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Chemical characterisation of palm kernel (*Elaeis guineensis Jacq.*), shea butter (*Vitellaria paradoxa C.F. Gaertn.*) and sesame (*Sesamum indicum L.*) seed oils as ingredients in breeding broiler diets

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Target audience: *Oil processor, Feed-millers, Poultry breeding farmers, Nutritionist*

Abstract

Lipids are important to both humans and livestock where they play important role as an excellent source of energy and enhances the absorption of fat-soluble vitamins. However, oils are used in formulation without any considerations given to the peculiarities of their innate constituents particularly, vitamin, fatty acids and phytochemicals. Thus, the basis of these determinations. Three lipids: palm kernel oil (PKO), shea butter (SB) and sesame seed oil (SSO), were analyzed chemically in triplicate using standard methods. Results showed that SB had the highest ($p<0.05$) peroxide value (meq/kg) of 7.4 while PKO (0.7) and SSO (0.3) were similar ($p>0.05$). The iodine values (g/100g) of the lipids were not significantly different ($p>0.05$). The saponification value (mgKOH) of PKO (249.9) was significantly higher than SBO (190.9) and SSO (15.8) while the acid value (mgKOH/g) of SBO (10.6) was significantly lower ($p<0.05$). The α-tocopherol of SBO was 119.2 µg/mL which was significantly higher ($p<0.05$) than 69.6 µg/mL in SSO and 24.4µg/mL in PKO while there were significant variations ($p<0.05$) in the fatty acid composition of the oils. Analyses revealed the oils possessed variable chemical characteristics; while PKO would be most appropriate for soap production, SBO and SSO would be more susceptible to rancidity

Keywords*: palm kernel oil, sesame seed oil, shea butter, pro-vitamin,*

Description of Problem

Lipids are indispensible part of every diet of animals and they also exist in the living tissues of plants and animals (1). They can be classified into fats and oils depending on their state at room temperature. Although, other types of lipids such as waxes, steroids and phospholipids exist. Fats are solid at room temperature while oils are liquid.

A typical fat molecule is made up of a glycerol backbone and three fatty acid tails. The glycerol is usually similar for all fats, however, the chemical composition of each fat or oil is imposed by the varying fatty acid composition (2).

Fatty acids are made up of varying number of carbon and hydrogen and they are linked to the glycerol backbone by esterification resulting in the hydroxyl group of the glycerol backbone combining with the carboxyl group of the acids in a dehydration synthesis reaction. They can be saturated or unsaturated depending on the type of bond joining the neighboring carbons (3).

Fats and oils play important roles in the diet of both human and livestock and vegetable oils account for 80% of the world's natural oils and fat supply (4). They are particularly added in the diets to enhance their energy density and to improve the absorption of fat-soluble vitamins. This is because they are rich in dietary energy and contain more than twice the

caloric value of equivalent amount of sugar. Oils are also rich in essential nutrients such as vitamins and antioxidant compounds (5). Examples of dietary fat and oil are palm oil, palm kernel oil, shea butter, sesame oil.

Palm kernel oil (PKO) is derived from the kernel of oil palm after the removal of the major oil which is palm oil from the mesocarp of the palm fruit. These two oils are also quite different in terms of their chemical composition (6). The oil palm tree is available in the tropical rain forest region of West African countries (7).

Shea butter (SBO) on the other hand is derived from the nut of African shea tree. The shea tree grows naturally in the wild in the dry savannah belt of West Africa from Senegal in the west to Sudan in the east, and on to the foothills of the Ethiopian highlands.

Sesame seed and its oil (SSO) have been utilised as food for nearly 6000 years and it is believed to have originated from Africa (8). It was estimated that 1,900,000 tons of sesame oil was produced annually (9).

However, factors such as cultivar type, degree of maturity of the plants from which the oil is derived and environmental conditions affect the chemical composition of the oil and each oil contain varying profile of fatty acids (10, 11).

Oil are used in human and livestock diets as energy source without knowledge of the chemical characteristics and constituents. The study was aimed at characterisation of shear butter oil, sesame seed oil and palm kernel oil.

Materials and Methods

Experimental Site

The research was accomplished at the Central Nutrition Laboratory of Animal Science Department, University of Ibadan, Ibadan, Nigeria located in the tropical rain forest zone of Nigeria within the latitude $7^{o}26.05$ N and longitude $3^{o}54.74$ E, and an average altitude of 277meters above sea level. Temperature range and average relative humidity of the location were between 20-35 ^{o}C and 60%, respectively.

Selected samples

Three lipids, shea butter (SB), sesame seed oil (SSO) and palm kernel oil (PKO) were selected for the experiment. The basis for their selection was based on: their relative availability, increased interest in the fats and oils both for therapeutic and consumption purposes.

Sample collection

Palm kernel oil (PKO) was purchased at a palm kernel mill in challenge area in Ibadan as finished product while shea butter (SB) was purchased at the open market in Oja oba in Ibadan. Sesame seed oil (SSO) was purchased at Bodija market in Ibadan.

Chemical Analyses

The peroxide values of the PKO, SB and SSO were determined by titration according to AOAC (2000). The values were then calculated (12,13).

PV = A x V

Where: PV = Peroxide value, V = Vol of $Na_2S_2O_3$ used, A = (N x 1000) / W,

N = Normality of $Na_2S_2O_3$, W = Weight of oil

Iodine value of the samples (PKO, SB and SSO) were determined according to AOAC, (2000). The iodine value was then calculated by the equation below (12,13). The determinations were in triplicates.

$$IV = \frac{[(V_2 - V_1) \times M \times 12.7}{W}$$

Where: IV = Iodine value, V1 = Amount of $Na_2S_2O_3$ in cm^3 used for the oil V2 = Amount of $Na_2S_2O_3$ cm^3 used for the blank, M = Molarity of $Na_2S_2O_3$used, W = Weight of oil used.

12.7 = ~ constant used to convert from milliequivalent thiosulphate to gram (Molecular weight of Iodine = 126.9)

The saponification value of the PKO, SB and SSO was according to (12). The saponification values were then calculated by the formula (12, 13).

$$SV = \frac{[(V_2 - V_1) \times M \times 56.1]}{W}$$

Where: SV=Saponification value, V_1=Amount of HCl used in cm^3 for the oil,
V_2 = Amount of HCl used in cm^3 for the blank, M = Molarity of the HCl, W = Weight of oil used,
56.1 = Molecular weight of KOH.
The acid value of the samples was determined by titration according to AOAC (2000) and the acid calculated (12, 13).

$$AV = \frac{[T \times M \times 56.1]}{W}$$

Where: AV = Acid value, T = Volume of NaOH, M = Molarity of NaOH, W= Weight of oil, 56.1 = Molecular weight of KOH.
Fatty acid component of the oils was determined with gas chromatography (12) in triplicates using the at a detector temperature of 200 ^oC.

Vitamin and Provitamin Determination

The α-tocopherol composition of oils was carried out by the method of (14) in triplicates using HPLC at 292 nm. The total carotene assay was according to (12), using spectrophotometer at 440 nm

Statistical Analysis

Data were subjected to analysis of variance using the general linear model of SAS (2002) while means were separated using Duncan's multiple range test option of the same software at $\alpha_{0.05.}$

Results and Discussion

The chemical characteristics of shea butter (SB), palm kernel oil (PKO) and sesame seed oil (SSO) is presented in table 1. The saponification value of PKO was 249.9 mg/KOH/g which was significantly higher ($p<0.05$) than 190.9 mg/KOH/g for SBO of 15.8 mg/KOH/g in SSO. The values obtained for PKO was similar to 247 g/KOH/g obtained by (15). The same authors however, recorded lower saponification values of 187-196 (mgKOH) for corn oil and 188-196 mgKOH for groundnut oil. However, 15.8 mg/KOH/g obtained in the current study for SSO was lower than 189-190 mg/KOH/g reported by (15). (16) reported that the saponification values of shea butter mostly fall within 132 and 207.5 mgKOH/g (17). Shea butter also contained insoluble impurities.

Saponification value can be used to predict the molecular weight of the component fatty acids in the oil. The higher the saponification value, the lower the molecular weight of the constituent fatty acids (18). Report of this research was in consonance with that of (19) that shea butter consisted of triglycerides and unsaponifiable components, which are important basic product for the manufacture of soap and cream. Similarly, (20) reported a value ranging from 1.2 to 17.6% for the unsaponifiables in shea butter. However, (21) observed a converse correlation between the fruit ripeness and the degree of unsaponifiables, while (22) noted that the measured unsaponifiables in fruit were different on yearly bases and also depended on environmental variations. Most vegetable oils have lower unsaponifiables compared to shea butter (23).

The iodine values observed in the oils were not significantly different ($p>0.05$), although SSO value of 6.9g/100g was the highest. (24) remarked that iodine value was an index of saturation or unsaturation of the oil or fat. It is important in the determination of the shelf life of the oil because iodine numbers has a direct relationship with the degree of saponification and an inverse relationship with the shelf-life. Iodine value of oil or fat is the amount of iodine which can be absorbed by

100g of the oil or fat, the level of saturation is determined with the iodine uptake (25). It is important in the determination of the degree of reactivity of the oil. Lipids with greater iodine values contain more double bond than those with lower iodine values. In the present study, PKO with iodine value of 4.7g/100g was the most saturated of all the oils that were considered, however, (26) observed a higher iodine value of 23.52 g/100g for PKO at a temperature of 25 ^{o}C.

The SSO had the lowest peroxide value of 0.3 meq/kg compared to PKO with 0.7 meq/kg while SB with a value of 7.4 meq/kg was highest. The present result corroborates the findings of (20) who recorded a range of 0.5-29.5 meq O_2/kg. In the soap, cream and confectionaries production, the peroxide value range of SBO used varies from 1 to below 10 meq O_2/kg (27).

Peroxide formation are slow when fats and oil is stored because of an induction period depending on the type of oil and its temperature. Peroxide values are indices of rancidity of oil and the extent which the oil had undergone primary oxidation (28). Oils containing greater composition of unsaturated fatty acids are more likely to receive oxygen and become rancid compared to their counterpart with lesser unsaturated fatty acids. (29) recommended a maximum peroxide value of 10 milliequivalent of active oxygen per kilogram for fats and oils suitable for consumption hence, all the oils under consideration in the present study were suitable for consumption.

Higher acid value was observed in PKO compared to SB and SSO. The acid value of lipids indicates the rate of decomposition of triglycerides by lipases or other exposures including heat, light and temperature. This can be used to determine oil state and edibility. The acid values for SB differed significantly ($p<0.05$) from 0 to 21.2 mg KOH/g as observed (17). However, (30) observed higher figure of 128.2 mg KOH/g in CO_2 extracted shea oil from shea seed that had been preserved over a prolong period of up to two years. However, the result of the acid value of the lipids under consideration indicated that PKO was the most hydrolysed.

Table 1: Chemical characteristics of shea butter, palm kernel oil and sesame seed oil

Parameters	PKO	SB	SSO
Saponification (mgKOH)	249.90±12.08^{a}	190.89±9.12^{b}	15.80±4.31^{c}
Iodine (g/100g)	4.74±1.43	4.83±3.69	6.94±4.20
Peroxide (meq/kg)	0.74±0.31^{b}	7.41±3.34^{a}	0.34±0.24^{b}
Acid (mgKOH/g)	25.29±2.46^{a}	10.65±1.00^{c}	17.21±3.22^{b}

^{a,b} Means with different superscripts along the row are significantly different ($p<0.05$); PKO-Palm kernel oil; SB-Shea butter; SSO-Sesame seed oil

The total carotene and α- tocopherol composition of PKO, SB and SSO is presented in table 2. The α-tocopherol composition in SB was 119.18±5.80 mg/mL and was significantly higher ($p<0.05$) than 69.6±2.21 mg/m in SSO and 24.37±1.25 mg/mL in PKO. The relatively high α-tocopherol of SB was analogous to the assertion of (31) who also reported a value of 112 mg/100g for butter. However, (32) recorded a lower α- tocopherol range of between 26.3 and 44.4 mg/100g for shea butter grown in Uganda. Factors such as environment, genetic influences and storage period, all affect the α-tocopherol concentration of fats and oil. This is because some of the α-tocopherol were used up during

the period of storage to neutralise free radicals (33). Higher concentration of tocopherol in SSO was also observed by (34). Although a large proportion of it exist as gamma tocopherol. Shea butter had significantly higher total carotene content of 7533.20µg/mL compared to PKO (3041.10) and SSO (4624.30).

Table 2: Total carotene and α-tocopherol of shea butter, palm kernel oil and sesame seed oil

PARAMETER	PKO	SB	SSO
α-tocopherol (µg/mL)	24.37±1.25[c]	119.18±1.25[a]	69.57±2.2[b]
Total carotene (µg/mL)	3041.10±144.01[c]	7533.20±264.09[a]	4624.30±107.3[b]

[a,b] Means with different superscripts along the row are significantly different ($p<0.05$); PKO-Palm kernel oil; SB-Shea butter; SSO-Sesame seed oil.

Fatty acid profile of SB, PKO and SSO is presented in table 3. Fatty acid composition is one of the most vital attributes that can be used to determine the identity of oils or fats. Oil type differed significantly in fatty acids profile. Caproic, caprylic, capric, lauric and myristic acids were significantly higher ($p<0.05$) in PKO than SSO and SB, while palmitic, linoleic and behenic acids significantly higher ($p<0.05$) in SSO compared to PKO and SB. However, stearic, oleic, arachidonic, palmitoleic and linolenic acids were significantly higher ($p<0.05$) in SB compared to PKO and SSO.

It can be deduced from table 3 that SB had the most balanced ratio of unsaturated to saturated fatty acids. According to (35), there were three main considerations for classification of oils as being healthy and it include a balanced proportion of saturated/unsaturated fatty acid. A balanced proportion of essentials fatty acids (omega 6/omega 3) and the content of innate antioxidants. From the above consideration, SB was observed to contain a better proportion of saturated to unsaturated fatty acid and this agreed with the observation of (36) that after selection of shea kernels samples from different regions, shea butter fat contain about 16 fatty acids, of which the most prominent were oleic, stearic, palmitic, linoleic, and arachidic acids. The most abundant fatty acid reported was oleic acid, which varied from 37.2% to 60.7% (19). Stearic acid was the next most abundant, varying from 29.5% (32) to 55.7% (19). Some authors (19, 36, 37) observed variations in the shea butter fatty content from Uganda and other West African countries. The authors reported that a higher value of oleic acid for butter from Uganda while stearic was higher for the other regions. Conversely, in the present study, oleic acid percentage in the shea butter (44.82%) was higher than stearic (42.47). The palmitic acid content of 4.01% in shea butter in this study was lower and at variance with higher value of 7.5% obtained by (32). However, (36) obtained a percentage of 3.4% for palmitic acid. The stated linoleic acid composition of 5.5% (38) conformed to 5.57% in the present trial but lower than 7.9% obtained by (39). (40) observed that linoleic acid is an important fatty acid because it is not synthesised by the body and is critical in the building of the cell membrane.

Linoleic acid component of shea butter in the present study was in agreement with a range of 6 –8% reported by (41) thereby making it vital in human nutrition. Arachidic acid of 1.15% was higher than 0.6% reported by (38) whereas, linolenic acid in literature varied from 0.2% to 1.6% (42) but a value of 0.25% was obtained for shea butter in this study.

Table 3: Fatty acid profile of shea butter, palm kernel oil and sesame seed oil (%)

Fatty Acid	Palm kernel oil	Sheabutter oil	Sesame seed oil
Caproic	0.79±0.01[a]	0.00±0.00[b]	0.00±0.00[b]
Caprylic	10.49±0.50[a]	0.00±0.00[b]	0.00±0.00[b]
Capric	6.99±0.10[a]	0.00±0.00[b]	0.00±0.00[b]
Lauric	43.55±0.90[a]	0.74±0.06[b]	0.00±0.00[b]
Myristic	22.31±0.60[a]	0.26±0.04[b]	0.16±0.06[b]
Palmitic	7.82±0.10[a]	4.01±0.03[b]	9.20±0.10[a]
Stearic	2.64±0.10[b]	42.47±0.86[a]	5.80±0.30[b]
Oleic	4.88±0.10[b]	44.82±0.02[a]	41.09±1.62[b]
Linoleic	1.07±0.05[b]	5.57±0.04[a]	42.63±0.75[a]
Arachidonic	0.00±0.00[b]	1.15±0.03[a]	0.63±0.12[a]
Linolenic	0.00±0.00[b]	0.25±0.01[a]	0.00±0.00[b]
Palmitoleic	0.00±0.00[b]	0.24±0.03[a]	0.00±0.00[b]
Behenic	0.00±0.00[b]	0.00±0.00[b]	0.37[b]±0.15[a]

[a,b] Means with different superscripts along the row are significantly different ($p<0.05$)

Conclusions and Applications

1. Iodine values of the three oils under consideration were similar. However, the saponification value of PKO was higher relative to the others, while shea butter had higher antioxidant properties.
2. The choice of oil should be based on the chemical properties of interest.

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