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Assessment of the Physicochemical Quality of Unrefined Shea Butter Produced in the Localities of Sarh and Koumra (Chad)

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Abstract

Introduction: The shea tree (*Vitellaria paradoxa*) is one of the plant species supplying Non-Timber Forest Products (NTFPs) in Chad. His edible fruits containing almonds are used as a raw material in butter processing. This processing activity is carried out by both informal units and cooperatives. **Aim:** The aim of the study is to contribute to the improvement of the physicochemical quality of unrefined shea butter produced in the localities of Sarh and Koumra (Chad). **Methodology:** The methodology consists of conducting surveys in these units and cooperatives to identify production stages and sample butter. The samples taken were analysed for seven (7) physicochemical parameters to assess their quality. The tests are carried out in the laboratories of the Food Quality Control Center (CECOQDA). The results take into account for seven (7) physicochemical parameters that are: 1) Criteria Organoleptic: 50% black and fondant butter; 50% yellow and compact butter; 28.57% strong smell, 28.57% low odour, 21.43% medium odour and 21.43% rancid; 2) Water Content: 0.14% ± 0.020% for yellow butter and 0.25% ± 0.040% for black ($p = 0.002$); 3) Insoluble Impurities: 3.49% m/m ± 0.27 for yellow butter and 3.88% m/m ± 0.38 black; 4) Acid Index: 5.11% ± 0.090% for yellow butter and 3.57% ± 0.130% for black; 5) Iodine Index: 21.12 g I_2/100 g ± 0.670 for yellow butter and 20.67 g I_2/100 g ± 0.62 for black; 6) Peroxide Index: 11.86 mEq/Kg ± 0.42 for yellow butter and 3.65 mEq/Kg ± 0.28 for black ($p = 0.008$); 7) Saponification Index: 182.64 mg KOH/g ± 0.80 for yellow butter and 193.45 mg KOH/g ± 0.70 black ($p = 0.037$). **Conclusion:** This study evaluated the quality of the two varieties of unrefined shea butter. The yellow variety proves to be better in view of the results. However, efforts still

have to be made on the processes to connect to the values required by the Codex Alimentarius.

Keywords

Butter, Shea, Organoleptic, Physicochemical, Quality

1. Introduction

The shea tree is a tree of the family Sapotaceae, which can reach about fifteen meters high. It grows in the wooded savannahs of Africa [1] [2]. Its distribution area corresponds to the Sudano-Sahelian climate that covers sixteen countries: Benin; Burkina Faso; Cameroon; Central African Republic; Chad; Côte d'Ivoire; Gambia; Ghana; Guinea; Mali; Niger; Nigeria; Uganda; Senegal; South Sudan and Togo [3].

This tree is identified as a single species in taxonomy as *Vitellaria paradoxa*, however, there are two subspecies: *Vitellaria paradoxa paradoxa* and *Vitellaria paradoxa nilotica* [4]. The paradoxa subspecies whose solid butter is rich in stearic acid is present in the western zone and the nilotica subspecies whose liquid butter is rich in oleic acid occupies the eastern zone.

Shea is classified among the pioneers of Non-Timber Forest Products (NTFPs) in Chad. But paradoxically, this species struggles to be domesticated in order to maintain sustainable exploitation in the face of bushfires and excessive cutting [5]. Its fruits have been used for food and cosmetic purposes by the indigenous population of the Middle-Shari and Mandul provinces since the dawn of time [6]. Shea fruits are delicious ovoid berries containing high-fat almonds, which are used to extract butter. Butter is widely used in African countries by women in the preparation of dishes. They anoint their babies with butter to make babies strong and beautiful [7]. Nowadays, it is also used by the food industry (oil mills, chocolate factories) and cosmetics (body and hair creams) [8]. Butter is indispensable on a socio-economic level, thanks to its physicochemical properties and its many virtues widely exploited in food, cosmetics, pharmaceuticals and chemistry [9]. It constitutes, like any Non-Timber Forest Product (NTFP), a real source of income for the population thanks to its essential contribution to food and cosmetics [10].

Several scientific studies are focused on the exploitation of the shea sector. The most relevant issue that has focused more on the same issue as ours is the one conducted by (Womeni, *et al*., 2006) on "the effect of cooking and drying shea nuts (*Butyrospermum parkii* (G. Don) Kotschy) on the quality of butter" [11]. This study showed that cooking and drying shea seeds change the biochemical characteristics that affect the quality of butter. These changes are related to the time and interaction effect between these two variables. These conditions would inactivate the natural enzymes and those were produced by the mi-

croorganisms responsible for the deterioration of butter.

The processing of butter faces the challenges of quality, which is a major challenge in meeting market requirements [12]. Because locally, women use an artisanal processing process to produce black shea butter through direct cooking to meet the needs of direct consumption. At the same time, Caritas Switzerland and Swissaid have jointly coordinated the SODEFIKA project since 2017 to provide financial and technical support to the production units of village women's cooperatives with improved methods for butter processing of shea non-refined churned meeting the needs of the food industry and export.

The objective of this study is to evaluate the quality of unrefined shea butter collected in the localities of Sarh and Koumra. Specifically, the composition must be evaluated via three organoleptic parameters (colour, texture and odour) and six physicochemical parameters (water content, insoluble impurities, acid index, peroxide index, iodine index and saponification index). The results will be compared by considering as a reference the limit values of the Codex Alimentarius, in particular the regional standard for unrefined shea butter (CXS 325R-2017) jointly amended in 2020 by FAO and WHO.

The study complements previous research and is above all a scientific document made available to technical partners and processors for the extension of the shea sector in Chad.

2. Materials and Methodology

2.1. Study Area

This study was carried out in the provinces of Middle-shari and Mandul located in the south of Chad, precisely in the localities of Sarh and Koumra. Fieldwork began in December 2021 with surveys and sampling in informal units and cooperatives producing unrefined shea butter. The rest of the testing work takes place at CECOQDA followed by data analysis throughout 2022 to 2023.

The survey was carried out mainly among a targeted population composed mainly of women who process of unrefined shea butter. This was followed by the taking of fourteen samples of butter which will be analyzed to assess the quality based on seven (7) physicochemical parameters (organoleptic criteria, water content, insoluble impurities, index of acid, iodine value, peroxide value and saponification value). (**Figure 1**)

2.2. Plant Material

Unrefined shea butter is the plant material on which the work is carried out: 14 samples (7 black samples from direct cooking and 7 yellow samples from churning) were taken in the study area. (**Figure 2**)

2.3. Field Survey

The field survey was conducted in Sarh and Koumra, the two localities selected as study areas. It was carried out by favouring areas with a large natural shea tree

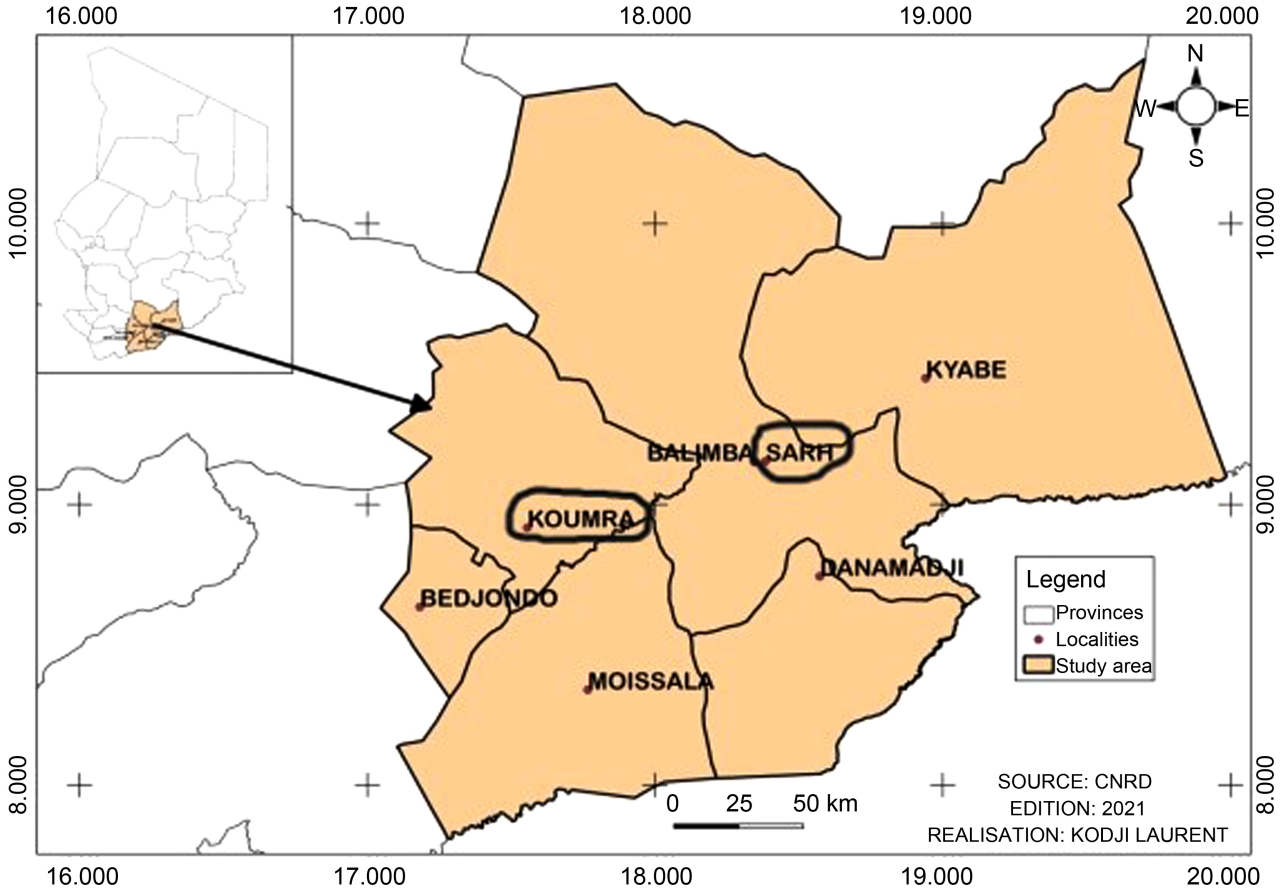

Figure 1. Area study.

Figure 2. Samples of yellow and black butter in the laboratory.

and a tradition of transforming almonds into butter [13].

The interview sheet contains structured questionnaires to collect information on the collection of nuts, the processing of butter and the use of shea by-products. This is thanks to closed questions (yes or no answers) and open questions (expression of points of view). Individuals from different cooperatives were interviewed individually in the two localities surveyed.

Regarding the collection of nuts and processing, the questions are more focused on the identification and varieties of shea in the locality. The processing stages and the use of butter are also discussed with questions about the procedures, the critical points and the areas concerned by the use of butter. In addition, information on raw materials, varieties of butter (black and yellow) and the maximum shelf life of butter was also provided. We essentially interviewed the women to better understand the practical details.

2.4. Sampling

The sample size is limited to 14 to assess the comparison between the two unrefined shea butter varieties within the two study locations. The samples were taken in the production units belonging to the persons surveyed, in order to have as much information as possible on the progress of the activities and especially the varieties of butter produced there.

The representative sampling technique was used to collect samples. Our selection criteria are based on the accuracy of the estimates, the nature of the population of interest, the known information about that population, and some operational constraints. Butter samples are taken just after the completion of the survey forms within the production units concerned

Samples were taken in clean plastic bottles under strict hygienic conditions and placed in coolers and stored in the laboratory at a temperature around −23˚C. In the best cases, the samples taken are those freshly produced on the same day. Where appropriate, those from the most recent production shall be taken in default. Each sample was identified by the collection order number, collection location, date, time and name of the sampler. (**Table 1** and **Figure 3**)

2.5. Physicochemical Analysis

The physicochemical parameters, which number seven (7), are used to evaluate the intrinsic quality of the samples of butter that have been collected.

- The organoleptic criteria reflect the appreciation of the colour, texture and smell of the collected samples. They are defined through sensory testing by replacing the "taste" character with the "smell" character. The panel of testers gathered essential criteria to classify the samples [13]. The colour of the butter was evaluated by placing small amount shea butter on a sheet of white paper. The texture was evaluated by crushing, between the thumb and the index finger, the equivalent of one gram of shea butter. Butter is called "melting", when it melts at the first friction, and "compact", otherwise. The

Table 1. Distribution of collection points and identification of samples.

PROVINCES	DEPRTEMENTS	LOCALITIES	SAMPLES CODES
Moyen-Chari	Barh-Koh	Sarh	SB.SAR1; SB.SAR2; SB.SAR2; SBSAR8; SB.SAR9; SB.SAR10; SB.SAR11;
Mandoul	Mandoul Oriental	Koumra	SB.KOUM4; SB.KOUM5; SB.KOUM6; SB.KOUM7; SB.KOUM12; SB.KOUM13; SB.KOUM14

SB.SAR1, SB.SAR2, SB.SAR3, SB.SAR8, SB.SAR9, SB.SAR10, and SB.SAR11: Samples Butter collected at Sarh and its surroundings. SB.KOUM4, SB.KOUM5, SB.KOUM6, SB.KOUM7, SB.KOUM12, SB.KOUM13, and SB.KOUM14: Samples Butter collected at Koumra and its surroundings.

Figure 3. Overview of shea butter samples.

smell has been defined as butter spread between the fingers: it is said "strong", when the butter exudes the characteristic scent of shea without the need for friction. It is described as "medium", if it is perceived only after friction between the fingers, and finally "weak", when it is barely perceptible, even after friction. Butter can also be described as "rancid" if its fragrance is ochre and pungent in the nostrils.

- The water and volatile matter content are assessed using the thermogravimetric method based on the drying/weighing of the samples (AFNOR NF T 60-305 conforming to International Standard ISO672 and ISO4318).
- Insoluble impurities are assessed by ISO663:2007 for animal and vegetable fats: Determination of insoluble impurities.

- ❖ The acid index is evaluated by the standardized ISO660:2020 method of animal and vegetable fats: Determination of acid index and acidity.
- ❖ The iodine index is determined using the method of ISO3961:2013 Animal and Vegetable Fats: Determination of Iodine Value.
- ❖ The peroxide index is determined using ISO3960:2017, Animal and Vegetable Fats: Determination of Peroxide Index.
- ❖ The saponification index is determined using the standardized ISO3657:2020 method for animal and vegetable fats: Determination of the saponification index.

This study is carried out after defining the specific questions, the measurement parameters and the data collection according to the measurement parameters followed by the treatment. Qualitative data (questionnaire results) were contextualized to generate results on variability and transformation processes. The statistical data (parameters analyzed in the laboratory) were analyzed using Excel 2010. This software allowed us to evaluate the statistical values of the mean, of the standard deviation especially of the significance of the results.

In addition to this, it made it possible to easily interpret the table of all the physico-chemical parameters in histogram to further explain the trends of each sample.

3. Results

3.1. Identification of Shea

Shea takes its etymology from the Bambara name "Shi yiri" meaning butter tree. The tree was generally known by its first scientific name is *Vitellaria paradoxa*. In Chad, precisely in the study area, shea is best known in local dialects by two names: "Roy" and "Kyon" in Sara.

The identification of the varieties of shea feet is done according to the shape of the fruits: round and small fruits, round and large fruits, fusiform fruits and fruit in pairs containing two nuts. The shea's feet are as well in the fields as in the forests: the character of fruit tree puts them a rank of heritage that comes under private property.

3.2. Varieties of Shea Butter

Two varieties of shea butter are covered by this study in the localities of Sarh and Koumra.

The variety of black butter is that obtained by the direct cooking of the dough to obtain the butter. It is a butter whose production is totally artisanal. It is widely used in the diet and also in the maintenance of the body and hair.

The variety of yellow butter is that obtained by churning the dough to obtain the butter. It is a kind of butter from an improved process with tools such as mills and churning machines and many other materials. It is also a new type of butter that the population gradually integrates into the diet, however, it is widely used in cosmetics: notably in the manufacture of body creams, shampoo and

soap. This variety is also the most popular on the international market.

3.3. Shea Nut Treatment

The first process of treatment is artisanal, consists in collecting the ripe fruit, followed by depulpating by hand. The nuts obtained dried in the sun then peeled to release the almonds. The almonds still undergo a second drying before being put in stock to undergo further processing resulting in unrefined butter.

The second process the improved version of the first: it also begins with the collection of ripe fruits which are depulped to extract the nuts, and then which are cooked, dried in the sun afterwards and peeled to release the almonds. These almonds are still dried before being stored. (**Figure 4**)

3.4. Shea Butter Processing

The artisanal process of direct cooking, begins with the crushing of the almonds, follows by roasting and after a slight display for cooling, they are crushed by mortar using a pestle or ground in the mill. The resulting paste is baked until the oil is separated from the water-paste mixture, then the skimming phase takes place to collect the oil in another container for the foam purification phase followed by the settling and obtaining of the butter.

The improved churning process also begins with crushing, followed by roast

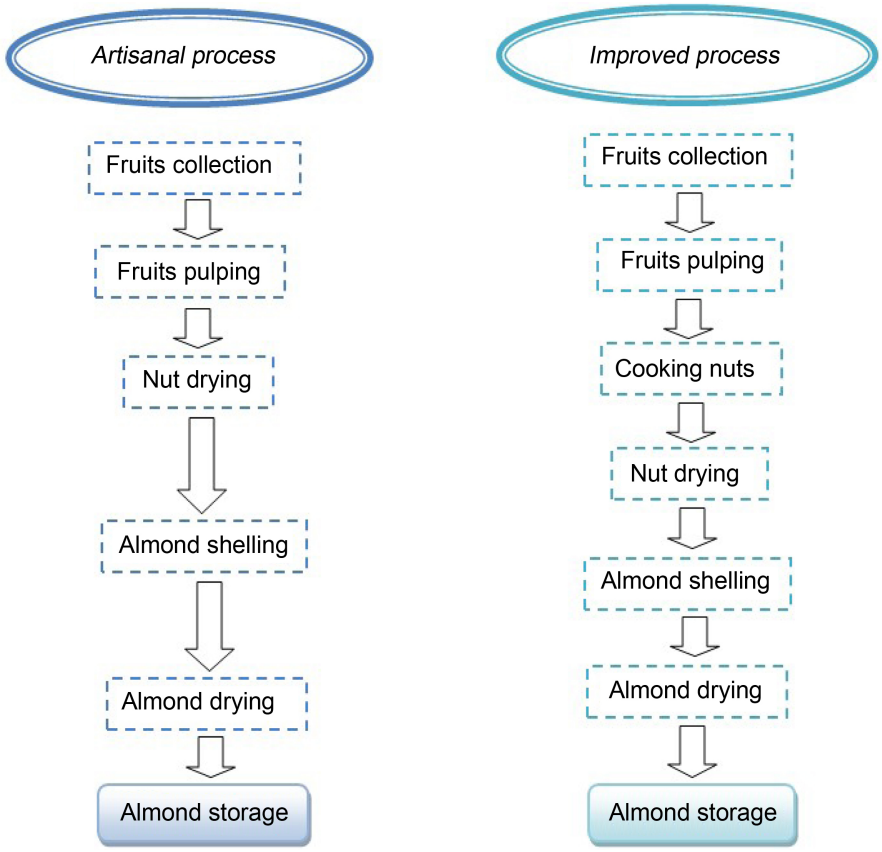

Figure 4. Shea almond processing.

ing and grinding to obtain the dough. The dough undergoes the final churning phase with a certain amount of water to facilitate the extraction of the butter. The collected butter is washed and then heated for purification before being subjected to decantation to obtain the butter.

Laboratory test results show a number of differences among samples. This is justified by the variability of the processes through the time factor (roasting, cooking and cooling) and the grinding size of the almonds in the production units [14]. (**Figure 5**)

3.5. Physicochemical Parameters

Organoleptic criteria provide information on inter- and intra-sample variability of unrefined shea butter. The first organoleptic evaluation criterion is colour: the black colour is due to the extreme roasting of the almonds coupled to the direct cooking of the dough and the yellow colour is due to the cooking of the nuts coupled to the churning of the dough, seven samples (50%) have the colour black and seven others (50%) have the colour yellow. The second criterion chosen for the organoleptic evaluation is the texture which has a clear correlation with the colour: the seven black samples (50%) have a melting texture and the

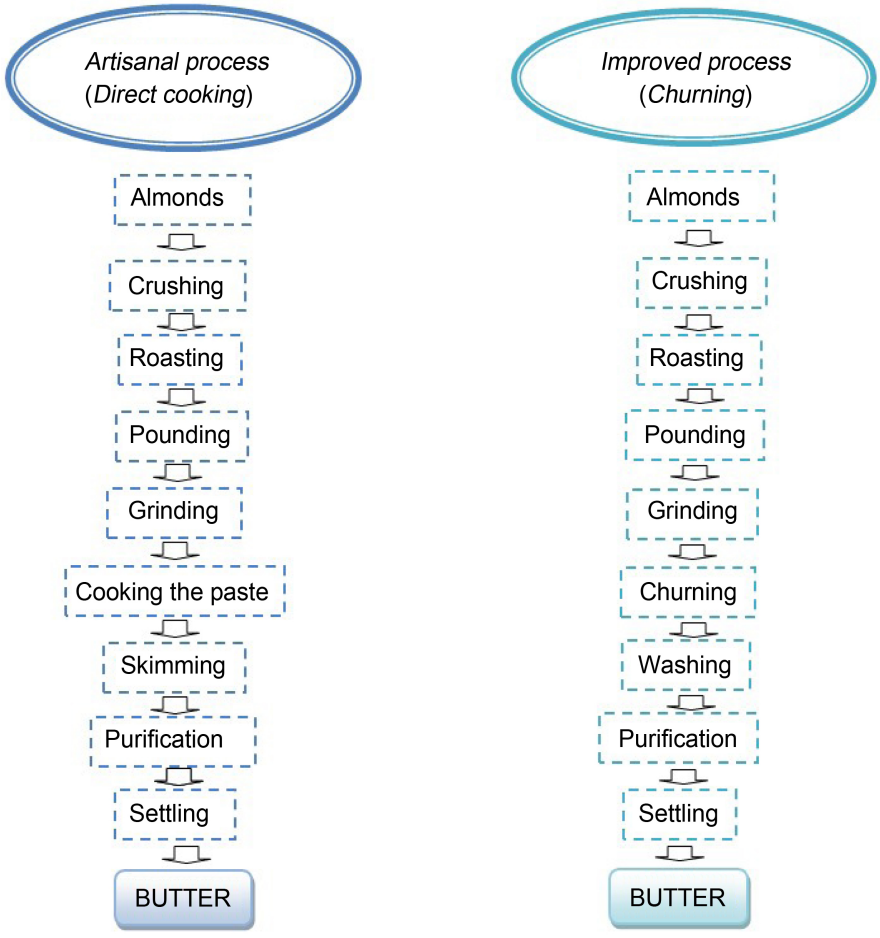

Figure 5. shea butter processing.

other seven yellow samples (50%) have a compact texture. The third criterion, which is not the least in the organoleptic evaluation, is the smell: it has a direct correlation with the storage conditions and the processes of transformation of the butter, four black samples (28.57%) have a strong characteristic smell, four yellow samples (28.57%) have a characteristic low odour, three samples of which two black and one yellow (21.43%) have an average characteristic odour and three samples of which two yellow and one black (21.43%) have a rancid odour. (Table 2)

The mean water content of the yellow butter samples is 0.14% ± 0.02% and the mean water content of the black butter samples is 0.25% ± 0.04% ($p = 0.002$), thus all butter samples are classified in Category II.

The mean insoluble impurities of the yellow butter samples are 3.49% m/m ± 0.27 and the mean water content of the black butter samples is 3.88% m/m ± 0.38. This is explained by the presence of particles during the transformation and especially the purification technique and finally by the defects during the preservation.

The acid index provides information on the treatment and preservation of triglycerides in unrefined shea butter. The mean acid index of the yellow butter samples is 5.11% ± 0.09% and the mean acid index of the black butter samples is 3.57% ± 0.13%. This disparity is due to the exposure of shea butter to the open air, which explains the high level of acidity.

The mean iodine value of the yellow butter samples is 21.12 g I2/100 g ± 0.67 and that of the black butter samples is 20.67 g I2/100 g ± 0.62. These low iodine

Table 2. Organoleptic criteria distribution of shea butter samples.

CODES	COULOURS	TEXTURES	ODOURS
SB.SAR1	Black	Fondant	Strong
SB.SAR2	Black	Fondant	Strong
SB.SAR3	Black	Fondant	Strong
SB.KOUM4	Black	Fondant	Medium
SB.KOUM5	Yellow	Compact	Low
SB.KOUM6	Yellow	Compact	Low
SB.KOUM7	Yellow	Compact	Low
SB.SAR8	Yellow	Compact	Rancid
SB.SAR9	Black	Fondant	Rancid
SB.SAR10	Black	Fondant	Strong
SB.SAR11	Black	Fondant	Medium
SB.KOUM12	Yellow	Compact	Rancid
SB.KOUM13	Yellow	Compact	Medium
SB.KOUM14	Yellow	Compact	Low

values are explained by the lack of control over storage conditions and especially the adequate amount of heat during cooking and roasting.The mean peroxide index of the yellow butter samples is 11.86 mEq/Kg ± 0.42: these high peroxide values are due to lack of preservation and disparity in treatment processes [15]. That of the black butter samples is 3.65 mEq/Kg ± 0.28 ($p = 0.008$): it is below the limit value of 10 for category I (from 1.69 to 6.49). Comparison of these results with those of other studies shows agreement, especially for butter from churning, but there is a divergence in direct-cooking butter [16].

The mean saponification index of the yellow butter samples is 182.64 mg KOH/g ± 0.80 and the mean saponification index of the black butter samples is 193.45 mg KOH/g ± 0.70 ($p = 0.037$). As regards the saponification index, the results of the 14 samples of unrefined shea butter submitted to our study: ten have values that are within the limit set by the Codex Alimentarius and four have values that exceed this limit. This is part of the scope of some work in the sub-region [16]. (**Figure 6** and **Tables 3-5**)

4. Discussion

The shea tree, although widely exploited for its nuts, is still considered a natural species. It is rarely planted, because of slow growth. Despite this, among this population, there are cases of excessive cutting for the manufacture of coal: this threatens the species of a possible extinction in the long term.

Regarding shea butter: the black variety is at first sight the one whose processors inherited the processes of the ancestors. It is very popular in food: except that the quality assessment shows gaps to be corrected before sustaining its popularization and benefiting from export on the international market. The yellow variety is the one whose technique is popularized within the processing units. This variety keeps all its components: it is in high demand on the local and international market, even if its use is limited because of the high price.

The treatment of nuts is very sensitive for a quality production of butter: notably through the cleaning, sorting and reconditioning of raw materials. Processing follows to produce varieties of butter according to needs: Different steps are required

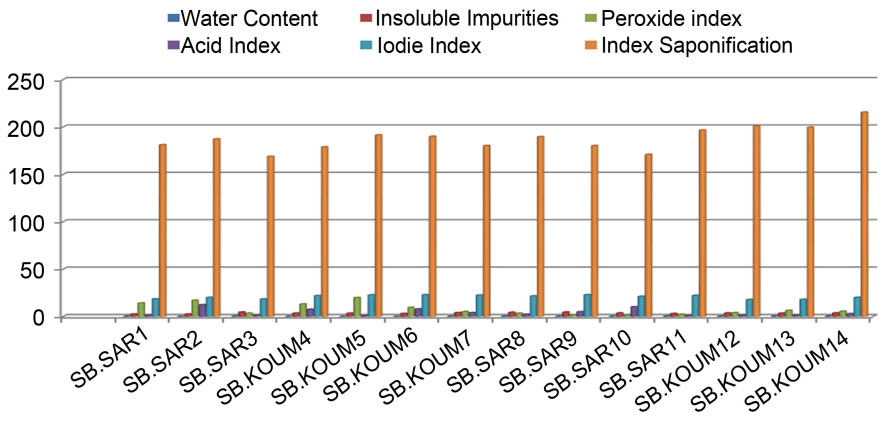

Figure 6. Histogram of physicochemical parameter of shea butter.

Table 3. Physicochemical parameters of shea butter.

Codes	Water Content (%)	Insoluble Impurities (% m/m)	Acid Index (%)	Iodine index (g I_2/100 g)	Peroxide index (mEq/Kg)	Saponification Index (mg KOH/g)
SB.SAR1	0.17 ± 0.01*	2.64 ± 0.32	1.40 ± 0.05	18.61 ± 0.77	14.19 ± 0.78*	181.25 ± 0.83*
SB.SAR2	0.12 ± 0.01*	2.62 ± 0.06	12.42 ± 0.09	20.21 ± 0.38	17.26 ± 0.58*	187.38 ± 0.81*
SB.SAR3	0.23 ± 0.06*	4.73 ± 0.06	1.41 ± 0.06	18.49 ± 0.96	03.60 ± 0.40*	168.92 ± 0.70*
SB.KOUM4	0.11 ± 0.03*	3.60 ± 0.90	7.62 ± 0.23	22.08 ± 0.76	13.29 ± 0.08*	178.96 ± 0.81*
SB.KOUM5	0.09 ± 0.00*	3.53 ± 0.13	0.86 ± 0.06	22.75 ± 0.38	19.90 ± 0.50*	191.53 ± 0.80*
SB.KOUM6	0.08 ± 0.01*	3.21 ± 0.06	8.01 ± 0.04	23.01 ± 0.68	09.60 ± 0.20*	190.13 ± 0.81*
SB.KOUM7	0.18 ± 0.01*	4.12 ± 0.39	4.07 ± 0.06	22.67 ± 0.77	05.19 ± 0.40*	180.30 ± 0.80*
SB.SAR8	0.25 ± 0.00*	4.42 ± 0.24	2.42 ± 0.17	21.74 ± 0.38	03.59 ± 0.19*	189.70 ± 0.80*
SB.SAR9	0.18 ± 0.01*	4.68 ± 0.49	5.12 ± 0.12	23.01 ± 0.29	01.69 ± 0.29*	180.26 ± 0.79*
SB.SAR10	0.27 ± 0.10*	3.79 ± 0.10	10.27 ± 0.33	21.30 ± 0.90	01.70 ± 0.10*	171.01 ± 0.70*
SB.SAR11	0.23 ± 0.06*	3.18 ± 0.94	1.06 ± 0.05	22.33 ± 0.50	02.39 ± 0.39*	196.73 ± 0.81*
SB.KOUM12	0.22 ± 0.05*	3.74 ± 0.25	1.62 ± 0.05	17.94 ± 0.64	04.08 ± 0.10*	201.13 ± 0.73*
SB.KOUM13	0.34 ± 0.05*	3.59 ± 0.61	1.51 ± 0.16	18.13 ± 0.91	06.49 ± 0.29*	199.72 ± 0.69*
SB.KOUM14	0.31 ± 0.08*	3.74 ± 0.02	2.99 ± 0.06	20.25 ± 0.74	05.60 ± 0.60*	215.59 ± 0.40*

Notice: *Significant values below the p-value of the student test (<0.05).

Table 4. Limit values for quality criteria (CXS 325R-2017).

Criteria	Unrefined Shea Butter			
	Category I		Category II	
	Maximum limit		Minimum limit	Maximum limit
Water content	-	0.05	0.06	0.2
Insolubles impureties	-	0.09	0.1	0.2
Free fatty acids	-	1	1.1	3
Peroxid indice	-	10	11	15

Table 5. Limit values of physicochemical parameters (CXS 325R-2017).

Parameters	Minimum limit	Maximum limit
Relative density (20˚C)	0.91	0.98
Density (40˚C)	0.89	0.93
Refraction index (44˚C)	1.4620	1.4650
Melting point (˚C)	35	40
Iodine index (g I_2/Kg)	30	75
Saponification index (mg KOH/g de graisse)	160	195
Insaponifiables (% m/m)	1	19

to obtain butter that meets the requirements of the standard.

Seven physico-chemical parameters were taken into account to assess the quality of the two butter varieties under study. Organoleptic criteria values confirm previous studies with a slight difference in proportion [15]. The high rate of rancid samples from yellow versus black butter is due to the instability of the components of yellow butter that are sensitive to temperature rise during storage [16]. The maximum margin of moisture content is difficult to obtain for unrefined butter [17]. This shows that all butter samples are classified in Category II. Black butter have a greater quantity of water than yellow butter: this is explained by the lack of respect for cooking time, which corroborates with previous work [18]. The insoluble impurity content of the unrefined shea butter samples gives values well above 0.09% for category I and 0.2% for category II. This is explained by the presence of particles during the transformation and especially the purification technique and finally by the preservation defects. However, these values are lower than previous work in West Africa [15]. The acid index provides information on the treatment and preservation of triglycerides in unrefined shea butter. This disparity is due to the exposure of shea butter to the open air, which explains the high level of acidity resulting from hydrolysis and oxidation, as confirmed in previous studies [19]. This diversity of results is explained by the difference in roasting, cooking, cooling times and grind size. The iodine index results for the unrefined shea butter samples analyzed are lower than the Codex Alimentarius. These results differ from previous studies conducted elsewhere in almost the same field of study about 15 years ago [19]. These low iodine values are explained by the lack of control over storage conditions and especially the adequate amount of heat during cooking and roasting, because a good iodine index requires reactions catalyzed by light, heat and metal ions [20].

In view of previous studies on processing processes, it appears that the optimum conditions for extraction efficiency are, among other things: a crushing size of 3.5 mm, a cooking time of 180 minutes and a cooling time of 54 minutes [14]. Little work has been done to address the effect of free air exposure of shea butter on quality. This could explain the relatively high values of the acid indices and the low results of the iodine index.

5. Conclusions

Unrefined butter is a kind of flagship product processed from almonds collected under shea's feet. It is one of the main income-generating activities carried out by women living in the study area. Despite the natural availability of the resource, its exploitation is impacted by difficulties that prevent its popularization. However, the technical support of the Swiss cooperation through the SODEFIKA project has enabled the development of processing units for unrefined shea butter by popularizing a new type of churning process.

This study focuses on the control approach of the finished product with the objective of evaluating the physico-chemical quality of unrefined shea butter for

inter-variety comparison. In addition, this also made it possible to compare these results with the limit values of the Codex Alimentarius normative requirements and above all to further enhance the shea sector.

Seven (7) physico-chemical characteristics (organoleptic criteria, water content, insoluble impurities, acid index, iodine index, peroxide index and saponification index) were taken into account to assess the quality of fourteen samples of non-refined butter, including seven from direct cooking (black butter) and seven from churning (yellow butter).

This study assessed the quality of the unrefined shea butter produced in the localities of Sarh and Koumra. This will contribute to its popularization among the Chadian population but also especially take into account the requirements of the Codex Alimentarius on the basis of which, the market of non-saturated shea butter is regulated internationally.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Dah-Dovonon, J.Z. (2002) Espèces ligneuses du Bénin: *Vitellaria paradoxa* subsp. Parkii (G. Don) Hepper (Sapotacées). In: Matig, E.O., Gaoué, O.G. and Dossou, B., Eds., *Espèces Ligneuses Alimentaires. Compte rendu de la première réunion du Réseau des espèces ligneuses alimentaires du* 11-13 *décembre* 2000 *à Ouagadougou* (*Burkina Faso*), IPGRI Regional Office for sub-Saharan Africa, Nairobi, 9-10.

[2] Matig, E.O., Gaoué, O.G. and Dossou, B (2000) Espèce ligneuse du Mali: *Vitellaria paradoxa* (Sapotaceae). In: Matig, E.O., Gaoué, O.G. and Dossou, B., Eds., *Espèces Ligneuses Alimentaires. Compte rendu de la première réunion du Réseau des espèces ligneuses alimentaires du* 11-13 *décembre* 2000 *à Ouagadougou* (*Burkina Faso*). IPGRI Regional Office for subsaharan Africa, Nairobi, 97-100.

[3] Goreja, W.G. (2004) Shea Butter: The Nourishing Properties of Africa's Best-Kept Natural Beauty. Amazing Herbs Press, New York.

[4] Bonkoungou, E.G. (2002) Actes de l'atelier international organisé par l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture, Le Fonds Commun pour les Produits de Base et le Centre de Suivi Ecologique, portant sur: Le traitement, La valorisation et le commerce du karité en Afrique: L'arbre à karité (*Vitellaria paradoxa*) et les parcs à karité en Afrique. Dakar, Sénégal. https://www.fao.org/3/y5952f/y5952f00.pdf

[5] Madjastan, T.R. (2000) Data Collection on the Shea Sector in Chad. Consultation report, Inades-Formation Chad, 15.

[6] Djekota, C., Mouga, M., Djimramadji, A., Djelassem, B., Mbayngone, E., Maïga, D.R., Rimgoto, K. and Noubady, D. (2014) Shea Potential in Chad (*Vitellaria paradoxa* C.F. Gaertn. Subsp. Paradoxa). *Journal of Animal & Plant Sciences*, **23**, 3646-3656. http://www.m.elewa.org/JAPS

[7] Schreckenberg, K. (2004) The Contribution of Shea Butter (*Vitellaria paradoxa* C.F. Gaertner) to Local Livelihoods in Benin. In: Sunderland, T. and Ndoye, O., Eds., *Forest products, Livelihoods and Conservation*.

[8] Nitidae (2014) Karité au Tchad— *Vitellaria paradoxa*. https://www.nitidae.org/files/33ab01da/karite_15.09.pdf

[9] Mbaïguinam, M., Mbayhoudel, K. and Djekota, C. (2007) Physico-Chemical Characteristics of Fruits, Pulp and Nuts and Shea Butter in Mandoul, Southern Chad. *Asian Journal of biochemistry*, **2**, 101-110. https://doi.org/10.3923/ajb.2007.101.110

[10] Kapseu, C. (2009) Conférence Chevreul: Production, analyse et applications des huiles végétales en Afrique. *OCL*, **16**, 215-229. https://doi.org/10.1051/ocl.2009.0280

[11] Womeni, H.M., Ndjouenkeu, R., Kapseu, C., Tchouanguep, M.F., M. Parmentier, M. and Fanni, J. (2006) Effet de la cuisson et du séchage des noix de karité (Butyrospermum parkii (G. Don) Kotschy) sur la qualité du beurre. *TROPICULTURA*, **24**, 175-182.

[12] Lovett, P.N.C. (2004) The Shea Butter Value Chain: Production, Transformation and Marketing in West Africa. Technical Report, 52. https://www.researchgate.net/publication/272022672_The_Shea_Butter_Value_Chain_Production_Transformation_Marketing_in_West_Africa/link/54d8ef6b0cf25013d04092c4/download

[13] Dandjouma, A.K.A., Adjia, H.Z., Kameni, A. and Tchiégang, C. (2009) Procédés traditionnels de production et circuit de commercialisation du beurre de karité au Nord-Cameroun. *Tropicultura*, **27**, 3-7.

[14] Mohagir, A.M., Kamga, R. and Kapseu, C. (2011) Influence of Operating Conditions on the Extraction of Shea (*Vitellaria paradoxa* Gaertner F.) Butter. In: Ardil, C., Ed., Proceedings of International Conference on Applied Chemistry, WASET (World Academy of Science, Engineering and Technology), Paris, 1641-1654.

[15] Megnanou, R.M. (2007) Contribution à l'étude du beurre de karité produit en Côte d'Ivoire et optimisation qualitative de sa fabrication artisanale. Ph.D. Thesis, Université d'Abidjan-Cocody, Abidjan.

[16] Kapseu, C., Womeni, H.M., Ndjouenkeu, R., Tchouanguep, M.F. and Parmentier, M. (2005) Influence des méthodes de traitement des amandes sur la qualité du beurre de karité. *Proc. Biol. et Alim*, **3**, 1-18.

[17] Bernatchez C. (2007) Amélioration de la qualité du produit et des procédés de production du beurre de karité biologique et de la logistique des opérations en Afrique: cas du Burkina Faso. Master's Thesis, Université du Québec à Trois-Rivières, Trois-Rivières.

[18] Nkouam, G.B., Kapseu, C., Barth, D., Dirand, M. and Tchatchueng, J.B. (2007) Oil Extraction from Shea Nut Kernel (*Vitellaria Paradoxa* Gaertn) and Canarium Pulp (*Canarium schweinfurthii* Engl.) Using Supercritical CO_2. *5th Euro Fed Lipid Congress on Oils, Fats and Lipids: From Science to Applications*, Gothenburg, September 2007, 16-19.

[19] Dieffenbacher A., Buxtorf, P., Derungs, R., Friedli, R. and Zürcher, K. (2000) Graisses comestibles, huiles comestibles et graisses émulsionnées. In: Neukom and Zimmermann, Eds., *Manuel suisse des denrées alimentaires*, Société des chimistes ana-listes suisses, Berne, 1-249.

[20] Martine, F. (2008) Beurre de Karité: Développement d'innovations techniques, économiques, organisationnelles, dans la filière karité. Edition GRET, Paris, 12.

Annexes

SHEA GENERALITIES
FIELD SURVEY SHEET
Date: _____/_____/2022 N°_____

Civil Resgistration

1) Name & First name: ……..……..
2) Age:……
3) Sex:…….....
4) Ethnicity:……
5) Department:……
6) Locality:…….....…
7) Adresse/Call phone:……...……
8) Profession (principal activity):……..…

Shea Identification

9) What is the shea tree called in your language? …….
10) What do you call the shea fruit in your language? ..…….
11) What are the different forms of shea fruit? *Fusiform*/ *Rounded*/ *Paired*/
12) Where do you meet shea? *Dwellings*/ *Fields*/ *Bushes*
13) Are you owner of shea foot? …….
14) If yes, how many feet do you hold? …….
15) At what age does shea become productive?……
16) What product do you get from shea? *Fruits*/ *Nuts*/ *Butterrs*/ *Firewood*/ *Sculptures*/
17) How often in the year the shea gives flowers and fruits? …….
18) What is the lifespan of shea? …….

Processing of Shea Butter

19) What variety of butter do you produce? *Noire* (*Handcrafted*)/ *Jaune* (*Improved*)
20) Why do you crack shea nuts? …….
21) Why are shea nuts cooked? ……..
22) Why are shea nuts cooked? ……..
23) How long does it take to cook the dough? ……..
24) How is the purification of shea butter done? ……....

Use of Shea Butter

25) What is the look of shea butter? *Fondant*/ *Compact*/
26) What kind of smell of shea butter you know?
Strong/ *Medium*/ *Low*/ *Rancid*/
27) What is the colour of the shea butter you know? *Black*/ *Yellow*/
28) What is black shea butter used for? *Cooking*/ *Anoint to the body*/ *Massage*

the body| Apply to hair| Make the soaps| Do customary rituals|

29) What is yellow shea butter used for? *Cooking| Anoint to the body| Massage the body| Apply to hair| Make the soaps| Do customary rituals|*

30) What is the shelf life of shea butter? *One year| Two years| Three years*

SHEA BUTTER SENSORY TEST

ORGANOLEPTIC CRITERIA

Date: _____/_____/2022 N°_____

Panelist's name and surname: Mr/Mrs ……..……..

Function: …….

This test takes into account three criteria for classifying the butter matrix subject to your assessment. Using your sense organs (*fingers, nose and eyes*), *please give the organoleptic characteristics based on your sensations.*

1) TEXTURE

Use your fingers (forefinger and thumb) and apply a first friction

a) If butter melted check box □

b) If butter no melted check box □

2) SMELL

Take a few grams with the index finger, butter as you approach the nose, what do you feel?

a) If the quantity sampled the characteristic smell of butter is Strong, check the box □

b) If the amount taken, after friction feels a little, it is Medium, check the box □

c) If the amount taken despite the friction barely senses, it is Low check the box □

d) If the quantity collected has an ochre smell and is pungent, it is Ranci, check the box □

3) COLOUR

Place a little butter on the blank sheet at your disposal. Let the butter melt and then tell us the colour of the stain left after the butter has been melted?

a) If it is a Black spot, check the box □

b) If it is a Yellow spot, check the box □

Thank you for your participation in the panel, for the advancement of research