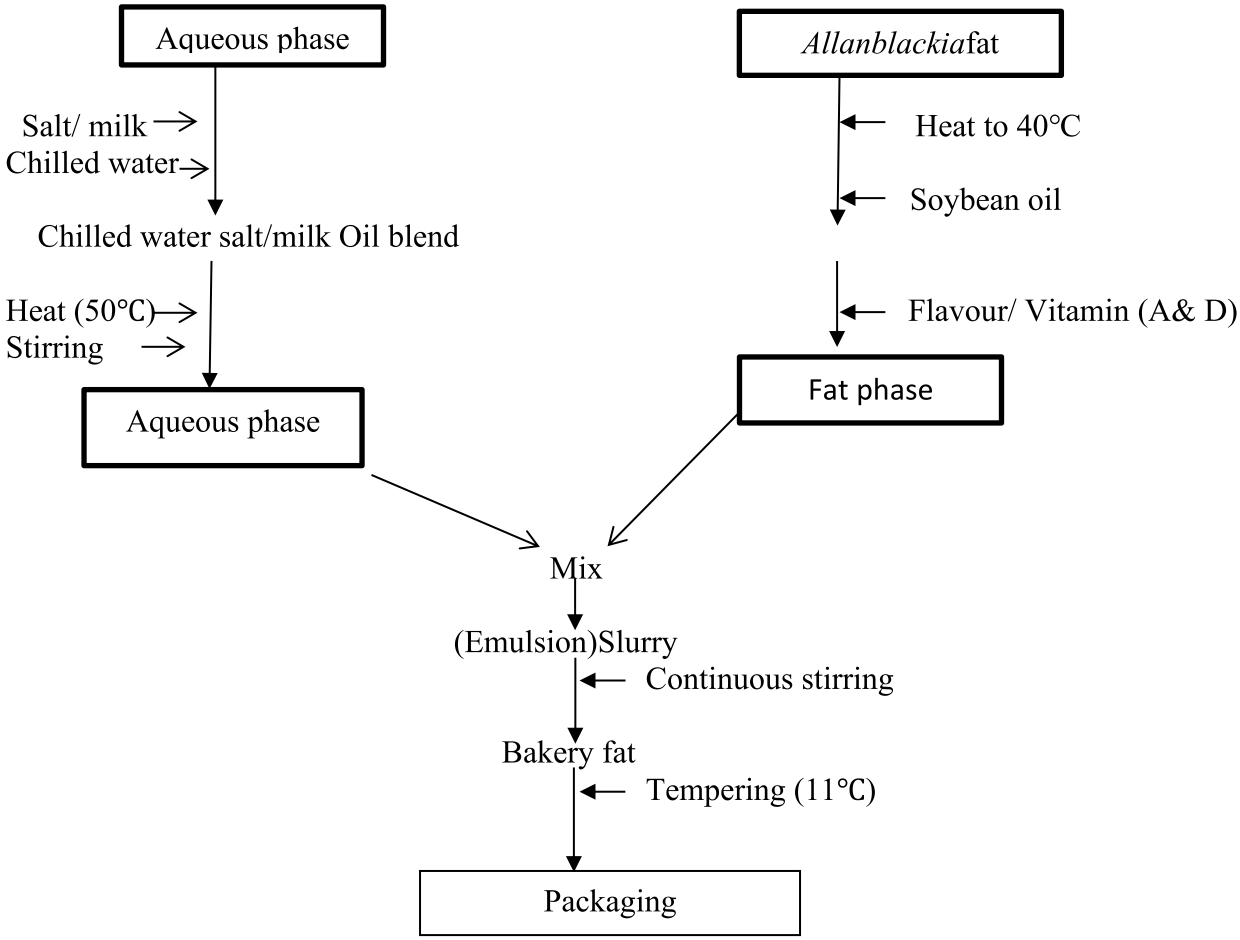


**Fig. 2: Bakery fat Production**

**Bakery Fat Analysis**

**Determination of Free fatty acid**

Two (2.0 g) grams bakery fat sample was introduced into a 250 $cm^3$ conical flask and 100 mL neutralized ethanol followed by adding few drops of phenolphthalein indicator (AOCs, 2017). The mixture was heated to melt and then titrated with 0.1 M NaOH solution until a pink color developed. Free fatty acid was calculated using the equation below:

$$\text{Free fatty acid (\%)} = \frac{T \times M \times Mw}{w} \qquad \text{Eq. (8)}$$

Where,
T = titre value
M = molarity of the titrant
W = weight of oil used
Mw = molecular of dominant fatty acid

**Determination of water content**

Water content was determined in accordance with reference method provided in AOAC, (2019) standard method as described by Adak *et al.,* (2017). Approximately 3 g of the product was placed in a petri-dish and dried in the oven at 105℃ for 6 h. water content was calculated using the equation shown below:

$$WC = \frac{M2 - M1}{M3} \times 100 \quad \text{Eq. (9)}$$

Where;
WC - water content of the sample, expressed as mass fraction in percent
$M_2$ - mass of sample and petri-dish prior to drying, given in gram
$M_1$ - mass of sample and petri-dish after to drying, given in gram
$M_3$ - mass of sample

**Melting point (moisturized)**
The open capillary tube as described in AOAC, (2019) was used without holding in refrigerator, before melting point determination.

**Melting point (de- moisturized)**
Moisture was removed from the bakery fat after which, the de-moisturized bakery fat was taken in capillary tubes until 1 cm high column and held in a refrigerator for 15 min, the melting point was then determined.

**Salt content**
As described by AOAC, (2019), a test portion of the bakery fat was melted in boiling water. The dissolved chloride in mixture was titrated with a solution of silver nitrate prepared by dissolving 13.6 g of silver nitrate in a 1000 mL volumetric flask. The silver nitrate was calibrated against 100 mL of a solution containing 0.400 g/L of sodium chloride (NaCl), previously dried at 300℃, using potassium chromate as indicator.
Calculation;

$$\% \text{ salt content (as sodium chloride (NaCl)} = \frac{titre\ difference \times 0.1 \times 58.5}{weight\ of\ sample} \quad \text{Eq. (10)}$$

Where,
Normality of silver chloride = 0.1
Molecular weight of sodium chloride = 58.5

**Fat content**
Fat content was determined by adopting the method given by AOAC, (2019). One gram (1 g) bakery fat was weighed into a thimble and the top of the thimble plugged with fat free cotton wool. The thimble was dropped into a fat extraction tube of soxhlet apparatus. Bottom of the extraction tube was attached to a receiving flask containing approximately 250 mL n-hexane. The top of the extraction tube was attached to a condenser, and then set-up experiment was extracted for 5 h on a water bath set at 70-80℃. At the end of the extraction period, the thimble was removed from the apparatus and the hexane distilled off by allowing it to collect in a soxhlet tube and recovered. The residual hexane was evaporated in the oven at 60℃ for 1 h after which the recovered oil was cooled in the desicator and weighed. The difference in weight was taken as he fat present in the sample expressed as below:

$$\text{Fat } (\%) = \frac{weight\ of\ fat\ recovered}{initial\ weightof\ sample} \times 100 \quad \text{Eq. (11)}$$

**Statistical Analysis**

Tests were done in three replicates and results expressed as mean ± standard deviation (SD). Data were analyzed by one-way analysis of variance (ANOVA) using the Minitab 18 analytical software, USA). Statistical significant means were separated using Duncan Multiple Range Test (DMRT). Deviations were considered significant at $p < 0.05$.

**Results and Discussions**

Table 1 shows the physicochemical properties of *A. floribunda* and Soybean oil; moisture content figures are low and inconsistent with the report of Jonathan *et al.* (2021) who reported mean moisture content of 4.35% in *A. floribunda* in their study of proximate, antioxidant properties, oil yield and characterization of vegetable tallow tree (*Allanblackia floribunda* Oliv.). Low moisture content of oil is an advantage against microbes and is key to the water activity of many foods (Konuskan *et al.*, 2019). Local or low technology used in vegetable oil production displays high moisture content leading to increased oil acidification and peroxidation processes and which likely undergoes rancidity (Merkx *et al*., 2018).

According to Table 1 the lowest and highest smoke points were 189° C and 194° C, measured for *Allanblackia* oil and soybean oil, respectively. These values are within the smoke point standard limit of 190-200° C given by ESFA, (2017) for refined vegetable oils. However, the result presented in this report for smoke point is for un-refined *Allanblackia* and soybean oil. No standard limit has been given for crude samples. The word smoke point of oil refers to the temperature, at which oil starts to break down, forms a bluish smoke and thus, be damaged in flavor and nutrition. Smoke point shows the collapse of fats to glycerol and FFAs, it contains acrolein which is irritating to eye and chokes the throat (Yee *et al.,* 2018). The higher the smoke point, the better the baking and frying oil will be. However, this depends on the oil quality and some minor component such as sedimentation (solids left over from processing) and volatile matter (Alvarenga *et al.,* 2018). Other factors that contribute to smoke point include oil's thermal stability which also affects flavor and other oil properties when heated, in other words high smoke point oils have better thermal stability during frying (Yee *et al.,* 2018). Sediment refers to non-fat solids contained in cooking oil. These solids begin to smoke at lower temperatures. Free fatty acid (FFA) content is another factor behind smoke points. Most fatty acids in cooking oils are in triglyceride form, but slowly break down into FFAs. FFAs in cooking oils are less stable than fatty acids in the triglyceride form, and so smoke at lower temperatures. Therefore, the higher the free fatty acid and volatile matters in oil, the quicker it will break down and start smoking, thereby reducing the oil capacity to withstand heat. The influence of degree of unsaturation is minimal but chain length has an important effect; oils containing short chain fatty acids (e.g. lauric acid) have lower smoke point than oils with predominantly longer chain fatty acids, heating oil to the point where the oil begins to smoke produces toxic fumes and harmful free radicals which may destroys omega-3-fatty acids quicker (Guillaume *et al.,* 2018).

Allanblackia oil had a flash point slightly higher than soybean oil; these values are within specified range given for flash point of most edible vegetable oils (230-300°C) (ESFA, 2017) the oils are therefore safe for frying and baking requiring high temperature. Flash point of oil is the lowest temperature at which vapors of a volatile material will ignite when given an ignition source (De Alzaa*et al.,* 2018). It is a descriptive characteristic that is used to distinguish between flammable liquid and combustible liquids. When fats or oil is heated past its smoke point, that fat starts to break down releasing fume radicals and some substances called acrolein, the chemical that gives burnt foods their acrid flavor and aroma. Flash point can be used to determine the transportation and storage temperature requirement.

The melting point of Allanblackia oil was significantly ($p< 0.05$) higher than that of soybean oil but similar to Shea butter reported to having a melting point range of 32 - 42°C. Melting point of Allanblackia oil reported by European Food Safety Authority (EFSA, 2017) ranged from 39-42°C; the degree of hardness of fat has a direct relationship with its melting point. It has been shown that fat having a higher amount of saturated fatty acids have higher melting points. Consequently, fats having less saturated and more unsaturated fatty acids have lower melting point. According to (Hassim and Dian 2017), fats that are spreadable, have low solids at low temperatures. In addition, fat should be completely melted below 37°C at least at body temperature for good oral meltdown. When margarine is said to have good mouth-melt characteristics, it means that the oil phase in the product melts sharply at body temperature resulting in the complete collapse of the mixture in the mouth thus, releasing the flavor filled water phase (Cisse and Yemiscioglu 2019).

The values recorded for Allanblackia and soybean oil colour are within the stipulated standard of 5R maximum (Lovibond scale) for refined vegetable oil set by FAO, (2015). The alphabet Y and R, are derived from the Lovibond tintometer, meaning Yellow and Red. Colour of oils is of great importance in food formulation as it determines appearance of the product.

One of the most important physical properties of a fluid system is the viscosity (Azinta *et al*., 2021) it is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. Allanblackia oil was more viscous when compared with soybean oil.

Solid fat content of Allanblackia oil completely melted at 40°C with solid fat of 84.50% at 10℃. The solid fat content (SFC) of a lipid influences many of its sensory and physical properties, such as spreadability, firmness, mouthfeel, processing and stability. The solid fat content is the percentages of the total lipid that is solid at a particular temperature, the density of solid fat is higher than the density of liquid oil, and so there is an increase in density when fat crystallizes and a decrease when it melts. It is possible to determine the solid fat content by measuring the density over a choice of temperature (Zhang *et al*., (2017). The study showed significant ($p<0.05$) difference in SFC between the Allanblackia oil and soybean oil at the temperatures. A value of not less than 10% solid fat content in oil is essential to prevent oiling out. High amount of saturated fatty acids contributes to high solid fat content (Chai *et al.,* 2018).

Refractive index of the oil samples falls within specified range by EFSA, (2017), which is 1.470 - 1.276℃. The refractive index of oil is lower than that of water; this means that when light passes through oil, it bends less than it would in water. In vegetable oil, refractive index determines how it will interact with light which leads to the possible chances of rancidity development. The higher the refractive index, the higher is the chances of spoilage due to oxidation (Soh *et al*., 2019). Quality control check for purity of oil as well as monitoring hydrogenation and isomerization uses the information of refractive index. It has been reported that close relationships exist between molecular weight and refractive index, accordingly, there is an increase in refractive index with increasing chain length and number of double bonds present in the oil.

The free fatty acid content of the oil samples were within specified standard by EFSA, (2017), given as 0.05-1 max, free fatty acids should not be more than 0.3%max as stated by FAO, (2015). From the name free fatty acids are the unattached fatty acids present in a fat or oil; it is

an important parameter in evaluating the quality of fats and oils with respect to rancidity and oxidation. A high percentage of free fatty acids in crude oil are undesirable because; they result in high losses of neutral oil during refining, they render unpleasant odour and deteriorate the quality of the product by hydrolysis and/or oxidation (Hatmi, 2021), hence, some vegetable oil in crude form must be refined before consumption (Umeda and, Jorge, 2021). The presence of high free fatty acids in vegetable oils poses many problems for storage and result in an undesirable color and odor in the final product. Many methods for free fatty acids elimination have been developed to improve the value of degraded vegetable oils. These include chemical refining with caustic soda neutralization and physical refining based on steam distillation.
Saponification value of Allanblackia fat (Table 1 is in line with EFSA, (2017) specification which ranged from185 -198 mgKOH/g. The saponification value corresponds to the mass in mg of potassium hydroxide (KOH–commonly known as potash) needed to neutralize the free fatty acids and saponify the esters contained in a gram of material (Olagunju *et al.*, 2022). Coconut oil and palm kernel oils contain appreciable quantities of low-molecular-weight fatty acids thus have high saponification value. The reports of Brahmi *et al*. (2020) showed that fats and oils with high saponification values are those with high amount of shorter carbon chain lengths of the fatty acids. The smaller the saponification value the larger the average molecular weight of the triglyceride. Fatty acids capable of yielding more energy on combustion had been reported by to be those that possess low molecular weight with the oil fraction having saponification values of 200 mgKOH/ g and above.

Values reported for unsaponifiable matter varied significantly ($p<0.05$); 0.09 and 0.7% respectively. During processing or degradation of oil, a variety of non-glyceride bioactive substances made up of a mixture of sterols, paraffin, hydrocarbons, aldehyde, ketones, pigments, mineral oil, fat-soluble vitamins and contaminants such as heavy metals that may occur naturally or may be formed and manifest in form of unsaponifiable matter (Karoui *et al*., 2020). Oils stability against oxidation depends not only on the degree of unsaturation, but also on the antioxidant content present in the unsaponifiable fraction. This is the matter remaining when oil has been saponified. Unsaponifiable matter analysis helps to check oil adulteration; however, in analysis of Vitamin A, the determination of unsaponifiable matter is needed.
The peroxide value recorded against Allanblackia and soybean oil is within acceptable limit 10 meq/kg for edible oils as stated by FAO, (2015). A rancid taste is often noticeable in many oils when the peroxide value goes up to 20 and 40 meq/kg oil (Nanayakkara *et al*., 2020). Report have shown that high saturation levels of oil will have high oxidative and thermal stability during storage of the product due to the presence of lower unoccupied chains, this leads to a slower rate of deterioration of lipid characteristics (Novidzro *et al*. 2019). Peroxide value is an important tool in measuring the oxidative rancidity and the degree of deterioration of lipids. The stability of Allanblackia seed oil has been evaluated in an accelerated oxidative test where the oil was stored at elevated temperatures (EFSA, 2017).
The iodine value for Allanblackia seed oil was significantly ($p<0.05$) lower than 122g /100g reported for soybean oil. Value for Allanblackia oil is relatively low indicating a low degree of unsaturation or a high degree of saturation. The iodine value (IV) is a measure of the average number of grams of iodine that a fat or oil molecule can hold per 100 grams of the substance. Specifically, iodine value is a measure of the degree of unsaturation of a fat or oil expressed in grams of iodine per 100 grams of fat or oil. Fats and oils that are more unsaturated have a higher iodine value (Lee *et al.* 2021).

**Table 1: Physicochemical Properties of *A. floribunda* and Soybean oil**

| Parameters | *A. floribunda* oil | Soybean oil |
|---|---|---|
| Moisture (%) | 0.49±0.01[f] | 0.25±0.00 [e] |
| Smoke Point (°C) | 194.00±0.14 [a] | 189.00±8.49 [b] |
| Flash point (°C) | 266.50±2.12 [a] | 249.00±1.41[b] |
| Density g/cm$^3$ | 0.888±0.00 [e] | 0.915±0.01[e] |
| Melting Point | 36.50±2.12 [e] | -20.50±2.12[e] |
| Colour (Lovibond scale) | 20.2Y,3.2R | 20.0Y, 4.2R |
| Viscosity Cst | 35.00±7.07 [e] | 25.00±2.83[d] |
| Solid fat content 10°C | 84.50±6.36[c] | -3.00±0.00[e] |
| 20°C | 77.00±1.41[c] | *ND* |
| 30°C | 57.00±1.41[d] | *ND* |
| 40°C | 0.00±0.00[f] | *ND* |
| Refractive index [40 °C] | 1.46±0.01[f] | 1.47±0.00[e] |
| Free fatty acid (%) | 0.06±0.02[f] | 0.045±0.00[e] |
| Saponification value (mg KOH/g) | 198.50±0.70[b] | 193.00±1.41[b] |
| Unsaponifiable matter (%) | 0.09±0.021[f] | 0.70±0.14[b] |
| Peroxide Value (meq/kg) | 0.36±0.021[f] | 0.80±0.14[e] |
| Iodine value (g/100g) | 39.50±0.70[e] | 122.00±1.4[c] |

*Values are means of triplicate determination ± SD. Means bearing different superscript down the column are significantly different (p<0.05). ND=not determined*

**Effect of Blending on the Physicochemical Properties of Oil**

The effect of blending on the physicochemical properties of oil or fat is presented in Table 2: it is important to have knowledge of the physicochemical properties of oil blended in order to project the blends with formulations suitable for use in exact food applications.

Moisture content of the blends was in agreement with moisture value range of 0.3-0.5% specified by the European Food Safety Authority, (2019). Moisture content is a commonly used parameter in processing and testing of food quality.

Blending soybean oil (liquid at room temperature) with and more viscous Allanblackia fat (solid at room temperature) modified the oil blends in terms of viscosity. This is an indication that the generated oil blend can be used for bakery fat formulation, however, Dorni *et al*. (2018), revealed that the viscosity, like all other Newtonian fluids, decrease with an increase in temperature due to the destruction of the solidified oil crystals.

Slip melting point (SMP) of soybean oil increased with addition of Allanblackia oil to the blend owing to high quantity of saturated fatty acid (stearic acid) present in Allanblackia oil. Dorni *et al*. (2018), while observing oil blend with palm stearin added into the palm kernel olein (PKO) reported that the slip melting point in oil increased with an increase in the amount of palm stearin in the blends with palm kernel olein oil due to high amount of high melting triacylglycerols, oleodipalmitin (POP) and tripalmitin (PPP) in palm stearin (PS). Slip melting point is the temperature at which a fat in a capillary tube placed in water becomes soft enough to slip or rise up the tube.

Smoke point of the blends is considered adequate necessary in food processing for thermal stability (Tian, 2021). Oils high in monounsaturated fats (including Allanblackia avocado, canola, and olive) have medium smoke point while oil high in saturated fats, such as coconut and palm oils, have higher smoke points (Garg, 2021).

Soybean oil has an antagonistic effect on the solid fat content of Allanblackia- soybean oil blend; this was probably due to low solid fat in the unsaturated oils leading to reduced solid content. Reduction in solid fat content with increased SBO had earlier been reported (Medeiros de Azevedo, *et al.,* 2020). Solid fat content is the quantity of fat crystals in a fat or fat blend. It has a great influence on the suitability of the fat or fat blend for a particular application (Moriya *et al*., 2020). The addition of fatty acids in the form of triglyceride alloys to a mixture will change the ratio between saturated and unsaturated fatty acids that affect the content of solid fat in the mix, the polymorphic structure and, melting temperature. Solid fat content is responsible for many product characteristics in bakery fat, margarines, shortenings and fat spreads, including their general appearance, ease of packing spreadability, oil exudation and organoleptic properties. According to Ostrikov*et al.* (2020), the mechanical properties of edible fats can be influenced by a series of factors, including the amount of SFC, the polymorphism of the solid state as well as the microstructure of the network of crystalline particles.

The density of unsaturated glycerides is higher than the corresponding saturated ones due to their molecular weight (Nasirpour-Tabrizi*et al.,* 2020). This is reflected in the blend ratio soybean (60%) and Allanblackia (40%).

According to Medeiros de Azevedo, *et al*. (2020), blending has a significant influence on iodine value (IV) where linoleic acids from soybean oil tend to migrate into oil blends. Soybean oil is characterised by high unsaturation reflected in its higher iodine value (Table 1). The iodine value of oil blends required in bakery fat formulation was improved by addition of Allanblackia oil;this may be probably due to high monounsaturated fatty acid composition of Allanblackia oil leading to reduction in the Iodine value of the blends

It is important to relate changes in chemical properties, due to blending, to projecting changes in physical properties. Kumar *et al.* (2018) concluded that simple blending of natural fats and oils can help to achieve desired characteristics without resorting to drastic methods such as chemical or enzymatic modifications, which often are expensive and time consuming.

**Table 2: Effect of Blending on the Physicochemical Properties of *A. floribunda* and Soybean Oil**

| Parameter | Result |
|---|---|
| Moisture (%) | 0.52 |
| VS (Cst) | 48.91 |
| SMP (°C) | 34.00 |
| SP (°C) | 220.50 |
| SFC (%) | 46.15 |
| DN (g/mL) | 0.9057 |
| IV (g/100g) | 91.75 |

Key: ASO = Allanblackia seed oil, SBO = Soybean oil, VS = Viscosity, SMP = Slip melting point, SP = Smoke point, SFC = Solid fat content, DN = Density, IV= Iodine value

**Physiochemical Properties of Bakery Fat from Blends of Allanblackia and Soybean Oil**

Table 3 shows result of the physiochemical properties of bakery fat from blends of Allanblackia and Soybean oil. Result of the melting point is consistent with baker's requirement because it is very difficult to work with bakery fat with relatively low melting point in hot weather. Solid fats in bakery fat melt at specific temperatures during baking. The melting process releases trapped gases, contributing to the leavening effect and further enhancing oven spring (Obinna-Echem, Okwechime, Mepba, 2023). At the other extreme, fats with a very high melting point are not very palatable, since they tend to stick to the palate. Bakery fat producers have therefore attempted to customize fats to accommodate the various needs of bakers. Fats with a melting range between 40°C and 44°C (104°F and 112°F) are considered to be a good compromise between convenience in handling and palatability. In order for bakery fat to melt cleanly without seeming gummy or waxy, it should be completely melted at body temperature.

The value of free fatty acid from the results of this study was lower than the control sample with free fatty acid values of 0.08% and 0.21%, respectively. The level of free fatty acids contained in bakery fat can be one of the parameters determining the quality of the oil used in the production. The amount of free fatty acids in oil is indicated by the value of the acid number. A high acid number indicates that the free fatty acids in vegetable oil are also high.

Water content of the formulated bakery fat was significantly lower than the water content observed in the control sample. Water is a basic component in a food ingredient and has effect in the appearance, texture and taste of food. The water content in food ingredients determines the acceptability, freshness and shelf-life of foodstuffs (Kirkhus *et al.,* 2015). However, water in the form of moisture in bakery fat is essential because fat itself traps and retains moisture, preventing baked goods from drying out and contributing to a tender crumb and enhanced flavor. Fats create a barrier that slows moisture evaporation, making bake goods like cookies soft and chewy.

Salt plays an important role in preserving margarine; however, its main role is to impart a desirable flavor to the product Sodium chloride (NaCl) is traditionally used as a food additive in food processing because, in addition to influencing the product taste, it plays an important role in texture and storage.

From table 3, fat content of formulated bakery fat was significantly ($p<0.05$) higher (82.04%) than the control sample (80.20%). Nevertheless, both samples are within acceptable limits. Bakery fat is a solid emulsion of water in fat or oil, meaning that the dispersed phase is water and the continuous phase is solid. Bakery fat should have at least 80% fat component, the source of the edible oil can be vegetables, animals, but it should not come from milk fat, making it distinct from butter (Nguyen *et al,* 2021). A good bakery fat should not suffer oil separation, hardening, sandiness, graininess, water separation, discoloration, or oiliness. The type of fat or oil and its melting point can affect the results. Different fat or oil has varying effects on dough properties and baking performance. Allanblackia Fat provides a solid fat base with a high melting point, which is crucial for creating bakery fat that maintain their shape and structure during baking.

**Table 3: Physiochemical Properties of Bakery Fat**

| Parameter | Formulated Bakery Fat | Commercial Bakery Fat |
|---|---|---|
| Melting point (moisturized) °C | $40.10\pm0.14^{b}$ | $43.15\pm0.212^{a}$ |
| Melting point (de- moisturized) °C | $37.90\pm0.14^{b}$ | $41.05\pm0.07^{a}$ |
| Free fatty acid (%) (as oleic acid) | $0.08\pm0.01^{b}$ | $0.21\pm0.001^{a}$ |
| Water content (%) | $16.35\pm0.21^{b}$ | $18.30\pm0.14^{a}$ |
| Salt content % | $1.45\pm0.01^{b}$ | $1.50\pm0.04^{a}$ |
| Fat content (%) | $82.04\pm0.01^{a}$ | $80.20\pm0.14^{b}$ |
| Peroxide value (meq/kg oil) | $0.31\pm0.01^{b}$ | $1.07\pm0.01^{a}$ |

*Values are means ± standard deviation of duplicate determinations.*
*Means bearing the different superscript on the same column are significantly different ($p<0.05$)*

**Conclusion**

Blend ratio 40:60 (Allanblackia: Soybean) was successfully used to produce bakery fat with similar physiochemical properties as the commercial counterpart with balance of three principal fatty acids: saturated, polyunsaturated and monounsaturated. Blending Allanblackia fat rich in monounsaturated fatty acid provided a solid fat base with a sharp melting point, which is vital for creating bakery fat that maintain their shape and structure during baking. On the other hand, soybean oil rich in polyunsaturated fatty acids contributed to blends that produced bakery fat with desired properties for good baking performance that will influence dough structure and delaying starch retro gradation. No modification in terms of fraction, interesterification or hydrogenation was required on Allanblackia and soybean oils before the production of the bakery fat. This blend is recommended for bakery fat production. More studies on Allanblackia oil in food processing for value addition to reduce scarcity of raw material in food industries and to encourage utilization of local crops are needed.

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