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Quality characteristics of shea butter recovered from shea kernel through dry extraction process

Olaniyan AM*, Oje K

Department of Agricultural Engineering, Faculty of Engineering and Technology, University of Ilorin, P.M.B. 1515, Ilorin-240003, Kwara State, Nigeria

*E-mail:amolan397@hotmail.com

Dry extraction of shea *(Vitellaria paradoxa*) butter from shea kernel was carried out in an instrumented mechanical expression rig. Shea butter was expressed at a pressure of 8.8 MPa applied at the rate of 2.5 mm/min on crushed shea kernel heated at 50, 70, 90 and 110°C. The characteristics investigated on shea butter were specific gravity, refractive index, moisture content, melting point, viscosity, colour intensity, saponification value, iodine value, free fatty acid value, ester value, total acid value, peroxide value and rancidity index. Ester values of 216.6, 211.0, 194.2 and 180.3 while iodine values of 85.4, 83.3, 81.7 and 78.8 were obtained at 50, 70, 90 and 110°C, respectively and saponification values at these temperatures were 261.3, 258.1, 244.7 and 237.7 while free fatty acid values were 6.3, 7.6, 12.2 and 15.4, respectively.

Keywords: Shea nut, *Vitellaria paradoxa*, Shea kernel, Shea butter, Dry extraction, Mechanical expression rig, Quality characteristics

Shea nut (SN) is known as Kandayi, Osisi and Emi among the Hausa, Igbo and Yoruba people of Nigeria, respectively. It is obtained from the fruit of shea tree (*Vitellaria paradoxa)*, which exists in the wild and grows in an uncultivated state in most parts of Africa. Shea fruit (SF) is made up of a green epicarp, a fleshy mesocarp (pulp) and a relatively hard shell (endocarp) which encloses the shea kernel (embryo). The kernel, according to Axtell et al (1993) contains about 60% edible fat (shea butter) and the residual product, from which the butter is extracted (shea cake), is an excellent ingredient for livestock feed production. Shea butter (SB) is good as table oil because of its high nutritive value. It is widely used locally for curing leprosy and other ailments. It also has various industrial uses that include soap making, cosmetics, lubricants and paints. According to Russo and Etherington (2001), shea products, such as solid fat (butter or stearin) and the liquid oil (olein) are ideal for use as raw materials for cooking oil, margarine, cosmetics, soap, detergents and candles. However, they have found their primary market as a substitute for cocoa butter in the chocolate and confectionary industry.

According to the American Shea Butter Institute (ASBI 2004), 100% pure natural SB is an all-natural vitamin A cream. SB has been shown to be a superb moisturizer, with exceptional skin healing properties. ASBI (2004) compiled a list of skin conditions where 100% SB has been proved to be effective. These skin conditions are dry skin, skin rash, skin peeling after tanning, blemishes and wrinkles, itching skin, sunburn, shaving cream for a smooth silky shave, small skin wounds, skin cracks and tough or rough skin (on feet). Others are cold weather, frost bites, stretch mark prevention during pregnancy, insect bites, health skin, muscle fatigue, aches and tension, skin allergies such as poison ivy or poison oaks, eczema, dermatitis and skin damage from heat. It is because of these unique healing properties that the shea tree is called karite tree which means tree of life (ASBI 2004).

It was reported by ASBI (2004) that SB has unparalleled moisturizing property and this is due to several natural moisturizers present in it. It was also discovered by ASBI (2004) that the moisturizers in SB are the same moisturizers produced by the sebaceous glands in the skin. In the same development, ASBI (2004) reported that the positive biochemical and physiological effects SB has on skin injuries makes it ideal for wound healing. Reports from many users of SB have shown that this product promotes and accelerates wound healing. Further more, vitamin E in SB is helpful to the skin and such benefits could be accomplished by increasing the microcirculation to the skin. This eventually results in increased blood supply to and from the skin. Also, vitamin E in SB may serve as an anti-free radical agent thereby preventing the deleterious effects of sun and environmental exposure.

The traditional method of SB extraction from shea kernel (SK) involves roasting, wet milling, mixing, cooking and clarification prior to fat extraction. These operations, known as wet extraction process, are tedious, time consuming, energy sapping, environmentally unfriendly and grossly inefficient. Some modified and improved methods invented in some parts of West Africa, though slightly improved the yield, are also based on the wet extraction process that is cumbersome and labour intensive. The dry extraction process has gained a worldwide popularity and acceptance in modern vegetable oil industry. Unfortunately, this process has not been extended to SB extraction in most rural communities in Nigeria.

The objective of this study was to investigate the quality characteristics of SB recovered from SK through dry extraction using a mechanical oil expression rig. Such information should elucidate the problems of quality attributes and provide useful data for the development of process line for dry extraction of SB from SK.

Materials and methods

Mechanical expression rig: The mechanical expression rig consists of a piston-cylinder rig in conjunction with universal testing machine (Model M500-

50 KN, TESTOMETRIC Company Ltd., England, United Kingdom). The universal testing machine (UTM) is of 50 KN capacity and its vital parts include the control console, load frame, crosshead, load cell, personal computer and the printer. The piston-cylinder rig is made up of a compression piston, a press cage cylinder, a supporting platform and an oil collecting pan. The piston serves as the pressing ram and it distributes pressure from the UTM evenly on the oilseed sample in the press cage cylinder.

A 605 W electric band heater was installed to enfold the press cage cylinder and hence serves as a heating device for mechanical expression process. The rig is adequately instrumented with a temperature transducer to control the expression temperature while the pressure for expression is obtained from the UTM. The temperature transducer is a system of thermocouple connected to an electronic temperature controller (Model JTC–902, Japan). The temperature range of the electronic temperature controller is 0–400 ^{0}C with the voltage of 110/220 V, frequency of 50/60 Hz and output of 840 W. In operation, the heat sensor (thermocouple probe) is inserted into the oilseed sample (crushed shea kernel) through a hole drilled on the side of the press cage cylinder 70 mm height from the base. The arrangement of the mechanical expression rig is shown in Fig. 1.

Dry extraction procedure: This experiment was carried out in the Engineering Materials Testing Laboratory, Technical and Scientific Services Complex, National Centre for Agricultural Mechanization (NCAM), Idofian, Ilorin. The average room temperature of the laboratory was about 30^0C throughout the period of experimentation.

A sample of 200 g of crushed SK was transferred into the press cage cylinder. The sample was heated inside the press cage cylinder with the aid of the temperature-controlled band heater at 50^0C for 30 min. Using the jug mode of the UTM, the compression piston was moved down to touch the sample in the press cage cylinder. The sample was then pre-compacted to a height of 70 mm inside the press cage cylinder by UTM loading at a constant speed of 10 mm/min. After pre-compaction, the crushed SK sample was compressed by the UTM through the compression piston at a constant loading speed of 2.5 mm/min to a pressure 1.5 MPa for 10 min. The oil extracted was collected in the oil collecting pan placed below the drainage area.

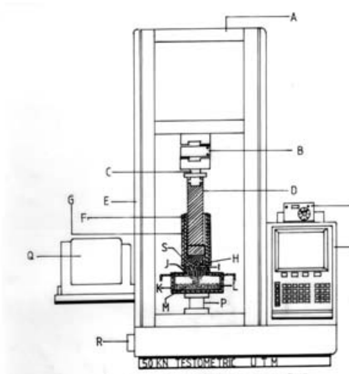

Fig. 1. The mechanical expression rig.
A - Crosshead; B - Load cell of the UTM; C - Upper attachment of the UTM; D - Compression piston; E - Frame of the UTM; F - Press cage cylinder; G - Heating device; H - Thermocouple probe from the electronic temperature controller; I - Oilseed cake; J – Drainage channel; K - Supporting platform; L - Oil collecting pan; M - Oil expressed; N - Electronic temperature controller; O - Control console; P - Lower attachment of the UTM; Q - Computer system with printer; R - Switch of the UTM; S - Wire mesh

After extraction, the compression piston was lifted well above the press cage cylinder by the jug mode of the UTM. The press cage cylinder (with the residual cake inside) was unscrewed and the residual cake was extruded into the cake extruding die. The experiment was repeated for the 3 heating temperatures of 70, 90 and 110^0C.

Quality analysis: Specific gravity of SB obtained from each extraction temperature was determined using a specific gravity bottle. Refractive index was determined with the aid of the refractive sensitive plane of the refractometer (Model Zeiss 74111 Butyrorefractometer, Bellingham and Stanley Limited, United Kingdom). Moisture content was determined using the moisture can method. The melting point of the SB was determined according to the method described by Olatunji and Owoyale (2005). The apparatus used for the measurement of the viscosity of SB was the Brookfield Digital Viscometer (Model DV–I–DVTD, Brookfield Engineering Laboratory, Stoughton, USA). The apparatus used for the determination of colour intensity of the SB are the Lovibond tintometer, Curette cell and Munsell colour charts.

The saponification, iodine, ester and total acid values were determined according to the method of BPC (1988). Free fatty acid and the peroxide values were determined by the titration method of AOAC (1984). Rancidity index was determined by a 1-inch curette cell and a Lovibond tintometer scale.

Results and discussion

Results are presented in Table 1.
Specific gravity (SG): SG decreased from 0.917 to 0.870 when the heating temperature was increased from 50 to 110^0C. This is because of the burning of the oil as the heating temperature increased and increase in volume due to expansion of the oil as a result of heating. SB expressed at temperatures of 90^0C and below will be appropriate for bulk shipment.

Refractive index (RI): As the heating temperature was increased from 50 to 110^0C, RI increased progressively from 1.465 to 1.475. According to Fashina and Ajibola (1989), the RI is used for rapid sorting of fats and oils of suspected adulteration. SB continue to be adulterated as the heating temperature increased beyond 90^0C. This is due to excessive burning of the oil at heating temperatures above 90^0C.

Moisture content (MC): MC decreased from 0.56 to 0.10% when the heating temperature increased from 50 to 110^0C. According to Feather (1977), loss of moisture occurs as a result of dehydration and drying of carbohydrate and oil contents during heat treatment of oilseeds. It is proper to recommend a temperature of 70-90^0C for dry extraction of SB from SK. This corresponds to post-extraction MC of 0.30-0.40 %. The low moisture content of SB expressed in this study is an indication that the oil is of good quality. This is because oils with high MC are susceptible to recontaminations or rancidity (Fellows 1997).

Melting point (MP): MP increased from 35.0 to 38.0^0C when the heating temperature was increased from 50 to 90^0C. However, a further increase in the heating temperature from 90 to 110^0C

Table 1. Quality characteristics of shea butter

	Extraction temp, °C			
	50	70	90	110
Specific gravity	0.917	0.916	0.908	0.870
Refractive index	1.465	1.468	1.471	1.475
Moisture, %	0.56	0.40	0.30	0.10
Melting point, °C	34.5	37.0	38.0	37.5
Viscosity, cp	80	100	100	80
Saponification value	261.3	258.1	244.7	237.7
Iodine value	85.4	83.3	81.7	78.8
Free fatty acid, %	6.3	7.6	12.2	15.5
Total acid value, %	44.7	47.2	50.5	57.5
Ester value, mg KOH/g	216.6	211.0	194.2	180.3
Peroxide value, meqO_2/g	22.1	31.8	43.6	44.9
Colour intensity*	13.6 R	13.6 R	10 R	6 R
	20 Y	20 Y	20 Y	20 Y
	0.1 B	0.2 B	0.9 B	1.5 B
Rancidity index *	10 R	12 R	8 R	6 R
	20 Y	20 Y	20 Y	20 Y
	0 B	0 B	0.3 B	0.8 B

* R – Red; Y – Yellow; B - Blue

reduced MP from 38.0 to 37.5°C. This means that SB is a solid fat below 35.0°C. The MP of SB increased with increase in the heating temperature and decreased after heating beyond 90°C. This suggests that the purity of SB increased as the heating temperature was increased from 50 to 90°C and decreased with a further increase in the heating temperature from 90 to 110°C.

Viscosity: Viscosity increased from 80 to 100 cp as heating temperature increased from 50 to 70°C, remained constant at 100 cp with an increase in the heating temperature from 70 to 90°C and finally decreased to 80 cp when the heating temperature increased further from 90 to 110°C. However, an optimum viscosity of about 100 cp can be obtained at a heating temperature between 70 and 90 °C. The more viscous a vegetable oil is, the better it is as a lubricant. This study shows that SB extracted from SK that has been pre-heated at temperature between 70 and 90°C will have high lubricating properties.

Colour intensity: Yellow was the dominant colour of the SB at all the heating temperatures. The red colour gave way to the appearance of blue colour as heating temperature was increased from 90 to 110°C resulting in the darkening of the oil. This darkening could be attributed to the loss of moisture. Feather (1977) reported that the formation of colours from carbohydrate in food involves the loss of one or more molecules of water from the carbohydrate.

The colour of SB extracted from SK samples heated at 110°C was dark and unattractive. This dark colour suggests the need for a special refining process. For a small-scale oil processor, refining may be too costly to embark upon. Apart from increasing cost of production, Ohlson (1976) reported that it might be difficult to hydrogenate oils extracted from oilseeds heated to temperatures of 110°C and above. The results of this study indicate that it is not necessary to heat SK at a high temperature of 110°C before SB extraction.

Saponification value (SV): SV of SB extracted from SK decreased from 261.3 to 237.7 when the heating temperature was increased from 50 to 110°C. High SV may suggest possible use of the oil in the soap industry. Therefore, the higher the temperature of oil extraction, the lower the chance of the oil being used for the manufacturing of soaps.

Iodine value (IV): IV decreased from 85.4 to 78.8 when the heating temperature was increased from 50 to 110°C. The IV expresses the level of unsaturation of oils. The higher the iodine numbers the higher the rate of absorption of oxygen from the air at ordinary temperatures. The absorption of oxygen causes paint to polymerize after application to form tough, adherent, impervious and resistant films (Fashina and Ajibola 1989). The higher IV at lower heating temperatures suggests that SB extracted at lower temperatures can be used in varnish industry for the manufacture of paints.

Free fatty acid (FFA): FFA increased from 6.3 to 15.5% when the heating temperature was increased from 50 to 110°C. According to Feather (1977), the formation of FFA in oilseeds starts with the destruction of oil cells especially during the thermal pretreatment of the seeds prior to oil extraction. At higher heating temperatures, thermal rupturing of the oil cells occur more rapidly leading to the formation of more FFA compared with lower heating temperatures.

Increasing the temperature of heating increases lipase activity thus leading to increased FFA. The progressive increase in the FFA content with increasing heating temperature from 50 to 100°C suggests that the levels of heating temperature considered in this study were not high enough for the inactivation of the enzyme lipase. Ohlson (1976) observed such inactivation by dry heat at 140 – 160°C. Adeeko and Ajibola (1989) also observed similar trend in groundnut oil.

Total acid value (AV): AV increased from 47.7 to 57.5 when heating temperature was increased from 50 to 110°C. The rate of acid formation was higher when the heating temperature was increased from 90 to 110°C. This suggests that heating SK above 90°C is not appropriate for SB extraction. Acid formation could also be due to breaking up and destruction of cells during size reduction of the SK prior to heat treatment. This was also observed by Adeeko and Ajibola (1989) while studying mechanical expression of groundnut oil.

Ester value (EV): EV decreased from 216.6 to 180.3 when the heating temperature was increased from 50 to 110°C. The higher the EV, the more the palatability of the oil. For SB to be palatable and have good taste, the temperature of extraction should not be too high.

Peroxide value (PV): PV increased

from 22.1 to 44.9 when heating temperature increased from 50 to 110 ^{0}C. The rate of increase in the PV was faster with increase in the heating temperature from 50 to 90^{0}C but slower when it was increased from 90 to 110^{0}C. High PV is associated with the development of rancidity in fats and oils, which eventually limits their use in the food industry. The PV obtained for SB at heating temperatures of 50 to 70^{0}C suggest that the product is of a high commercial value.

Rancidity index: As the heating temperature increased, there was an increase in the rancidity index as indicated by the appearance of blue colour. Rancidity also indicates the degree of deterioration of fats and oils. Blue colour appeared as 0.3 at 90^{0}C and increased to 0.8 at 110^{0}C. Therefore, as the heating temperature was increased, there was increase in appearance of blue colour, which indicates development of rancidity.

Yellow colour remained persistent with constant high value (20) at all levels of heating temperatures. This confirms that the dominant colour of SB was yellow when in liquid form after extraction. The results of this study confirm that a heating temperature of 70-90^{0}C will be appropriate for the heat treatment of SK prior to SB extraction. Although, rancidity sets in and was evident at 90^{0}C with the appearance of blue colour, it was with a very low level of 0.3.

Conclusion

This study revealed the effect of extraction temperature on quality characteristics of SB recovered from SK by dry extraction process. The result showed that a temperature of 70 to 90^{o}C will be appropriate for thermal pretreatment of SK prior to SB extraction by dry process. However, other factors like post-harvest handling, processing and storage of SF, SN and SK can also affect the quality characteristics of SB during and after extraction.

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