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Chemical analysis of cocoa butters and risk assessment of production processes in five localities in Cameroon

Nelly Ndee Mougang[1]
Stephano Tambo Tene[2]
Ronice Zokou[3]
Hermann Arantes Foffe Kohole[4]
Alix Ntongme Mboukap[5]
Arnellie Archelle Foudjin Abaoabo[6]
Elsa Nguepi Solefack[7]
Hilaire Macaire Womeni[8]

[1,2,3,4,5,6,7,8]*Research Unit of Biochemistry of Medicinal Plants, Food Sciences and Nutrition, Department of Biochemistry, Faculty of Science, University of Dschang, Dschang, Cameroon.*
[1]*Email: nellyndee2001@gmail.com*
[2]*Email: stambotene@yahoo.fr*
[3]*Email: zokouronice@gmail.com*
[4]*Email: hermannarantes@gmail.com*
[5]*Email: mboukapalix@gmail.com*
[6]*Email: foudjinarchelle@gmail.com*
[7]*Email: elsanguepi12@gmail.com*
[8]*Email: womeni@yahoo.fr*

(Corresponding Author)

Abstract

The quality of the cocoa product depends on the post-harvest treatment processes and the extraction method used; therefore, it is important to control the conditions applied to obtain a product of recommended quality. This study aimed to identify the critical stages in the post-harvest treatment and extraction of butter and to propose solutions for controlling them to obtain a product of good chemical quality. A survey of post-harvest treatments and extraction methods for cocoa butter (*Theobroma cacao* L.) was carried out, after which the critical control points of the process were determined. Samples of butter were collected from producers in various localities, and chemical analyses of fat were conducted. Three production methods were identified: artisanal, semi-industrial, and industrial. The producers of this semi-finished product were mainly women aged between 40 and 50 with no education. The cocoa butters marketed were generally of poor chemical quality. Oils from Yaoundé producers were overall the most chemically acceptable, while those from Douala were less so. These data suggest that producers should take these factors into account when post-harvesting cocoa beans and extracting the fat to guarantee a more stable, high-quality product.

Keywords: Artisanal extraction, Chemical quality, Cocoa beans, Cocoa butter, Post-harvest treatments, *Theobroma cacao* L.

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Contents

Contribution of this paper to the literature
This work has made it possible to identify the post-harvest treatments that can influence the quality of the final product from cocoa beans and to propose solutions using the HACCP tool to limit losses in order to improve the cost of the products.

1. Introduction

The cocoa sector directly or indirectly supports thousands of families in Cameroon. Cocoa is the leading export commodity (58.70%), according to an [1]. Fermented and dried cocoa provide the country's second-largest source of foreign currency (12% of exports) behind hydrocarbons (39.60%) and is grown in seven regions, of which the Centre and South-West are the two main production areas, with 50.36% and 31.54%, respectively [1]. The selection of cocoa quality and its properties (flavor, nutritional composition, and suitability for processing) are linked to numerous parameters such as variety, growing conditions, climate, soil, and agronomic practices [2]. Cocoa is exported in raw form (unprocessed form) but also undergoes artisanal processing locally. It is the raw material used to make certain food products (chocolate, cocoa paste, cocoa powder, cocoa butter, cocoa fondue, cakes, and cookies), as well as many other pharmaceutical and cosmetic products such as lotions, lip balms, and creams [3, 4]. The use of cocoa involves a number of stages, including bean selection, drying, and fermentation. These stages can have an impact on the final quality of the cocoa, particularly its flavor and the quality of by-products such as cocoa butter [5].

Cocoa butter, also known as 'theobroma oil', is an edible vegetable fat obtained from cocoa beans and has a sweet chocolate flavor. It is highly prized for its melting characteristics, remaining solid at room temperature or below but melting just below body temperature [6]. Cocoa butter contains antioxidants that prevent rancidity and give it a shelf life of two to five years. Processing cocoa butter to remove flavor and color also removes antioxidants, increasing its susceptibility to rancidity [6].

Cocoa butter is obtained using a variety of processes, from traditional to modern. Its quality can therefore be influenced by the quality of the cocoa beans used and the extraction method chosen [7]. Modern methods include hydraulic presses, centrifugation, and solvent-assisted extraction [7-9]. The so-called artisanal methods include cold pressing, which has a low yield, the use of jute sacks, and thermal degreasing, which is very widespread [10]. Thermal extraction, although leading to the formation and release of flavors, also leads to lipid oxidation, which can significantly affect the final quality of the butter [11]. Lipid oxidation products responsible for the formation of rancid odors are involved in the genesis of cardiovascular disease and are carcinogenic [12].

In developing countries, particularly in Cameroon, small-scale production and marketing of cocoa butter remain booming businesses. Small-scale producers do not master the quality criteria for the cocoa beans they use, and there is significant variability in post-harvest treatments, as well as variations in the implementation of traditional cocoa butter extraction processes. These factors lead to inconsistencies in the quality of marketed cocoa butter, thereby reducing its marketability and competitiveness compared to products from industrial production.

In light of the above, the aim of this work is to determine the critical stages in the post-harvest treatment and extraction processes for cocoa butter that influence the chemical quality of cocoa butter marketed in several localities in Cameroon.

2. Materials and Methods

2.1. Materials

2.1.1. Survey Data Collection Material

The collection of information on the various stages of cocoa butter processing and production, with a view to identifying the risky or critical stages, was carried out using a survey form. The target population consisted of butter producers, and the aim was to highlight the post-harvest processing methods, the extraction of cocoa butter, and the characteristics of the final butter.

2.1.2. Plant Material

The cocoa pods used in this study consisted of cocoa butter collected from 25 producers in Douala (Littoral-Cameroon), Limbé (South-West Cameroon), Yaoundé (Central Cameroon), Bertoua (East Cameroon), and Kékem (West Cameroon), then transported to the laboratory for various chemical analyses. Figure 1 shows a map of the cocoa butter samples collected from the different collection areas.

Figure 1. Cocoa butter collected.

2.2. Methods

2.2.1. Study Area

The study was conducted in the five leading cocoa butter-producing localities across five regions of Cameroon. The sample collection locations are detailed in Table 1.

Table 1. Geographical localisation of studies area.

Locality	Region
Douala	Littoral
Limbé	South-West
Yaoundé	Centre
Bertoua	East
Kékem	West

2.2.2. Size of the Study Population

This work was carried out among cocoa butter producers in the aforementioned localities. To do this, 25 producers were surveyed in the five localities, and the distribution by region was done randomly and depended on the density of activity in the area.

2.2.3. Survey of Post-Harvest Cocoa Treatment and Butter Extraction Processes

A survey of the production process was carried out, during which information on post-harvest cocoa processing methods and the characteristics of the butter obtained were collected using a survey form. Producers were met in the towns of Douala, Yaoundé, Kékem, Limbé, and Bertoua. They answered the questions on the form, and their answers were recorded on it. Data collection was prospective and semi-administered.

2.2.4. Sampling Method, Frequency and Size

A random sampling plan was adopted in this study. The different cocoa butter samples were collected under aseptic conditions using single-use sterile gloves. Tins of butter were taken at random, and those sampled were tightly packed to prevent oxidation by atmospheric oxygen. The cocoa nut butters were collected directly at the end of each extraction process and transported on ice to the laboratory. The proximate mass per box of butter was 250 g. Table 2 shows the number of samples collected according to locality.

Table 2. Number of samples collected by locality.

Locality	Number of samples collected
Douala	10.00
Limbé	1.00
Yaoundé	6.00
Bertoua	5.00
Kékem	3.00

2.2.5. Transport of Samples to the Laboratory

Once they had been sampled, all the samples, previously packed in the containers used by the producers, were inserted into sterile Stomacher brand bags (Seward Limited, England) and carefully labeled with an individual identification number. The samples were transferred to the laboratory after being placed in a cool box containing Labsolute reusable ice packs (ref: 827.100001.49), which kept the temperature down to around 4°C to slow down the oxidation of the lipids within 24 hours.

2.2.6. Determination of the Chemical Quality of Marketed Butters

The quality of marketed butters was determined by means of lipid alteration quality indices.

2.2.6.1. Acid Index

The acid value was determined using the titimetric standard method of AFNOR [13]. Specifically, 5 g of cocoa butter was weighed and introduced into a 250 mL conical flask, to which 100 mL of 95% ethanol and two drops of 1% phenolphthalein were added. The mixture was vortexed (Perkin Elmer, USA) and then titrated with a 0.1 N potassium hydroxide ethanolic solution until the indicator turned pink (the pink color persisted). The results were expressed as a percentage of oleic acid according to Equation 1:

$$Acid\ value\ (\%\ of\ oleic\ acid) = \frac{\text{Acid value } (\frac{\text{mg}}{\text{g}}\text{KOHof fatty acid}) * 282 * 100}{56.1 * 1000} \quad (1)$$

2.2.6.2. Determination of the Peroxide Value

The peroxide value was determined using the standard spectrophotometric method of IDF [14]. To do this, 50 mg of the butter sample was mixed with 9.8 mL of a chloroform-methanol mixture (7:3), and the mixture was vortexed (Perkin Elmer, USA) for 10 seconds. Next, 50 μL of a 30% aqueous ammonium thiocyanate solution was added, and the mixture was stirred again before the addition of 50 μL of an aqueous iron II chloride solution, followed by further stirring. After 5 minutes of incubation at 25°C, the absorbance of the reaction mixture was read at 500 nm against a blank containing all the reagents except the oil (Perkin Elmer brand spectrophotometer, Lambda 35, USA). The procedure took place in a dimly lit chamber and was completed within a maximum of 8 minutes per sample run. The peroxide value, expressed in ppm, was calculated according to Equation 2:

$$Peroxide\ value\ (ppm) = \frac{(As - Ab) * m}{55.84 * w} \quad (2)$$

As = Absorbance of the sample; Ab = Absorbance of the blank; m = Slope, obtained from the calibration curve (38.46); w = Mass of the sample in g; 55.84 = Molar mass of iron II.

2.2.6.3. Determination of the Thiobarbituric Acid Index (TBA)

The thiobarbituric acid index, expressed as Malondialdehyde equivalent or MDA (mg/kg of sample), was assessed by reading the absorbance of sr-TBA on a visible spectrophotometer, following the methodology of Draper and Hadley [15]. In a 10 mL test tube, we weighed out 1 g of each butter sample and then added 1 mL of 0.1% trichloroacetic acid. The mixture was vigorously vortexed (Perkin Elmer, USA), and 1 mL of 0.375% thiobarbituric acid, 1 mL of 15% trichloroacetic acid, and 1 mL of 0.25 M hydrochloric acid were added. The mixture was again stirred and incubated in a water bath (Heraeus) at 95°C for 30 minutes. At the end of this step, the tubes were cooled in an ice bath, and the absorbance was read at 532 nm against a blank on the aqueous phase. The thiobarbituric acid index was calculated as follows (Equation 3):

$$Indice\ TBA\ (ppm) = \frac{Abs*VTCA*0.02*M}{1.56*m} \qquad (3)$$

Abs = Absorbance of sample; VTCA = Volume of trichloroacetic acid solutions; M = Molar mass of malondialdehyde (72 g/mol); m = mass of sample.

2.2.6.4. Determination of the Iodine Value (II)

The iodine value was determined according to the titimetric standard protocol of AFNOR [13]. To this end, 0.2 g of fat was introduced into a flask, followed by 15 mL of carbon tetrachloride (CCl_4) and 25 mL of Wijs' reagent. The flask was capped and gently shaken, then placed in a dark place for 60 minutes before the addition of 20 mL of 10% aqueous potassium iodide solution and 150 mL of distilled water. Using the starch solution (5 drops of 1% starch paste) as a color indicator, the solution was titrated with a 0.1 N sodium thiosulfate solution. Titration continued until, after vigorous shaking, the blue color no longer appeared. The iodine index, expressed in g I_2/100 g fat, was determined according to Equation 4.

$$Iodine\ index\ (g\ I2/100g) = \frac{(Vo-V1)*12.69*T}{m} \qquad (4)$$

T = exact titre of the sodium thiosulphate solution; m = mass in grams of the test sample; Vo = volume of the thiosulphate solution for the blank (ml); V1 = volume of the thiosulphate solution for the sample.

2.2.7. Determination of Critical Control Points for the Post-Harvest Cocoa Treatment Process and the Artisanal Cocoa Butter Extraction Method

The HACCP: Hazard Analysis Critical Control Point recommended by the FAO: Food and Agricultural Organization and adopted by the Codex Alimentarius [16] was used to identify the Critical Control Points (CCPs) for the cocoa post-harvest treatment process and the artisanal cocoa butter extraction method. This method is based on the 7 principles of HACCP and consists of 12 steps, 8 of which were carried out.

- Set up the HACCP team.
- Describe the product.
- Determine the intended use of the product.
- Draw up a flow chart.
- Confirm the flow chart on site.
- List all the potential hazards associated with each stage, carry out a risk analysis and define the measures needed to control the hazards identified.
- Determine the critical control points (CCPs) using the decision tree.
- Set critical thresholds for each Critical Control Point (CCP).

2.3. Statistical Analysis

The survey results were analyzed using SPSS version 18.0 software. The tables were generated using Excel 2013. Excel 2013 was used to express the results of the chemical analysis of the various butters in the form of means and standard deviations, and the Analysis of Variance (ANOVA) was carried out using Minitab version 18.1 (IBM STATISTICS). Means were compared using the Fisher test, and the confidence level was set at 5%.

3. Results

3.1. Survey of Cocoa Post-Harvest Treatment and Butter Extraction Processes

3.1.1. Socio-Demographic Characteristics of Cocoa Butter Producers

The socio-demographic characteristics of cocoa butter producers are presented in Table 3. This table indicates that the majority of producers are women (59.30%), with most being aged between 40 and 50 (37.00%). The predominant religion is animism (63.00%). Additionally, the majority of producers reside in Douala (37.00%), followed by Yaoundé (25.90%), and generally have primary education (37.00%).

3.1.2. Post-Harvest Treatment of Cocoa and Extraction of Cocoa Butter

Information on post-harvest treatments and cocoa butter extraction methods used by the surveyed producers is provided in Table 4. It shows that several producers (44.44%) did not remove the pods and, therefore, did not carry out post-harvest treatments, but instead purchased cocoa beans that were already dry. The majority of producers (55.56%) surveyed conducted post-harvest treatments. Furthermore, the time intervals between harvesting and shelling, as well as between shelling and fermentation, were one hour for most of the surveyed producers. Additionally, the majority of producers (88%) fermented their cocoa for 7 to 9 days, and almost all the surveyed producers (93.33%) used bag fermentation.

Table 3. Socio-demographic characteristics of cocoa butter producers.

Characteristics	Modalities	Frequencies	Producers (%)
Gender	Female	16	59.3
	Male	11	40.7
Age (Years)	[20-30]	3	11.1
	[30-40]	7	25.9
	[40-50]	10	37
	[50-60]	3	11.1
	>60	4	14.8
Religion	Animist	17	63
	Christian	10	37
City of residence	Bertoua	6	22.2
	Douala	10	37
	Kékem	3	11.1
	Limbé	1	3.7
	Yaoundé	7	25.9
Education level	No education	3	11.10
	Basic school education	5	18.5
	Primary education	10	37
	High school education	9	33.3
	University level	0.00	0.00

With regard to the type, time, and place of drying, it emerged that solar drying was the only method used by the producers surveyed. Moreover, the majority (66.67%) dried for a period of between 5 and 8 days. Producers dried cocoa beans on black tarpaulins (53.33%) and cemented areas (46.67%). Before being processed, dried beans could be kept for 5 days by the majority of producers surveyed (59.99%).

With regard to the cocoa butter extraction method, it emerged that it was primarily produced using the artisanal method (66.70%), followed by the semi-industrial method (29.60%) and finally the industrial method (3.70%). Extraction generally took between 4 and 7 hours (55.60%), with a yield of 0.25 liters of cocoa butter per kilogram of beans. The majority of producers kept the butter obtained for more than 24 months (29.60%).

Table 4. Post-harvest treatments and cocoa butter extraction methods.

Production stages	Characteristics	Modalities	Frequencies	Percentages (%)
Debossing	Debossing	Yes	15.00	55.56
		No	12.00	44.44
	Time between harvest and shucking (Hour)	<1h	1.00	6.67
		1h	11.00	73.33
		>1h	3.00	20.00
Fermentation	Time between shelling and fermentation (Hour)	1h	15.00	100.00
	Fermentation time (Hour)	[4-6]	3.00	20.00
		[7-9]	12.00	80.00
	Fermentation containers	Bag	14.00	93.33
		Heap	1.00	6.67
Drying	Heat source	Sun	15.00	100.00
	Drying surface	Black tarpaulin	8.00	53.33
		Cemented area	7.00	46.67
	Drying time (Days)	[0-4]	3.00	20.00
		[5-8]	10.00	66.67
		[9-12]	2.00	13.33
	Bean storage time (days)	2	1.00	6.67
		3	1.00	6.67
		4	4.00	26.67
		5	9.00	59.99
Extraction	Methods	Artisanal	18.00	66.70
		Semi-industrial	8.00	29.60
		Industrial	1.00	3.70
	Extraction time (Hours)	[0-3]	11.00	40.70
		[4-7]	15.00	55.60
		[7-10]	1.00	3.70
	Extraction yield (L/kg of beans)	0,25	27.00	100.00
	Shelf life (Months)	[0-6]	5.00	18.00
		[12-18]	4.00	14.80
		[18-24]	3.00	11.10
		[6-12]	7.00	25.90
		More than 24	8.00	29.60

In order to identify the best method for extracting cocoa fats, we cross-referenced the duration and frequency of use of each method by the different producers. This analysis, presented in Table 5, shows that the traditional method takes longer (4 to 7 hours) than the other methods used by the producers surveyed (semi-industrial and industrial methods).

Table 5. Production time according to cocoa butter extraction method.

		Production time (Hours)			Total
		[0-3]	[4-7]	[7-10]	
Method used	Artisanal	7.40% (2)	55.60% (15)	3.70% (1)	66.70% (18)
	Industrial	3.70% (1)	0.00% (0)	0.00% (0)	3.70% (1)
	Semi-industrial	29.60% (8)	0.00% (0)	0.00% (0)	29.60% (8)

Note: Numbers in brackets represent frequencies.

3.1.3. Cocoa Butter Extraction Diagram

Figure 2 shows the cocoa butter production diagrams for the industrial, artisanal, and semi-industrial methods. In the industrial method, the beans were cleaned to remove stones, pieces of wood, crabs, broken pieces, and ferromagnetic materials, then dried at 110°C for 3 minutes. This was followed by hulling, roasting at 120°C for 50 to 60 minutes before cooling to 65°C, and then grinding, pressing, filtering, and crystallizing the butter at 20°C. The semi-industrial method began with sorting; then the beans were roasted in an aluminum pot, crushed, winnowed, and pressed at temperatures of around 40°C. In the artisanal method, unlike the semi-industrial method, the beans were not pressed but crushed and then brought to a boil in an aluminum pot with 1.5 to 2 liters of water for 1 kg of paste. The butter was then collected on the surface of the dough, and the rest of the dough was soaked in a large quantity of water (3 L/kg of dough) for 6 to 8 hours. The butter collected on the surface was mixed with the previous batch and then heated.

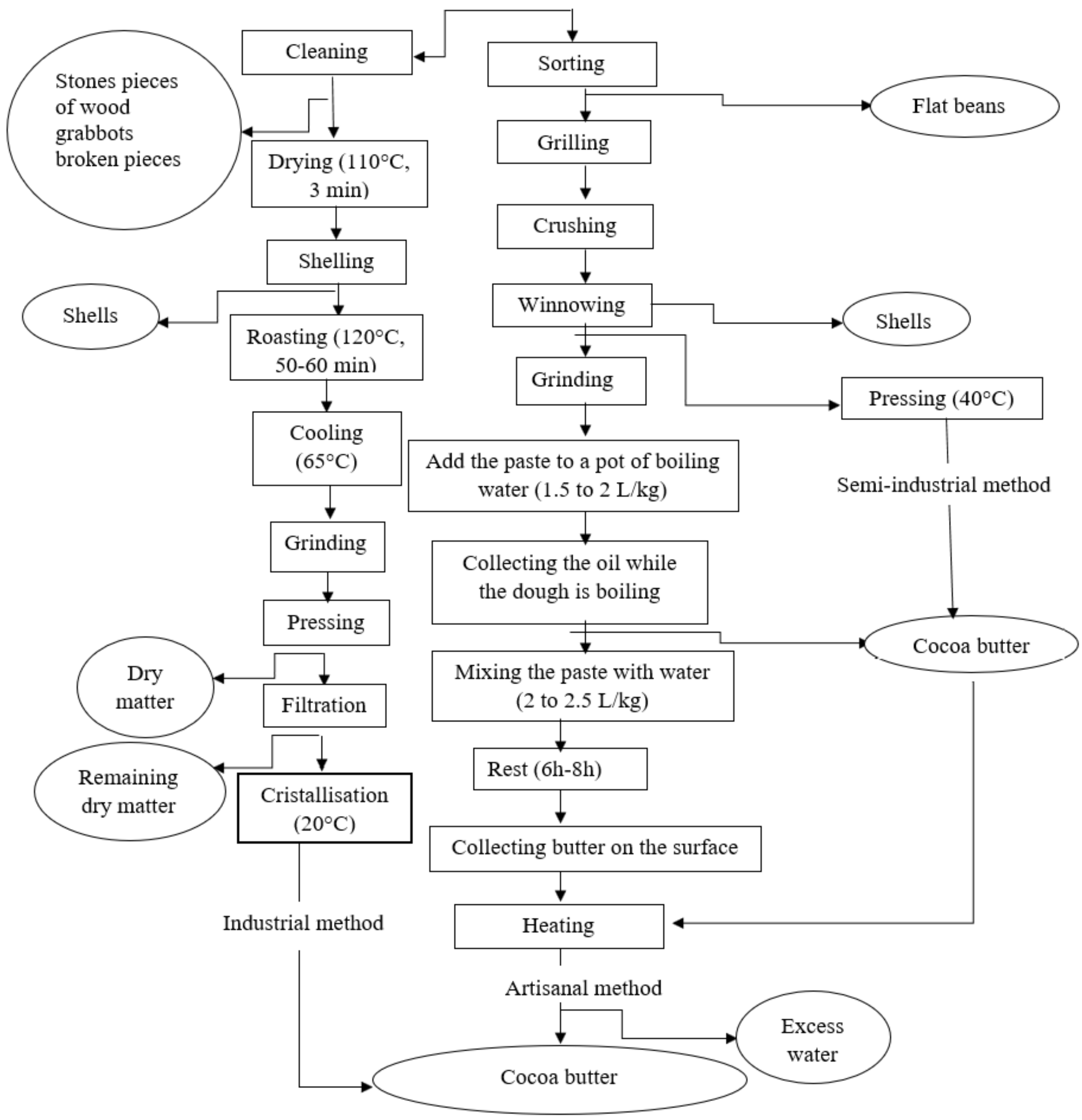

Figure 2. Different cocoa butter production diagram.

3.2. Analysis of the Chemical Quality of Marketed Cocoa Butters

The Table 6 presents the values of the thiobarbituric acid, peroxide, acid, and iodine indices determined for each of the cocoa butters collected during the survey in the towns of Douala, Limbé, Yaoundé, Kékem, and Bertoua. Cocoa butter sample 11 (Limbé) showed the highest thiobarbituric acid index (3.95±0.39 meq MDA/Kg), while the lowest was noted with sample 10 from Douala (1.09±0.02 meq MDA/kg). A significant difference ($p<0.05$) was observed between samples from different localities and between samples from the same locality. The evaluation of the peroxide value revealed that sample 8 (Douala) of cocoa butter had the highest lipid peroxidation value (20.45±2.67 meq O_2/Kg), while sample 6 (Douala) had the lowest value (3.05±0.00 meq O_2/Kg). Overall, the samples from Kékem were the least oxidized. In terms of acid value, sample 10 (Douala) showed the highest value (16.97±0.23% oleic acid), while number

5 from the same town showed the lowest value (0.50±0.00% oleic acid). A significant difference ($p<0.05$) was observed between the different samples regardless of locality. Evaluation of the degree of unsaturation showed that this parameter varied from 23.21±2.31 g I2/100 g to 51.28±0.00 g I2/100 g, and a significant difference ($p<0.05$) was observed between the different samples.

Table 6. Chemical quality of marketed cocoa butters.

City of origine	Samples	Thiobarbyturic acid value (meq MDA/kg)	Peroxide value (meq O_2/kg)	Acid value (% oleic acid)	Iodine value (g I/100 g)
Douala	1	$3.90±0.23^b$	$17.81±1.12^a$	$7.44±0.20^e$	$35.40±0.50^e$
	2	$2.48±0.19^b$	$17.27±0.70^c$	$4.00±1.23^f$	$35.10±0.29^e$
	3	$1.75±0.33^b$	$15.34±3.60^d$	$12.64±0.24^c$	$27.81±0.87^g$
	4	$1.36±0.00^j$	$5.46±0.49^f$	$2.17±0.68^g$	$26.17±1.12^h$
	5	$3.91±0.11^g$	$8.55±1.02^a$	$10.19±3.13^d$	$23.21±2.31^j$
	6	$3.21±0.22^l$	$3.05±0.00^b$	$0.84±0.39^k$	$25.06±0.44^i$
	7	$1.37±0.31^k$	$4.00±0.26^f$	$0.50±0.00^l$	$35.10±0.93^e$
	8	$1.16±0.14^a$	$20.45±2.67^g$	$7.33±0.00^e$	$45.63±0.22^b$
	9	$1.13±0.02^h$	$7.41±1.02^g$	$4.10±0.44^f$	$38.87±0.35^d$
	10	$1.09±0.02^i$	$6.27±0.64^g$	$16.97±0.23^a$	$40.08±0.27^d$
Limbé Yaoundé	11	$3.95±0.39^i$	$6.81±1.27^a$	$4.03±0.54^f$	$42.28±0.57^c$
	12	$1.66±0.02^c$	$12.37±2.11^d$	$14.92±0.00^b$	$51.28±0.00^a$
	13	$2.52±0.47^g$	$8.78±0.80^c$	$1.91±0.41^h$	$26.51±0.03^g$
	14	$1.58±0.16^j$	$5.71±1.18^e$	$0.54±0.00^k$	$33.93±0.39^e$
	15	$3.01±0.06^k$	$4.46±0.75^b$	$6.63±0.78^e$	$32.99±2.69^f$
	16	$1.36±0.04^g$	$8.30±0.01^f$	$2.46±0.42^j$	$39.54±1.18^d$
	17	$1.24±0.20^d$	$11.45±1.48^f$	$1.38±0.03^j$	$35.99±0.48^e$
Bertoua	18	$2.26±0.17^l$	$3.21±0.50^c$	$0.79±0.37^j$	$33.63±2.69^e$
	19	$1.09±0.01^e$	$10.53±2.84^g$	$3.01±0.42^f$	$32.92±1.30^f$
	20	$3.68±0.01^d$	$11.16±2.63^a$	$2.89±0.33^g$	$33.05±1.12^f$
	21	$2.05±0.18^f$	$9.48±0.67^c$	$4.23±0.39^f$	$24.50±0.46^i$
	22	$3.23±0.29^k$	$4.24±0.19^b$	$1.58±0.00^h$	$38.98±0.42^d$
Kékem	23	$1.67±0.17^m$	$3.31±0.46^c$	$4.10±0.21^f$	$34.12±0.12^e$
	24	$2.18±0.07^m$	$3.33±0.78^c$	$1.87±0.47^h$	$26.80±1.11^g$
	25	$1.79±0.12^m$	$3.25±0.22^c$	$1.69±0.00^h$	$36.18±2.76^h$

Note: Values (n =3) with different superscript (a,b,c,d,e,f,g,h,I,j,k,l,m) letters in the same column are significantly different ($p < 0.05$) according to Fisher post hoc test.

In order to better highlight the impact of the collection area on the chemical characteristics of the cocoa butters, an overall average for each index according to the cities was calculated. Table 7 shows that the collection area has a significant influence ($p < 0.05$) on the various quality indices evaluated. Butters from Limbé had the highest thiobarbituric acid index (3.93 meq MDA/kg), while those from Yaoundé and Kekem were statistically similar. The peroxide value was highest in the butters from Douala (10.56 meq O_2/kg), while those from Limbé, Yaoundé, and Bertoua were statistically similar. Butters from the town of Kekem, on the other hand, showed the lowest value for this index. The acid value ranged from 2.50% oleic acid (Bertoua) to 6.57% oleic acid (Douala). No significant difference ($p > 0.05$) was observed between the samples from Limbé and Yaoundé and those from Bertoua and Kekem. The Iodine Index ranged from 42.28 g I2/100 g (Limbé) to 29.03 g I2/100 g (Kekem). The samples from Bertoua and Kekem were significantly ($p < 0.05$) similar.

Table 7. Quality of butter sold by town.

Locality	Thiobarbyturic acid value (meq MDA/kg)	Peroxide value (meq O_2/kg)	Acid value (% oleic acid)	Iodine value (g I_2/100 g)
Douala	$2,13±0.16^c$	$10.56±1.56^a$	$6.57±0.66^a$	$33.24±0.73^b$
Limbé	$3.93±0.39^a$	$6.81±1.27^b$	$4.03±0.54^b$	$42.28±0.59^a$
Yaoundé	$1.90±0.16^d$	$8.52±1.06^b$	$4.64±0.27^b$	$36.71±0.79^b$
Bertoua	$2.47±0.13^b$	$7.73±1.37^b$	$2.50±0.31^c$	$32.61±1.20^c$
Kékem	$1.88±0.12^d$	$3.33±0.49^c$	$2.55±0.23^c$	$29.03±1.33^c$

Note: Values (n =3) with different superscript (a,b,c,d) letters in the same column are significantly different ($p < 0.05$) according to Fisher post hoc test.

3.3. Determining the Critical Points for Mastering the Cocoa Post-Harvest Treatment Process and the Artisanal Cocoa Butter Extraction Method

3.3.1. Post-Harvest Treatment Process

3.3.1.1. Description of the Post-Harvest Treatment of the Product

Dry cocoa beans (Theobroma cacao L.) harvested from pods, debulked, then fermented in bags and sun-dried on cemented areas or black tarpaulins were used as the study matrix. The dried beans are either used by the local people themselves or placed into jute bags and sold to Cameroonian industries or exported to other industries abroad. This raw material is used as a basic ingredient in the small-scale and industrial production of cocoa butter, chocolate, and cocoa powder. Obtaining dry beans involves a series of operations summarized in Figure 3.

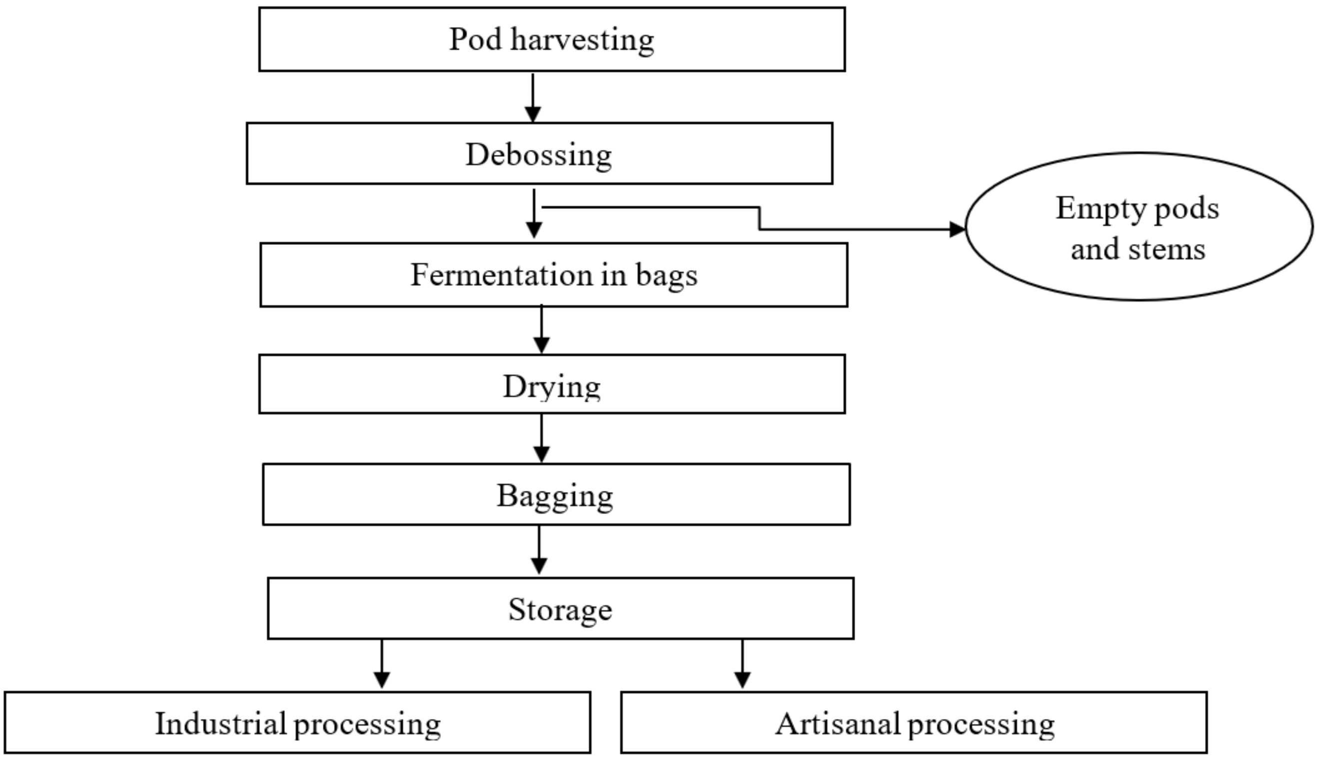

Figure 3. Diagram of operations for post-harvest treatment of cocoa beans.

3.3.1.2. Risk Analysis

Table 8 summarises the stages in the cocoa post-harvest treatment process, as well as the associated chemical risks and the preventive measures to deal with them. It should be noted that the shelling, fermentation, drying and storage stages are conducive to the presence of free fatty acids and lipid oxidation (this information have been obtained during survey).

Table 8. Risk analysis of post-harvest treatment of cocoa beans.

Step	Associated chemical risks	Preventive measures
Debossing	Presence of damaged beans.	Clubs will be used instead of sharp instruments
Fermentation	Presence of slaty and mouldy beans	Ensure adequate fermentation time
Drying	Presence of mouldy beans	Dry on cemented areas or black tarpaulins, avoid slow drying, stir the beans 5 to 10 times a day, and cover the beans overnight to prevent moisture build-up.
	Presence of biological contaminants	Sort beans when collecting or displaying them
Storage	Presence of mouldy beans	Avoid storing in damp conditions and stacking bags more than 5 m high, and sort the beans.
	Presence of moth-eaten beans	Insect repellent, bag maintenance, avoiding dust and breakage
	High content of free fatty acids in butter	Avoid storage in damp conditions, avoid breaking the beans

3.3.1.3. Determination of Critical Control Points (CCPs)

The determination of critical control points for the control of post-harvest cocoa processing, preventive measures, and threshold points to be respected was carried out and presented in Table 9. An analysis of this table shows that fermentation and drying, in particular, require precise and controlled conditions to prevent the risk of free fatty acids and lipid oxidation.

Table 9. Identification of critical points for the control of post-harvest treatment of cocoa beans.

Critical treatment	Preventive measures	Threshold points
Fermentation	Respect the fermentation time	6 to 8 days
	Brewing the beans	After 24 hours, then every 48 hours
Drying	Dry on suitable surfaces	Cemented areas and/Or black tarpaulins
	Avoid slow drying	4 to 6 days
	Stir the beans	5 to 10 times daily
	Cover the beans overnight to prevent moisture build-up	
	Sort beans when collecting or displaying them	Remove all defective beans (Flat, caked, broken, mouldy, etc.)., attacked by insects and sprouted beans) and contaminants
Storage	Avoid storage in humid conditions	Relative air humidity ≤ 70%.
	Avoid stacking bags too high	Height ≤ 5 m
	Sorting the beans	Eliminate all defective beans (Flat, agglomerated, broken, mouldy, attacked by insects and sprouted beans)
	Insect repellent, bag maintenance, avoiding dust and breakage	New bags, soft handling

3.3.2. Artisanal Cocoa Butter Extraction

3.3.2.1. Description of the Product Preparation

The cocoa butter (Theobroma cacao) is extracted using a traditional method that involves roasting the beans, grinding, and heating the paste to collect the butter. The cocoa butter (Theobroma cacao) is marketed by local companies, which either export it or use it to produce local chocolate. It is also produced by local people who sell it and use it therapeutically to treat ailments such as rheumatism, burns, scars, and other skin defects, including stretch marks. The diagram of artisanal cocoa butter production is summarized in Figure 4.

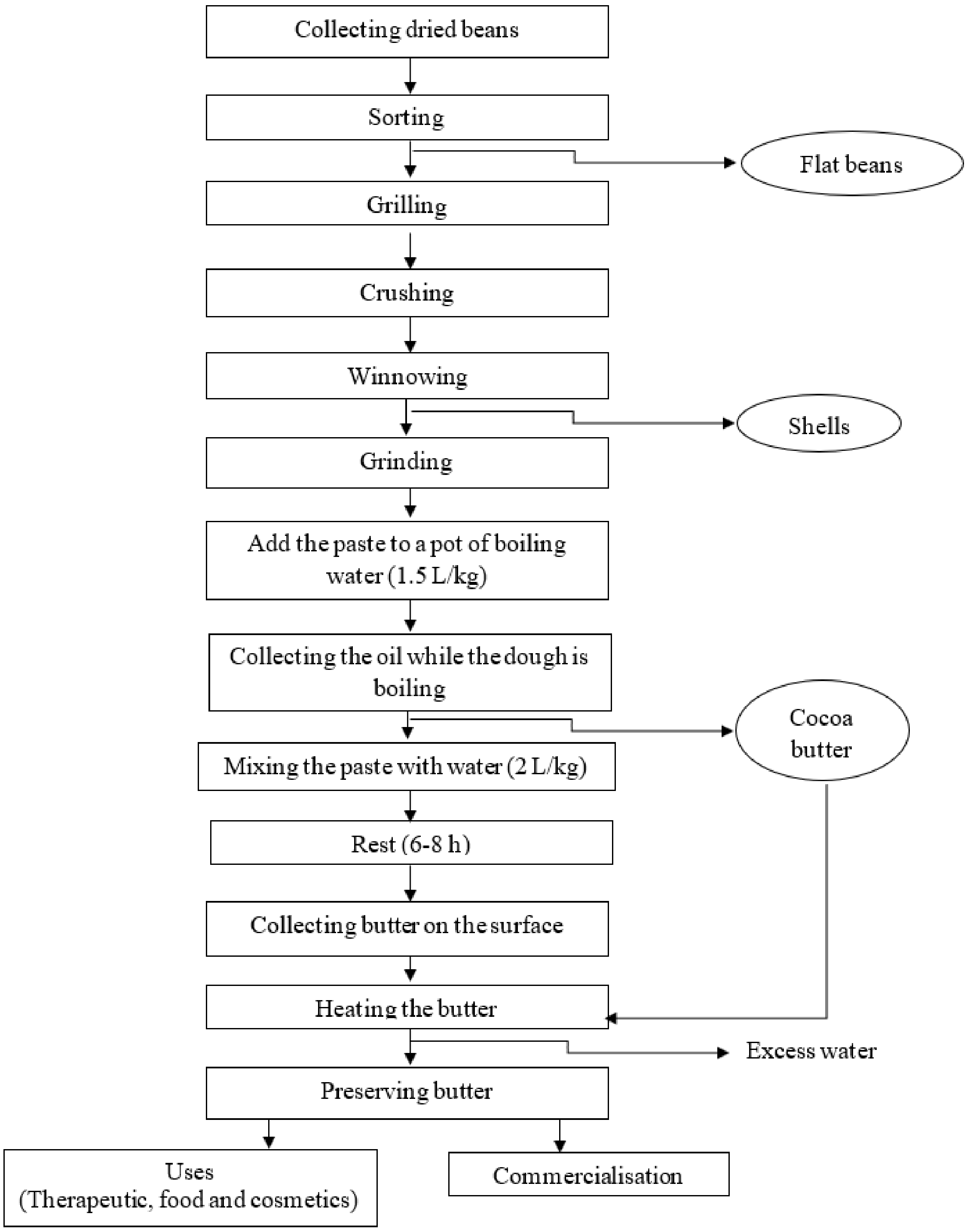

Figure 4. Diagram of artisanal cocoa butter production.

3.3.2.2. Risk Analysis

The risk analysis of the artisanal cocoa butter extraction process is summarized in Table 10. It shows that several stages are conducive to the risk of butter oxidation and acidity. These stages, from roasting to the conservation of the butter, are crucial for maintaining the chemical quality of the oils.

Table 10. Risk analysis of artisanal cocoa butter extraction.

Step	Associated risks	Preventive measures
Collection of dried beans	Collection of defective beans	Only healthy beans will be collected
Sorting	Omission of defective beans	Defective beans will be carefully removed
Grilling	Butter oxidation	Respect the roasting time and temperature
Winnowing	Presence of high levels of hulls	Careful winnowing
Collecting the butter in the boiling dough	Butter oxidation	Check the heating time of the paste
Heating the butter	High water content, butter oxidation	Check the heating time
Storing the butter	Rancidity of butter	Store in an opaque tin with a wide opening, away from light

3.3.2.3. Determination of Critical Control Points (CCP)

Table 11 presents the critical control points for the artisanal method of extracting cocoa butter, the preventive measures, and the threshold points to be respected. It shows that grilling, boiling the paste, and heating the butter, in particular, require precise and controlled conditions, with heating times of 30 minutes, 30 minutes, and 15 minutes, respectively, in order to prevent the risk of oxidation and acidity of the butter.

Table 11. Critical points for mastering the artisanal extraction of cocoa butter.

Critical treatment	Preventive measures	Threshold points
Grilling	Respecting the time and temperature of grilling	≤ 30 min
Boiling the dough	Check heating time and temperature	≤ 30 min
Heating the butter	Check heating time and temperature	≤ 15 min

4. Discussion

The socio-demographic data revealed that most of the cocoa butter producers were women (59.30%). This could be explained by the fact that the artisanal cocoa butter production process, which was the most represented, can be likened to culinary preparation. Indeed, from an early age, young African girls learn to cook, more by immersion than by explicit learning [17]. The majority of the producers (37.00%) were aged between 40 and 50, and most of them were animists (62.00%). People in this age group are more attached to old practices than the younger generation [17], hence their preference for work in the fields, artisanal extraction, and the animist religion. The majority of growers lived in Douala (37.00%) because it is one of Cameroon's major economic zones and is suitable for growing this plant. In addition, the high population density in this metropolis makes this activity more lucrative. The most common level of education was primary school (37.00%). Growers do not have a very high level of education, so they have turned to an income-generating activity that only requires practical skills [18].

Post-harvest processing includes three main stages: shelling, fermentation, and drying. Some of the producers surveyed (44.44%) purchased dry beans to produce their cocoa butter, as they felt they needed to produce large quantities to satisfy the high demand. As a result, post-harvest processing was seen as a waste of time and energy, leading to a loss of financial income. The most commonly used fermentation time (7-9 days) is closest to the recommended conditions of 6 to 8 days [19]. Fermentation time varies according to climatic conditions, fruit maturity, and the mass to be fermented [20]. The most commonly used fermentation method (in bags) is not the one recommended, although it is easier to implement given the relatively small quantity of cocoa to be fermented [20]. The heat source used by all the producers was the sun, as it was the cheapest and easiest to use. Drying was carried out for 5 to 8 days by the majority of producers; this range is close to that recommended [21]. The drying time varied according to local conditions and/or the possible use of an artificial dryer, with the ideal being 6-10 days for sun drying [21]. The drying surfaces used were primarily cemented areas and black tarpaulins, which corroborates the work of Barel [3] and Lainé [22], who also reported the use of these drying methods in their research.

Most cocoa butter is then extracted using the artisanal method. This can be attributed to the ease of its implementation, its relatively low cost, the accessibility of the necessary tools, and its yield, which is practically equal to that of the other methods when performed correctly [23]. The artisanal method is the most time-consuming and labor-intensive compared to the semi-industrial method [24].

Analysis of the chemical quality of the cocoa butters marketed revealed that these butters were of poor quality. Indeed, 72% of the samples have an acid value higher than the Codex Alimentarius standard for cocoa butter (≤ 1.75% oleic acid), and 40% of the cocoa butter samples have an iodine value outside the normal range defined by the Codex Alimentarius, which is 32 to 41 g I_2/100 g [16]. This may be due to poor execution of post-harvest treatments, the production method used, or even inadequate preservation of the butter, which promotes oxidation and rancidity [25]. In fact, during the bean drying stage, prolonged exposure of the almonds to the sun is responsible for the oxidation of the fat, leading to significant production of peroxides that destabilize compounds with a high melting point and low stability [26]. Similarly, roasting and heating steps are likely to alter the quality of the product obtained, as reported by Żyżelewicz, et al. [11] in their work.

The HACCP carried out on all stages of the post-harvest treatment process reveals fermentation and drying as critical points for the control of this process. The primary objective of post-harvest treatments is to transform the fruit borne by the cocoa tree into a marketable product. To this end, the simplest succession of treatments is as follows: picking, extraction of the beans (shelling), and drying. All these operations affect the characteristics of the beans and are highly interdependent. They, therefore, form a chain that determines the quality of the final product [21]. Fermentation is one of the main post-harvest activities in the production of cocoa beans [27], but it remains a complex process that is difficult to control, especially in the case of spontaneous or natural fermentation of cocoa beans, where microbial contamination occurs in a haphazard and random manner [28]. The drying process, on the other hand, must be carried out carefully to ensure that the beans have been properly prepared for storage and transport without being contaminated by mold, bacteria, Polycyclic Aromatic Hydrocarbons (PAHs), and other contaminants. Drying must be complete, and moisture content must be reduced to less than 8% [29].

The HACCP carried out on the artisanal cocoa butter extraction method revealed that the roasting, paste boiling, and butter heating stages are critical points for controlling this process. The time and temperature of roasting contribute to many physical and chemical changes, such as the intensification of the brown color and the development of the characteristic cocoa aroma [30]. On the other hand, the roasting process can contribute to the alteration of the composition of bioactive compounds, leading to changes in lipid degradation due to oxidation [11]. Boiling the paste and heating the butter are done at relatively high temperatures that can alter the quality of the cocoa butter obtained if the time taken for these operations is too long [31]. These results are similar to those obtained by Womeni, et al. [32], who carried out the HACCP on the industrial method of extracting cocoa butter and identified roasting as a critical control point. According to Womeni, et al. [32], the cooking time and drying temperature of shea seeds caused biochemical changes affecting the quality of the butter.

5. Conclusion

At the end of this study, which focused on the analysis of post-harvest cocoa treatments, cocoa butter extraction, and the identification of the critical stages of the two processes (HACCP), using a survey of producers, it emerged that butter extraction methods differ according to the producers. However, post-harvest treatments are generally standard, and the cocoa butters marketed are typically of poor quality. With regard to the critical stages, fermentation and drying were identified for post-harvest treatments, while roasting the beans, boiling the paste, and heating the butter were noted for the artisanal butter extraction method. In view of the above, compliance with production conditions and HACCP rules would result in better quality butter and more competitive products in the market.

References

[1] ONCC, "Order establishing the terms and conditions for marketing cocoa beans, N° 00026. " 2017.

[2] M. Crafack *et al.*, "Impact of post-harvest practices on cocoa (Theobroma cacao L.) flavour quality," *Food Research International*, vol. 54, no. 1, pp. 150-158, 2013.

[3] M. Barel, "From cocoa to chocolate, the epic tale of a delicacy," *Quae*, 2009.

[4] K. Davison, P. Howe, and J. Buckley, "Potential implications of dose and diet for the effects of cocoa flavanols on cardiometabolic function," *The Journal of Nutritional Biochemistry*, vol. 64, pp. 1-10, 2019.

[5] A. Aprotosoaie, S. Luca, A. Miron, and A. Trifan, "The sensory impact of cocoa fermentation on chocolate quality," *Foods*, vol. 5, no. 3, pp. 1-13, 2016.

[6] B. Encylopaedia, *Cocoa butter consulted online at cocoa butter | definition, characteristics, & uses |*. Britannica, 2023.

[7] D. Ghosh, A. Konar, and S. Sircar, "Solvent extraction of cocoa butter: Effect of some process parameters on extraction yield and oil quality," *Journal of Food Process Engineering*, vol. 35, no. 2, pp. 204-222, 2012.

[8] D. Adomako, C. Mardare, and C. Neagu, "Improvement in the cocoa butter extraction from cocoa beans using hydraulic press machine," *Journal of Food Processing and Preservation*, vol. 43, no. 4, pp. 13-80, 2019.

[9] E. O. Afoakwa, *Chocolate science and technology*. Oxford: Wiley-Blackwell, 2010.

[10] A. K. Edoh and E. L. Ngo-Samnick, "Cocoa production and processing," *CTA*, pp. 33-36, 2014.

[11] D. Żyżelewicz, G. Budryn, W. Krysiak, J. Oracz, E. Nebesny, and M. Bojczuk, "Influence of roasting conditions on fatty acid composition and oxidative changes of cocoa butter extracted from cocoa bean of Forastero variety cultivated in Togo," *Food Research International*, vol. 63, pp. 328-343, 2014. https://doi.org/10.1016/j.foodres.2014.04.053

[12] M. Turan, M. Gulluce, N. von Wirén, and F. Sahin, "Yield promotion and phosphorus solubilization by plant growth–promoting rhizobacteria in extensive wheat production in Turkey," *Journal of Plant Nutrition and Soil Science*, vol. 175, no. 6, pp. 818-826, 2012. https://doi.org/10.1002/jpln.201200054

[13] AFNOR, "Collection of French standards, fatty substances, oilseeds, derived products," 2nd ed. Paris: AFNOR, 1981, p. 438.

[14] IDF, "Determination of free fatty acids in milk and milk products," Bulletin of the IDF N° 265/1991, 1991.

[15] H. H. Draper and M. Hadley, "Malondialdehyde determination as index of lipid peroxidation," *Methods Enzymology*, vol. 186, pp. 421-431, 1990.

[16] C. Alimentarius, "Codex standard for cocoa butter," *Codex-Stan*, pp. 86-1981, 2001.

[17] P. Erny, "Ethnology of education," vol. 1. Paris: Harmattan, 1991, p. 163.

[18] T. Amraoui, "African artisans: Social study and organization of work. I. Social and legal status based on Latin inscriptions from Algeria," *Antiquités Africaines. L'Afrique du Nord de la Protohistoire à la Conquête Arabe*, vol. 52, pp. 59-80, 2016. https://doi.org/10.4000/antafr.728

[19] S. S. Thompson, K. B. Miller, and A. S. Lopez, "Cocoa and coffee food microbiology fundamentals and frontiers." Washington, D.C: ASM Press, 2001, pp. 721-733.

[20] C. Amani, "Cocoa: Obtaining quality beans," Agroivoire, 2014, p. 23.

[21] M. End and R. Dand, "cocoa beans: Quality requirements of the chocolate and cocoa industry," *ECA-Caobisco-FCC Cocoa Research Fund*, 2015.

[22] K. Lainé, "Survey on cultural practices in cocoa plantations in Ivory Coast," *Rapport de projet PACCC/ICCO/Industrie sur l'amélioration de la qualité du cacao en Côte d'Ivoire*, vol. 27, 2001.

[23] B. Njonga, "Cameroon: The manufacture of cocoa butter. The voice of the peasant. Consulted on March 18, 2023 on," Retrieved: https://www.lavoixdupaysan.net/cameroun-la-fabrication-du-beurre-de-cacao/. 2018.

[24] Agriculture au Cameroun, "Cameroon: How to make cocoa butter agriculture in Cameroon," Retrieved: https://www.agricultureaucameroun.net/cameroun-comment-fabriquer-du-beurre-de-cacao/. 2019.

[25] M.-E. Cuvelier and M.-N. Maillard, "Stability of edible oils during storage," *OCL Oilseeds and Fats Crops and Lipids*, vol. 19, no. 2, pp. 125-132, 2012. https://doi.org/10.1051/ocl.2012.0440

[26] H. M. Womeni, R. Ndjouenkeu, C. Kapseu, F. T. Mbiapo, M. Linder, and J. Fanni, "Application of the drying-frying process to shea almonds: Influence on the composition of unsaponifiable matter in the butter," *Oléagineux, Corps gras, Lipides*, vol. 14, no. 6, pp. 366-370, 2007. http://dx.doi.org/10.1051/ocl.2007.014

[27] R. F. Schwan and A. E. Wheals, "The microbiology of cocoa fermentation and its role in chocolate quality," *Critical Reviews in Food Science and Nutrition*, vol. 44, no. 4, pp. 205-221, 2004. https://doi.org/10.1080/10408690490464104

[28] B. Koffi, J. Diopoh, T. Karou, J. Nemlin, G. Ouattara, and S. T. Guehi, "Fermentations and marketability of cocoa beans," *Agronomie Africaine*, vol. 25, no. 2, pp. 159-170, 2013.

[29] W. Amoah-Awua, "Methods of cocoa fermentation and drying," *Cocoa and Coffee Fermentations*, pp. 71-128, 2015.

[30] S. T. Guehi, S. Dabonne, L. Ban-Koffi, D. K. Kedjebo, and G. I. B. Zahouli, "Effect of turning beans and fermentation method on the acidity and physical quality of raw cocoa beans," *Journal of Food Science and Technology*, vol. 2, no. 3, pp. 163-171, 2010.

[31] H. A. Kohole, "Influence of drying and cooking processes of peanut seeds (Arachis hypogaea) on the quality of lipids and some functional properties of proteins," Thesis University of Dschang, 2015.

[32] H. Womeni, R. Ndjouenkeu, C. Kapseu, F. Tchouanguep Mbiapo, M. Parmentier, and J. Fanni, "Effect of cooking and drying of shea nuts (Butyrospermum parkii (G. Don) Kotschy) on butter quality," *Tropicultura*, vol. 24, no. 3, pp. 175-182, 2006.