

Physicochemical Properties and Fatty Acid Profile of Shea Butter and Fluted Pumpkin Seed Oil, a Suitable Blend in Bakery Fat Production

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Abstract: Shea nuts (*Vitellaria paradoxa*) were cracked and sorted. Fluted pumpkin seeds (*Telfairia occidentalis* Hook) were dehulled and washed. The Shea kernel and *Telfairia* cotyledons were oven dried (60°C, 24h) separately in a hot air oven, milled into flour and oil extracted. Crude palm oil extracted from the palm fruit was used as control. The oil samples were analyzed for chemical composition, physical properties, and fatty acid profile. Shea nut oil (Shea butter) gave 58.00% ether extract, 0.88% free fatty acids, 1.7mgKOH/g acid value, 1.03mEqO₂/kg peroxide value, 70.00g/100g iodine value, 227.94mgKOH/g saponification value, 0.95% Unsaponifiable matter, and 226.17mgKOH/g ester value. Fluted pumpkin seed oil gave 52.60% ether extract, 0.71% free fatty acids, 1.41mgKOH/g acid value, 1.17mEqO₂/kg peroxide value, 119.67g/100g iodine value, 179.04mgKOH/g saponification value, 0.57% Unsaponifiable matter, and 177.63mgKOH/g ester value. The iodine value of Shea butter and *Telfairia* seed oil were significantly ($p < 0.05$) higher than that of the control which gave 57.33g/100g iodine value. Shea butter also gave 1.461 refractive index, 0.927g/ml density, 36.57°C slip melting point, 211.00°C smoke point, 83.92cSt kinematic viscosity, and 4red and 20yellow lovibond colour. Fluted pumpkin seed oil gave 1.463 refractive index, 0.903g/ml density, 18.60°C slip melting point, 244.50°C smoke point, 34.98cSt kinematic viscosity, and 5red and 20yellow lovibond colour. Shea butter gave 50.6% total saturated fatty acids, and 49.1% total unsaturated fatty acids, with stearic (45.8%) and oleic (42.5%) as the predominant saturated, and unsaturated fatty acids respectively. Fluted pumpkin seed oil gave 18.4% total saturated fatty acids, and 80.2% total unsaturated fatty acids, with palmitic (17.5%) and linoleic (62.4%) as the predominant saturated, and unsaturated fatty acids respectively. Shea butter, with a melting point of 36.57°C will provide a good solid base for bakery fat production, while *Telfairia* seed oil with iodine value of 119.33(g/100g) will provide healthy fatty acids and the needed plasticity. A blend of Shea butter and fluted pumpkin seed oil in bakery fat production has potential to improve the nutritional and functional properties of the end products.

Keywords: Shea Butter, Fluted Pumpkin, Physicochemical, Fatty Acid Profile, Bakery Fat

1. Introduction

Shea butter and Fluted Pumpkin seeds are good sources of fats and oil. Shea butter is obtained from the nuts of Shea tree (*Vitellaria paradoxa*), which exist in the wild in most parts of Africa [1]. It is a native of the dry Savanna belt of West Africa [2], where it grows wild across a 5000km wide belt of Savanna [3], inhabiting West African Countries of Senegal, Burkina Faso, Cote d'Ivoire, Mali, Ghana, Togo, Benin, Nigeria, Cameroon,

Niger, and further east into Sudan, Uganda and Ethiopia [4]. Shea butter is solid at room temperature, edible and used in food preparation in Africa [5]. It is commonly used as a domestic frying and cooking oil, and in the industries for cosmetics and medicinal purposes. There are no report of allergic reaction owing to consumption of Shea butter or its products [6].

Fluted pumpkin (*Telfairia occidentalis* Hook F) is a tropical crop that belongs to the Cucurbitaceae family, known for its great genetic diversity and widespread adaptation [7].

It is reported to be indigenous to the west tropical rain forest area of Nigeria [8]. It is grown in Nigeria for its vegetable and oil bearing seeds. Although the fruit is inedible, the seeds produced by the gourd are high in protein and fat [9] and can therefore contribute to a well-balanced diet. The blend of Shea butter (a solid fat) and fluted pumpkin seed oil, rich in essential polyunsaturated fatty acids is expected to produce bakery shortening with improved functionalities, nutrition and health value.

Bakery fats (shortenings) are tailored fat systems, whose nutritional and functional properties have been modified in order to deliver specific functional needs; as tenderizing agents, facilitate aeration, texture, mouthfeel, carry flavours and colours, provide a heating medium, and structural integrity to pies, breads, pasta and other bakery products [10]. This modification gives desirable consistency and keeping quality. Use of Shea nut and *Telfairia* seed oil in bakery fat production will further enhance the utilization of these agricultural raw materials. It will also provide a brand that will compete favorably with the predominant palm stearin based margarine and shortenings in Nigeria market. The objective of this study was to evaluate the physicochemical properties and fatty acid profile of Shea butter and fluted pumpkin seed oil, as fat blend in bakery fat production.

2. Materials and Methods

Healthy nuts of the Shea tree were procured from Minna, Niger State, while mature, freshly harvested fluted pumpkin fruits were purchased from Bori market in Rivers State. The Shea nuts were cracked and sorted. The *Telfairia* seeds were dehulled and washed. The Shea kernel and *Telfairia* cotyledons were both oven dried at 60°C, for 24h, separately in a hot air oven (model QUB 305010G, Gallenkamp, UK), ground using a laboratory mill (model MXAC2105, Panasonic, Japan), this was followed by oil extraction as described by AOAC [11].

2.1. Physicochemical Properties

Physicochemical properties including; acid value, iodine value, free fatty acids, peroxide value, Saponification value, Unsaponifiable matter, melting point, Refractive index and density were determined by the method of AOAC [11]. Viscosity measurement (in centistokes, cSt) was performed using an Ubbelohde glass capillary viscometer (size 2. A149, Cannon instrument, PA, USA). Refractive index was performed using the Abbe Refractometer model 2WAJ (Wincom, China).

2.2. Fatty Acid Profile

The individual fatty acids in the oil/fats were determined using the A. O. A. C [11] methods.

Fatty acid methyl esters (FAME) were prepared from the extracted fats/oil. In 50 ml round bottom flasks, 50 mg of each sample was kept in separate flasks and 3 ml of sodium methylate solution (0.5mol/l of methanolic solution of NaOH) was added. The reaction medium was refluxed for 10 minutes; 3 ml of

acetyl chloride was added; mixture was refluxed again for 10 minutes and then cooled to ambient temperature; 8 ml hexane and 10 ml of distilled water was added and allowed to stand for 5 minutes to establish a two phase solution. The upper organic phase was recovered into a vial for GC analysis, using Agilent 7890A, coupled with flame-ionization detector (FID).

2.3. Statistical Analysis

All the analyses were carried out in triplicate. Data obtained were subjected to Analysis of variance (ANOVA), differences between means were evaluated using Tukey's multiple comparison test, and significance accepted at $p \leq 0.05$ level. The statistical package in Minitab 16 computer program was used.

3. Results and Discussion

3.1. Chemical Properties of Shea Butter, Fluted Pumpkin Seed Oil and Crude Palm Oil

3.1.1. Ether Extract

Table 1, shows the percentage ether extract of Shea nut oil as 58.00 (%), this value was higher than 56%, 53.56%, and 47.5% reported by other researchers [12], [13], [14]

The fluted pumpkin seed oil gave an ether extract yield of 52.60 (%), this value was slightly lower than 54% earlier reported [15] but higher than 46.37% and 46.2% also reported [16], [17].

3.1.2. Acid Value

The acid value is a measure of the amount of potassium hydroxide (mg) necessary to neutralize the free acids in 1g of fat [18]. The acid value of unrefined Shea butter is 1.76mgKOH/g, this value relates closely to 1.2mgKOH/g earlier reported [14]. Higher values of 2.3 – 3.0mgKOH/g had also been reported [13].

The acid value of the unrefined fluted pumpkin seed oil was 1.41mgKOH/g. this value is lower than 3.97, 3.56, 3.48, and 2.22mgKOH/g reported by earlier researchers [19], [20], [21], [7], [16]. Lower acid values of 0.76mgKOH/g had also been reported [22].

The acid values (AV) of Shea butter and Fluted pumpkin seed oil were significantly ($p < 0.05$) lower than that of the control (crude palm oil) which gave AV of 7.29mgKOH/g.

A low AV means that an oil sample contains less free acids thus reducing its exposure to rancidification [23], [24]. The low acid value of Shea butter and fluted pumpkin seed oil shows that the fats are suitable for food and other industrial uses.

3.1.3. Free Fatty Acids

The free fatty acid content of unrefined Shea butter and fluted pumpkin seed oil were reported as 0.88% and 0.71% respectively, these were significantly ($p < 0.05$) lower than the CPO (3.33%). FFA of 0.71% compares with 0.73% recorded for cashew nut seed oil [25].

The low FFA of unrefined Shea butter and fluted pumpkin seed oil enhances their suitability for bakery fat and other food product formulations. The cost and energy required for refining

and modifications will be much less than that needed for palm oil refining.

3.1.4. Peroxide Value (PV)

The PV of Shea butter was 1.03mEqO₂/kg, this value was significantly ($p<0.05$) lower than 1.53mEqO₂/kg recorded by the control. PV of 1.03mEqO₂/kg agrees with the range (0.4 – 2.57mEqO₂/kg) earlier reported for unrefined Shea butter [14].

The PV of fluted pumpkin seed oil was 1.17mEqO₂/kg. This value was also significantly ($p<0.05$) lower than the CPO (1.53mEqO₂/kg).

The PV of the Shea butter and fluted pumpkin seed oil were much lower than 10mEqO₂/kg, which is the maximum allowable standard of PV for edible oil [28]. Peroxide value (PV) is the milliequivalent (mEq) of oxygen per 100g of fat, it is used to indicate the degree to which a fat has been oxidized [26]. Oxidation of an unsaturated oil takes place via the formation of hydroperoxides. The hydroperoxides been the primary products of oxidation do not have any off-flavour [27].

3.1.5. Iodine Value (IV)

Iodine value is a simple chemical constant used to measure unsaturation or the average number of double bonds in an oil sample. It is defined as the number of grams of iodine that could be added to 100 g of oil [26], [29].

The iodine value of Shea nut oil (Shea butter) was 70.00g/100g. This value was significantly ($p<0.05$) higher than the crude palm oil (57.33g/100g). IV of 70.00g/100g was higher than 60.37g/100g, 61.00g/100g and 61.31g/100g earlier reported [1], [31], [14]. Shea butter with IV of 83.3g/100g had also been reported [31]. IV of 70 fall within 58 – 72g/100g which is the acceptable range of IV for Shea butter at international level [32].

The IV of Shea nut oil was significantly ($p<0.05$) lower than that obtained for fluted pumpkin seed oil (119.67g/100g).

The low iodine value of Shea nut oil indicates that the oil is rich in saturated fatty acids, which ensures stability against oxidation and rancidity of foods prepared with the oil [33]. It also act as a good source of solid fat for shortening and margarine production.

High iodine value of fluted pumpkin seed oil (119.67g/100g), indicates that the oil is rich in polyunsaturated fatty acids, which enhances the nutritional value of food products in which it is used. The IV of fluted pumpkin seed oil (119.67g/100g) compares with IV of

119.92g/100g recorded for sunflower seed oil [34].

3.1.6. Saponification Value (SV)

The saponification value (SV) of Shea nut oil was 227.94mgKOH/g, this value relates to 227.49mgKOH/g recorded for groundnut [35]. SV of 227.94mgKOH/g was significantly ($p<0.05$) higher than 200.47mgKOH/g given by the control (CPO) sample. High saponification value is an indication of oil suitability for industrial use.

The SV of fluted pumpkin seed oil was 179.04mgKOH/g, this value agreed with 179.04mgKOH/g reported by earlier researchers [21], [7].

3.1.7. Unsaponifiable Matter (USM)

Unsaponifiable matter refer to substances dissolved in the fat, which are insoluble in aqueous solution but soluble in organic solvent after saponification [36].

The percentage USM in Shea nut oil was 0.95%, this was significantly ($p<0.05$) higher than that given by the crude palm oil of 0.55%. The USM of Shea butter had been reported to be relatively higher than other vegetable oils, given up to 4% USM [38]. The high USM content of Shea butter shows that the oil is rich in desirable bioactive components such as; antioxidants, antimicrobial, and anti-inflammatory substances [38] as well as the fat soluble vitamins. It has also been used to lower cholesterol levels by a pharmaceutical company, BSP Pharma [39].

The percentage USM in fluted pumpkin seed oil was 0.57%, this value agreed with the range 0.2 – 0.8% reported for groundnut, and 0.5% reported for soybean [36]. The Unsaponifiable fraction comprises only a small part of fluted pumpkin seed oil compared to triglyceride fraction.

3.1.8. Ester Value (EV)

The ester value of a fat is a function of the saponification value and the acid value.

It is an indication of the saponifiable fatty acids excluding the free acids of the fat [40].

The ester value of Shea nut oil is 226.17mgKOH/g, this value was significantly ($p<0.05$) higher than the control crude palm oil (193.18mgKOH/g). The EV of fluted pumpkin seed oil was 177.63mgKOH/g. The high ester value of Shea butter and fluted pumpkin seed oil is an indication that the fats are suitable for culinary purposes.

Table 1. Chemical properties of Shea butter, Fluted pumpkin seed oil, and crude palm oil.

OIL	AV	FFA	PV	IV	SV	USM	EV	EE
	(mgKOH/g)	(%)	mEqO ₂ /kg	(g/100g)	(mKOH/g)	(%)	(mgKOH/g)	(%)
FPSO	1.41 ^c ± 0.02	0.71 ^c ± 0.01	1.17 ^b ± 0.06	119.67 ^a ± 0.58	179.04 ^c ± 0.83	0.57 ^b ± 0.02	177.63 ^c ± 0.85	52.60 ^b ± 0.53
SNO	1.76 ^b ± 0.04	0.88 ^b ± 0.02	1.03 ^b ± 0.06	70.00 ^b ± 1.00	227.94 ^a ± 0.38	0.95 ^a ± 0.02	226.17 ^a ± 0.38	58.00 ^a ± 0.40
CPO	7.29 ^a ± 0.06	3.33 ^a ± 0.03	1.53 ^a ± 0.12	57.33 ^c ± 0.75	200.47 ^b ± 0.65	0.55 ^b ± 0.02	193.18 ^b ± 0.64	ND

Values are means ± standard deviation of triplicate samples.

Mean values bearing the same superscript in the same Column do not differ significantly ($p>0.05$).

Key: FPSO= Fluted pumpkin seed oil, SNO= Shea nut oil, CPO= Crude palm oil, AV= Acid value FFA= free fatty acid, PV= Peroxide value, IV= Iodine Value, SV= Saponification value, USM= Unsaponifiable matter, EV= ester value, EE= Ether extract, ND= not determined.

3.2. Physical Properties of Shea Butter, Fluted Pumpkin Seed Oil and Crude Palm Oil Refractive Index (RI)

Table 2 shows the physical properties of samples with the RI of Shea butter as 1.461, while the RI of fluted pumpkin seed oil was 1.463, these values were significantly ($p < 0.05$) higher than the control CPO. Refractive index of fat increases with increasing chain length and also with number of double bonds present in the oil [41]. RI also depend on the degree of unsaturation and the degree of conjugation of the oil [29]. The high RI of fluted pumpkin seed oil shows that the oil contains more unsaturated fatty acids than Shea butter, and palm oil.

3.2.1. Density (Dn)

The density gives information on the weight of the fat and the solid content at a specified temperature. In Table 2, the density of Shea butter was 0.927g/ml at 30°C. This was significantly higher than 0.900g/ml given by the control (crude palm oil).

The density of fluted pumpkin seed oil (FPSO) was 0.903g/ml, which showed no significant ($p > 0.05$) difference with the density of palm oil (0.900g/ml) at 30°C.

3.2.2. Slip Melting Point (SMP)

The slip melting point is an indication of the temperature at which the fat soften or becomes sufficiently fluid to slip or flow. The slip melting point of Shea butter was 36.57°C. This value was significantly ($p < 0.05$) higher than the control (crude palm oil) with SMP of 32.57°C. The melting value of Shea butter also compares with the range (34 – 38°C) earlier reported [1]. This melting range show that Shea butter is a solid fat below 36°C, and thus will act as a good source of solid fat for margarine and shortening production. While fluted pumpkin seed oil gave a melting point of 18.50°C, which was significantly ($p < 0.05$) lower than the SMP of crude palm oil. The lower melting point of FPSO indicates that it has less resistance to shear stress, and thus its inclusion in table or bakery margarine blend will enhance plasticity.

3.2.3. Smoke Point (SP)

The smoke point is the temperature at which oil gives off a thin bluish smoke. When fat over heat, it breaks

down/decompose into glycerol and its individual fatty acids. The glycerol is further hydrolyzed to a steel-blue acrolein smoke [42]. The smoke point indicates the temperature limit up to which that cooking oil can be used [43]. It correlate with the amount of free fatty acid in the oil [43]. The SP does tend to increase as the free fatty acid content decreases. The smoke point of Shea butter was 211.00°C, this was significantly ($p < 0.05$) lower than 230.05°C given by palm oil. Fluted pumpkin seed oil gave smoke point of 244.50°C, this value compares with that reported earlier [7]. The relatively high smoke point of Shea butter and FPSO indicates that the oil can be used for a wide range of cooking applications.

3.2.4. Viscosity (VS)

The viscosity of fat is its resistance to flow. It increases with the molecular weight of the oil and decreases with increasing unsaturation and high temperature [44]. The viscosity of Shea butter was 83.92cSt (centi stokes) at 40°C. This value was significantly higher than that of crude palm oil (42.48cSt). The high viscosity of Shea butter at 40°C shows high resistance to flow, this is an indication that Shea butter contains more saturated fatty acids and more solid fats at 40°C, making it a suitable source of hard stock (solid fraction) for bakery shortening and margarine production.

Fluted pumpkin seed oil gave 34.98cSt, which was significantly ($p < 0.05$) lower than the control. Low viscosity of 32.22cP and 45cSt had been reported for FPSO [20]. The relatively low viscosity value of fluted pumpkin seed oil shows that the oil is light and probably highly unsaturated [45].

3.2.5. Lovibond Colour Intensity

The Lovibond colour of Shea butter was 4Red and 20Yellow, Telfairia seed oil 5Red and 20Yellow. The lovibond colour of unrefined Shea butter and fluted pumpkin seed oil (4red and 5red) were significantly ($p < 0.05$) lower than that of crude palm oil (11red and 22yellow). This implies that it will be less expensive to bleach and refine Shea butter and Telfairia seed oil than palm oil.

Table 2. Physical properties of Shea butter, Fluted pumpkin seed oil, and crude palm oil.

OIL	RI	Ds	SMP	SMOK. P	VS	L. C
SAMPLE		(g/ml)	(°C)	(°C)	(cSt)	
FPSO	1.463 ^a ± 0.001	0.903 ^b ± 0.006	18.60 ^c ± 0.40	244.50 ^a ± 0.20	34.98 ^c ± 0.63	5R, 20Y
SNO	1.461 ^a ± 0.001	0.927 ^a ± 0.006	36.57 ^a ± 0.59	211.00 ^c ± 0.10	83.92 ^a ± 0.36	4R, 20Y
CPO	1.456 ^b ± 0.001	0.900 ^b ± 0.001	32.57 ^b ± 0.71	230.05 ^b ± 0.40	42.48 ^b ± 0.63	11R, 22Y

Values are means ± standard deviation of triplicate samples.

Mean values bearing the same superscript in the same Column do not differ significantly ($p > 0.05$).

Key: FPSO= Fluted pumpkin seed oil, SNO= Shea nut oil, CPO= Crude palm oil, RI= Refractive index, Ds= Density, SMP= Slip melting point, Smok. P= Smoke point, VS= Viscosity, L. C= Lovibond colour.

3.3. Fatty Acid Profile of Shea Nut Oil (SNO) and Fluted Pumpkin Seed Oil (FPSO)

As shown in Table 3, Shea nut oil (SNO) had 50.6% saturated fatty acids, and 49.1% unsaturated fatty acids. The

predominant saturated fatty acids in SNO was stearic acid (45.8%), while the predominant unsaturated fatty acid in SNO was oleic acid (42.5%). Fluted pumpkin seed oil (FPSO) had 18.4% saturated fatty acid and 80.2%

unsaturated fatty acids. The predominant saturated fatty acid in FPSO was palmitic acid (17.5%), while the predominant unsaturated fatty acid in FPSO was linoleic acid (62.4%). High linoleic acid content (64.4%) in fluted pumpkin seed oil had earlier been reported [7]. The linoleic acid content of FPSO was observed to be higher than that earlier reported for other vegetable oil noted for high linoleic acid content, such as; maize (58.5%), and soybean oil (54.3%) [7]. The high stearin fraction of Shea butter (50.6%) makes it a suitable source of solid fat, for bakery fat and margarine production. The high linoleic acid content of FPSO (62.4%) make it a rich source of essential fatty acid, this will enhance the nutritional value of the vegetable shortening.

Table 3. Fatty Acid profile of Shea butter and Fluted pumpkin seed oil.

FATTY ACIDS		FAT SAMPLES
(%)	SNO	FPSO
Myristic (C14:0)	0.3	0.1
Myristoleic (C14:1)	0.5	
Palmitic (C16:0)	4.1	17.5
Palmitoleic (C16:1)		1.2
Stearic (C18:0)	45.8	0.8
Oleic (C18:1)	42.5	14.1
Linoleic (C18:2)	6.1	62.4
Linolenic (C18:3)		
Arachidic (C20:0)		
Paullinic (C20:1)	0.6	2
Lignoceric (C24:0)		1.5

Key: SNO= Shea nut oil; FPSO= fluted pumpkin seed oil.

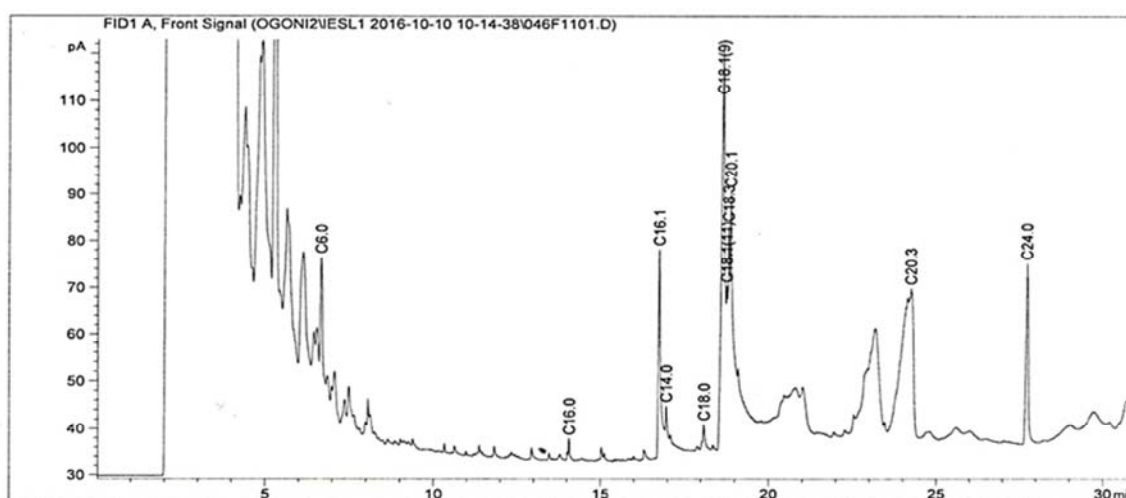


Figure 1. Fatty acid GC Chromatogram of Fluted pumpkin seed oil (FPSO).

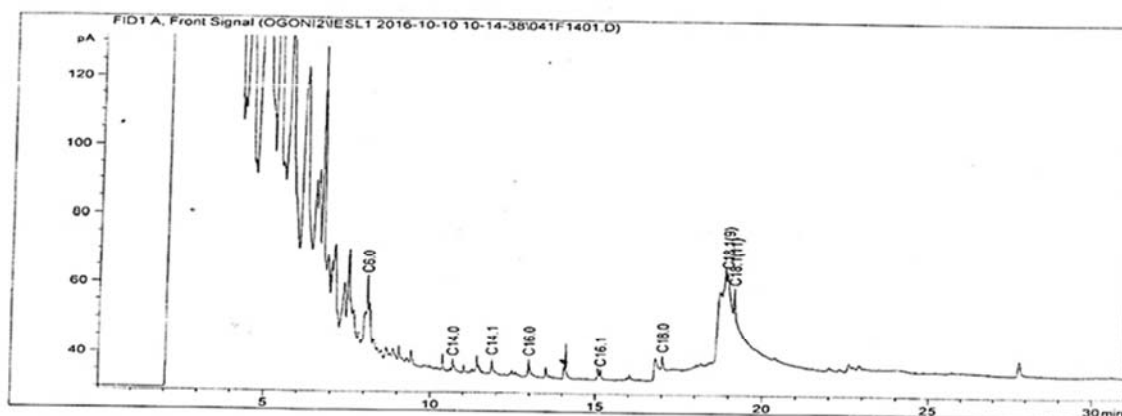


Figure 2. Fatty acid GC Chromatogram of Shea nut oil (SNO).

4: Conclusion and Recommendation

Shea nut oil has high recovery (58.00%) and is chemically safe for culinary purposes. Its physicochemical properties enhances its potential for incorporation into human food products and other industrial purposes such as in drugs and cosmetics. The high concentration of long chain solid fat components (stearic acids) makes it a stable solid at room

temperature and this enhances its usefulness in margarine, and bakery shortenings manufacturing. The use of Shea butter as a source of solid base stock in bakery fat production will not only eliminate trans-fat from partially hydrogenated hard stocks, but will ensure the use of the least deleterious saturated fatty acid (stearic acid), which is much healthier than palmitic and other saturated fatty acids, as regards cardiovascular health [2]. Fluted pumpkin seed oil has over 80% of unsaturated fatty acids, out of which over 62% is the

polyunsaturated specie (linoleic acid). Linoleic acid is an essential fatty acid which is safe, heart friendly and nutritionally desirable. A blend of Shea butter and fluted pumpkin seed oil in bakery fat/shortening production will give a product better described as linoleic acid rich Shea and Telfairia oil (LARSTO) shortening.

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