Characterization and Yield of Crude Cocoa Butter Extracted from Taiwanese Cocoa Beans under Different Fermentation Degree and Roasting Conditions

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Abstract High quality cocoa butter, due to its unique physicochemical properties and fatty acid composition, is widely used in food and cosmetic industries. Fermentation and roasting processes not only contribute a significant impact on the polyphenol content and flavor of cocoa beans, but also affect the physicochemical properties of cocoa butter. The objective of the present study was to determine the oil yield of crude cocoa butter extracted from Taiwanese cocoa beans under different fermentation degree and roasting conditions by mechanical press (54MPa and 60°C). A total of six couple (fermentation/roasting) extracted crude cocoa butter was obtained and their physicochemical properties, including acid value, iodine value, melting point, peroxide value, and fatty acid composition were determined. It was found that fermented cocoa beans roasted at 130°C for 25min had the highest oil yield of 79.9%, while the lowest oil yield of 57.9% was obtained from the unfermented and unroasted cocoa beans. There were statistical differences in the physicochemical properties and fatty acid composition among the extracted cocoa butters. The acid values of the analyzed cocoa butters were within the range of 0.43±0.01-1.72±0.12 mg KOH g⁻¹ of fat. The iodine values were within 34.93±0.15-36.30±0.08 g I₂ 100 g⁻¹ of fat. The melting points were ranged from 33.08±0.22 to 33.80±0.08 °C. The peroxide values were within the range of 1.03±0.04-2.88±1.12 meq kg⁻¹ of fat. The analyzed fatty acid profiles indicated that saturated fatty acids were present in higher proportions than unsaturated fatty acids, with stearic and oleic acids as the main fractions. These physicochemical parameters were within the norms. Taken together, the cocoa butter extracted from unfermented and unroasted cocoa beans possessed the highest melting point, the lowest iodine value, and the highest level of saturated fatty acids, which are the indications of high quality cocoa butter.

Keywords: crude cocoa butter, fermentation, roasting, oil yield, physicochemical properties

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1. Introduction

Dried cocoa beans contain numerous functional components, including cocoa butter, protein, fiber, starch, polyphenols, theobromine, caffeine, etc., among which the content of cocoa butter accounts for the highest proportion ranging from 45 to 55%. The variation of cocoa butter content is based on the diversity of cocoa tree species, the planting latitude, and climate conditions [1,2]. Cocoa butter is widely used in the food, cosmetics, and pharmaceutical industry [3]. The unique fatty acid composition and triglycerides form of cocoa butter make its melting point extremely narrow, ranging merely from 32°C to 35°C. Cocoa butter, as a highly valuable byproduct during chocolate processing, enables cocoa powder, paste, sugar and other additives to disperse, fluidize and diffuse more easily to form a homogeneously continuous phase [4,5]. Furthermore, the existence of cocoa butter facilitates the viscosity, plasticity, and texture of the chocolate product. More importantly, the crystalline lattice of cocoa butter brightens the surface of the chocolate products and enhances the snap sound while tasting [6]. Chocolate liquors are manufactured through a series of processes, including cocoa bean fermentation, drying, roasting, winnowing, grinding, refining, and eventually forming a liquid-like cocoa paste. The cocoa paste then undergoes a separation process to express out the cocoa butter [7,8,9]. The remaining cocoa lump is used to produce natural cocoa powder or alkalized with the addition of K₂CO₃ to obtain the alkalized cocoa powder, where about 12-15% of fat is still remaining in the cocoa powder. The entire process is time-consuming and the high-temperature roasting process might possibly influence its physicochemical properties and functional component. In recent years, numerous researches puts emphasis on maintaining more healthcare components in
cocoa powder or chocolate products. Light processing or using unfermented (blanching) cocoa beans are the new attempts to meet this specific demand of healthcare component in the terminal product [10,11].

Taiwan, a country located in East Asia, is one of the most important regions best known for growing cocoa tree. Taiwanese cocoa bean is appreciated internationally, due to their distinctive flavor and aroma. The photochemical composition and antioxidative activity of Taiwanese cocoa beans have been widely studied in recent years [12,13]. However, there is little information on the physicochemical properties and the profiles of fatty acid of cocoa butter extracted from Taiwanese cocoa bean.

Chocolate producing steps include fermentation, drying, roasting, grinding, winnowing, refining, tempering, molding and maturing. Among the whole processes, fermentation and roasting are the two most essential processes that determine the chocolate flavor and functional property, and they are also the process that is most likely to affect the physicochemical properties and functional component of cocoa butter. Moujouenpou, et al. [2] studied that a total of 13 couple (temperature/duration) cocoa butters was tested. The results showed the physicochemical properties, including iodine value and saponification value were within the norms. Roasting conditions affected the quantity of extracted cocoa butter. Servent, et al. [14] indicated that fermentation process appears to be necessary to enhance the quantity of cocoa butter extracted from the cocoa nibs. There is still lack of research that studies the effects of fermentation degree and roasting conditions on the physicochemical properties and fatty acid composition of cocoa butter. Therefore, the present study aims to use unfermented (blanching) and fermented cocoa beans as the basic materials. The cocoa butter was extracted from cocoa beans under different fermentation degree and roasting conditions by mechanical press. The resulting cocoa fat is called the extracted crude cocoa butter. The investigated parameters include extraction yield, oil yield, melting point, acid value, iodine value, peroxide value and the fatty acid composition. The method we chose for cocoa butter extraction could simplify the complicated and time-consuming procedures of traditional methods. Meanwhile, there is little information on the physicochemical properties and fatty acid composition of the Taiwanese crude cocoa butter in a wide range of processing conditions.

2. Material and Methods

2.1. Cocoa Pods

Cocoa pods were purchased from Pingtung orchard, Taiwan. The pods were opened through steel knife to remove the seeds. During the process, the seeds were carefully treated so that the seeds remain unharmed, then the seeds were prepared for further fermentation process or blanching process.

2.2. Fermentation Process

The fermentation was performed in a wooden box. It was divided into up, middle, and bottom three compartments, with each a size of 50cm x 50cm x 50cm. In the beginning, the fresh cocoa seeds are put in the upper compartment with the surface covered with a layer of banana leaves and a sack to prevent heat loss during fermentation. After 48h, the cocoa seeds in the upper compartment were transferred down to the middle compartment and blended thoroughly for another 48h. Next, the fermented cocoa beans were transferred to the bottom compartment, and flopped over twice a day for the next 72h. The fermented cocoa beans then were oven-dried at 60°C until the moisture content fell down to about 6%. The cocoa beans were then cooled and stored in a fridge for further usage.

2.3. Blanching Process

Fresh cocoa seeds were blanched in boiling water for 10min and washed in iced water for removing the remained pulps. The cocoa beans were then drained and oven-dried through a rotational dryer at 60°C until the moisture content dropped to about 6%. The cocoa beans were then cooled and stored in a fridge for further use.

2.4. Cocoa Butter Extraction

Table 1 indicates that the six types of cocoa butter samples extracted from Taiwanese cocoa bean under different fermentation degree and roasting conditions by mechanical press with operating conditions: 54MPa and 60°C. The six samples were stored at -20°C in the freezer for further analysis.

Table 1. Basic materials and roasting conditions for cocoa butter extraction

| Cocoa butter samples | Basic materials          | Roasting conditions (temperature-time) |
|----------------------|--------------------------|----------------------------------------|
| CB1                  | Unfermented and dried cocoa bean | Unroasted                              |
| CB2                  | Unfermented and dried cocoa bean | 130°C - 25min                          |
| CB3                  | Unfermented and dried cocoa bean | 155°C - 25min                          |
| CB4                  | Fermented and dried cocoa bean | Unroasted                              |
| CB5                  | Fermented and dried cocoa bean | 130°C - 25min                          |
| CB6                  | Fermented and dried cocoa bean | 155°C - 25min                          |

2.5. Physicochemical Property Measurement

The measurement of the melting point of cocoa butter is conducted based on the AOCS Ci1-25 (reapproved 2009) procedure by the melting point tester (Balance. science MP-2D). The measurement of the acid value of cocoa butter is based on the method of AOCS Cd 3d-63 (reapproved 2009). The measurement of the iodine value of cocoa butter is based on the method of AOCS Cd 1c-85 (reapproved 2009). The measurement of the peroxide value of cocoa butter is based on the method of AOCS Cd 8b-90 (reapproved 2009). All the measurements were run in quadruplicate.

2.6. Fatty Acid Composition Measurement

The measurement of the fatty acid composition of the six extracted cocoa butters is based on the method of AOCS Ce 1k-09 (reapproved 2009). Each cocoa butter sample (about 0.1g) was placed in a 50 mL round-
bottomed flask with the addition of 4mL of 0.5N KOH/methanol solution. Then attach coolant, water condenser to the flask. Reflux operation was performed at 90-100°C for 13 min after boiling begins, and then 3ml of BF₃/methanol solution was added to the boiling flask, reflux for additional 2 min, and finally 2mL of N-hexane was added to the flask, reflux for additional 1min. Then, the heat source was removed, and the flask was cooled to room temperature. 20 ml of saturated NaCl solution and 1 mL of 0.5% internal standard (C₁₅:0) was added into the flask. Stopper the flask and shake. Allow the layers to separate and transfer a clear portion of the top layer with a transfer pipette into a 7 mL vial containing 50mg of Na₂SO₄. Crimp on the aluminum cap and vortex mix. The resulting solution (0.5-1.0 µL) was sampled by syringe for analysis. The analysis was performed by Shimadzu 2010 gas chromatograph equipped with FID detector. The analysis condition being: column: 0.53 mm × 30 m, fused silica column; stationary phase: CP-Wax (film thickness, 1.0 µm); flow rate: 3-5 mL/min (splitter ratio=1:50); FID detector: H₂ flow rate 30 mL/min, Air flow rate 300 mL/min, Injection temperature=260°C, Detector temperature=280°C; the process of raising temperature in the oven is to maintain at 100°C for 3min, and then raise 10°C per minute until reaching 180°C and maintain at 180°C for 3 min. Next, 4°C were raised per minute until reaching 230°C and maintain at 230°C for 5 min. Each sample was performed in quadruplicate.

2.7. Statistical Analysis

All the measurements were run in quadruplicate, using analytical grade reagents. Results were expressed as means ± SD. Analysis of Variances (ANOVA) and Tukey’s Test were applied to analyze the significant difference of the means among the treatments. The significant level (α) was set at 0.05. The statistical computing software R 4.0 was used to perform all statistical analysis.

3. Results and Discussion

3.1. Extraction Yield

Table 2 showed the yield and extraction yield of cocoa butter extracted from cocoa beans under different fermentation degree and roasting conditions by mechanical press. The butter extraction yield was obtained from the weight of extracted cocoa butter divided by the weight of cocoa beans. Yield was calculated by dividing the weight of extracted cocoa butter with the weight of cocoa butter present in the cocoa beans. It was found that the quantity of cocoa butter was within the range of 522-720g. The extraction yields were within 26.1-36.0%. The yields ranged from 57.9 to 79.9%. Under the same roasting condition, the yields of the cocoa butter extracted from fermented cocoa beans were higher than that extracted from unfermented cocoa beans. The fermentation process was an essential and decisive step to affect the formation of the precursor substances of the cocoa flavor and aroma. When the fermentation duration exceeded 72h, acetic acid were generated through the function of acetic acid bacteria, and then penetrated into the cotyledon of the bean, causing a decrease in pH value of the cotyledon, degrading the proteins into amino acids and peptides, or possibly activating the lipolytic enzyme which further released the fatty acids and eventually increased the yield of the cocoa butter. This finding was similar to the study of Servent et al. [14]. They analyzed the cocoa butter content in cocoa bean from three selected countries (Madagascar, the Dominican Republic and Ecuador) along with the fermentation time. The results showed that the fermentation process was an essential step to improve the yield of cocoa butter. Under the same fermentation degree, the yields of cocoa butter extracted from roasted cocoa beans were higher than those of the unroasted ones. Table 2 highlighted that the fermented cocoa beans and roasted at 130°C for 25 min had the highest extraction yield (36.0%) and yield (79.9%). On the other hand, the extraction yield for unfermented and unroasted cocoa beans was merely 26.1%. The Maillard reaction during the roasting process though could darken the color of the cocoa beans and enrich the flavor, the polyphenol concentration of the cocoa bean would decrease instead. Meanwhile, the elaioplasts of roasted cocoa bean would crack up and the cocoa butter express more easily during mechanical press. However, as the roasting temperature rose to 155°C, the extraction yield decreased to 32.5%. This result was consistent with Mounjouenpou et al. [2], who used the flotation method to extract the cocoa butter. They reported that the optimized cocoa butter extraction yield was 25%, which was conducted under roasting temperature 125°C for 57 min, and 140°C for 40 min; yet, when rising the temperature up to 156°C for 25 min, the extraction yield fell to 22%.

Table 2. Extraction yield and yield of extracted crude cocoa butter

| Cocoa butter samples | Extraction yield (%) | Yield (%) |
|----------------------|----------------------|----------|
| CB1                  | 26.1                 | 57.9     |
| CB2                  | 34.3                 | 76.3     |
| CB3                  | 32.0                 | 71.0     |
| CB4                  | 32.1                 | 71.2     |
| CB5                  | 36.0                 | 79.9     |
| CB6                  | 32.5                 | 72.2     |

All mechanical press were performed at 60°C and 54MPa.

3.2. Physicochemical Properties of Extracted Cocoa Butter

3.2.1. Acid Value

The definition of the acid value is the required mg of KOH to neutralize 1g of fat. The value of the acid value indicated the content of free fatty acid in the fat. Figure 1 represented the means and standard deviations of the acid value of 6 extracted cocoa fat ranging from 0.43±0.01 to 1.72±0.12 mg KOH g⁻¹ of fat. There were no significant differences (p<0.05) among CB3, CB4, CB5, and CB6, but the means of acid value for CB1 and CB2 were lower than the rest of extracted cocoa butter at a level of significance of 95%. CB6 was the cocoa butter extracted from fermented cocoa beans roasted at 155°C for 25min. These processing procedures facilitated the activation of lipase and the reaction with fat substrates, causing an increase in free fatty acid content. As a result, the acid
value increased. Similar result was reported by Żyżelewicz, et al. [15].

Figure 1. Acid values of the analyzed crude cocoa butter samples

3.2.2. Iodine Value

The definition of the iodine value is the absorbed g of iodine in every 100g of fat. The iodine value is very important for the quality of the fat. It was frequently used for the measurement of the degree of unsaturation of the fatty acids. The degree of unsaturation in the fatty acids was generally in the form of C=C, where C=C would react with the iodine through the addition reaction. The higher the iodine value, the higher the amount of C=C in the corresponding sample. These kinds of fats were liquid-like at room temperature, while fats with lower iodine values was usually solid-like at room temperature. Chaisere and Dimick [16] stated that the iodine value could be used as an indicator for the hardness of the fat, with the higher the iodine value, the lower the hardness of the fat. Figure 2 depicted the means and the standard deviation of the iodine values, ranging from 34.93±0.15 to 36.30±0.08 g I₂ 100g⁻¹ of fat. The obtained result was consistent with the study in other countries, e.g., Bolivia, Brazil, Colombia, Ecuador, Peru, Costa Rica, Dominican Republic, Mexico, Panama, Ivory Coast, Nigeria and Malaysia, whose iodine values were within 34.4 -38.7 g I₂ 100g⁻¹ of fat [16]. CB3 possessed the highest iodine value, 36.30 g I₂ 100g⁻¹ of fat, and it was significantly higher than the others (p<0.05), implying CB3 contained more unsaturated fatty acids. This conclusion could also be confirmed from Table 3, which presented the fatty acid profiles of tested cocoa butters. This may be explained by high temperature roasting, causing unanticipated changes in the fatty acids presented in the triglycerides. Mounjouenpou, et al. [2] reported that a similar outcome by comparing the iodine value (33-42 g I₂ 100g⁻¹ of fat) among 13 roasting temperature/duration couple conditions. CB1, having the lowest iodine value 34.93 g I₂ 100g⁻¹ of fat, indicated that the hardest cocoa butter was obtained from unfermented and unroasted cocoa beans extracted by mechanical press. Liendo et al. [17] had claimed that cocoa butter manufacturers tended to produce cocoa butter with higher hardness. As a result, this study recommended that harder cocoa butter could be extracted from unfermented and unroasted cocoa beans.

Figure 2. Iodine values of the analyzed crude cocoa butter samples

3.2.3. Melting Point

The main triglyceride composition in the cocoa butter was constituted of glycerol-1,3-dipalmitate-2-oleate (POP), glycerol-1-palmitate-2-oleate-3-stearate (POS), and glycerol-1,3-diestearate-2-oleate (SOS). Due to these unique triglycerides and relatively uniform chemical composition, cocoa butter displays a relatively low and narrow range of melting points (32-35°C) [18]. The fluctuation of the melting point of cocoa fat extracted from cocoa beans under different processing conditions ranged from 33.08±0.22 to 33.80±0.08°C, as shown in Figure 3. The result was similar to the report by Lehrian [19], which indicated that the melting point of the cocoa fat was relatively stable and affected by the change of triglycerides. Among the cocoa butters, CB1 had the highest melting point (33.8°C), and was statistically significant differences with other cocoa butters (p<0.05). The value of the melting point was as well relevant to the degree of saturation of fatty acid in the fat, which meant that the iodine value of the fats was highly correlated with the melting point. This could be proved through the fact that CB1 possessed the lowest iodine value.

Figure 3. Melting points of the analyzed crude cocoa butter samples
that of CB5 (1.03 meq kg\(^{-1}\) of fat) and CB6 (1.22 meq kg\(^{-1}\) of fat). The peroxide value increased from 60°C to 155° C, the peroxide value dropped from 2.88±1.12 meq kg\(^{-1}\) of fat, as shown in Figure 4. For unfermented cocoa beans, as the roasting temperature increased from 1.94 to 2.88 meq kg\(^{-1}\) of fat; yet there was no significant difference among the fats (p<0.05). For fermented cocoa beans, as the roasting temperature increased from 60°C to 155°C, the peroxide value dropped from 2.09 to 1.22 meq kg\(^{-1}\) of fat; the three fats did not show significant difference either (p>0.05). The peroxide value of CB1 was 1.94 meq kg\(^{-1}\) of fat, which was higher than that of CB5 (1.03 meq kg\(^{-1}\) of fat) and CB6 (1.22 meq kg\(^{-1}\) of fat). The higher peroxide value of CB1 represented a higher degree of oxidation. This was because cocoa butter obtained from unroasted cocoa beans was more susceptible to the action of enzymes such as lipases, hydrolases, and lipoxygenase. The reactions along with these enzymes could cause an increase in the amount of free fatty acid. As a result, the fat will be more easily oxidized. The result was similar to the study of Żyżelewicz, et al. [15]. They studied the peroxide value of the cocoa butter extracted from the cocoa beans in Togo, a country located in West Africa, under different roasting conditions. Their results reported that the peroxide value of the cocoa butter in the unroasted raw cocoa beans was higher than that extracted from high temperature roastedcocoa beans. CB5 and CB6 had a relatively low peroxide value, may be explained by the formation of antioxidant substances, such as vitamin E, during fermentation and roasting processes [20]. Another possible reason proposed by Mounjouenpou, et al. [2] was that cocoa beans after long time roasting would cause the formation of lipid peroxide. These unstable products would proceed with a fast cracking process, transform into alcohol, aldehyde, ketone, or acid in forms of monomer, polymers, or cyclic compounds, and eventually result in the decrease in peroxide value.

3.3. Fatty Acid Composition

The content of the 14 types of the fatty acid composition was shown in Table 3. The major composition of all the cocoa butter was basically these three kinds of fatty acids: palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acid, with its content 24.02-24.48%, 35.48-36.08%, and 34.83-35.37%, respectively. Another important fatty acid was linoleic acid (C18:2) with the content ranging from 2.58 to 3.29%. The above mentioned four fatty acids accounted for above 98% of the total fatty acids. The result was consistent with some of the studies [15,21,22]. They reported that the content of palmitic being 24-27%, stearic being 34-36% and oleic acid being 32-35%. Asep et al. [23] utilized the supercritical fluid extraction technique to extract cocoa fat from cocoa beans originated in Malaysia. Their results showed that the majority of fatty acid compositions were palmitic (28.03-33.70%), stearic (33.70-40.22%), and oleic (26.36-30.49%) acid. The amount of palmitic acid (24.02-24.48%) of the Taiwanese cocoa fat was apparently lower than that of Malaysia, implying that different countries with different growing conditions affect the composition of fatty acid in cocoa butter. Lipp and Anklam [24] reviewed the fatty acid profiles among different countries. They indicated that the amount of palmitic acid ranged from the lowest 24.1% (Java) to the highest 25.8% (Ivory Coast); stearic acid ranged from the lowest 33.3% (Brazil) to the highest 37.6% (Ghana); oleic acid the lowest 32.7% (Ghana) to the highest 36.5% (Brazil); linoleic acid the highest 3.5% (Brazil). In general, the fatty acid composition of Taiwanese cocoa butter was consistent with the findings reported by Lipp and Anklam [24].

CB1 had the highest total saturated fatty acid 61.75% and was significantly higher than the others. CB1 extracted from the unfermented and unroasted cocoa beans, and its melting point was the highest, 33.8°C, among all the others, as shown in Figure 3. CB1 possessed the highest content of palmitic acid (24.48%), while CB4 had the lowest palmitic acid content of 24.02%.

The amount of palmitic acid in Taiwanese cocoa butter was at the lower limit 24% reported by Gunstone and Harwood [21]. The highest content of stearic acid (36.08%) was present in CB1, while the lowest was present in CB3. The amount of stearic acid was very close to the amount in other countries around the world [22]. Lovegren et al. [25] demonstrated that the rich stearic acid in the triglycerides facilitated the initiation of the crystallization of cocoa butter. CB4 possessed the maximum content of oleic acid 35.37%, while the minimum content 34.83% was present in CB1. The amount of oleic acid of Taiwanese
cocoa butter exceeded or was very close to the upper limit of 35% reported by Gunstone and Harwood [21]. For linoleic acid, CB3 had the highest content which was 3.29% and was significantly higher than those of the others (p<0.05), and the lowest (2.58%) present in CB1. The content of other fatty acids including palmitoleic acid (C16:1), margaric acid (C17:0), arachidic acid (C20:0) and linolenic acid (C18:3) were in the range of 0.14-0.86% in tested cocoa butters. Moreover, traces of other fatty acids were also identified and quantified, as shown in Table 3.

| Fatty acid (%) | CB1      | CB2      | CB3      | CB4      | CB5      | CB6      |
|---------------|----------|----------|----------|----------|----------|----------|
| C14:0         | 0.08±0.01a | 0.08±0.01b | 0.08±0.01c | 0.08±0.01d | 0.09±0.01e | 0.09±0.01f |
| C16:0         | 24.48±0.1a | 24.22±0.18b | 24.16±0.12c | 24.02±0.14d | 24.36±0.05e | 24.34±0.09f |
| C16:1         | 0.14±0.01b | 0.22±0.07b | 0.14±0.01c | 0.2±0.09d | 0.15±0.01e | 0.3±0.01f |
| C17:0         | 0.22±0.02b | 0.18±0.01b | 0.31±0.03c | 0.18±0.01d | 0.18±0.01e | 0.16±0.01f |
| C17:1         | 0.02±0.0a | 0.02±0.0 | 0.02±0.0 | 0.02±0.0 | 0.02±0.0 | 0.02±0.0 |
| C18:0         | 36.08±0.1a | 35.97±0.19b | 35.48±0.16c | 35.96±0.16d | 35.66±0.17e | 35.54±0.14f |
| C18:1         | 34.83±0.04a | 35.02±0.03b | 34.89±0.04c | 35.37±0.11d | 35.25±0.06e | 35.22±0.07f |
| C18:2         | 2.58±0.05a | 2.66±0.04b | 3.29±0.02c | 2.6±0.02d | 2.63±0.06e | 2.69±0.03f |
| C20:0         | 0.8±0.03c | 0.73±0.02b | 0.86±0.03c | 0.76±0.01d | 0.76±0.01e | 0.76±0.01f |
| C18:3         | 0.18±0.03c | 0.17±0.01b | 0.22±0.01c | 0.17±0.01d | 0.18±0.01e | 0.17±0.01f |
| C20:1         | 0.04±0.01a | 0.04±0.01b | 0.05±0.01c | 0.05±0.01d | 0.04±0.01e | 0.05±0.01f |
| C22:0         | 0.07±0.01a | 0.05±0.01b | 0.04±0.01c | 0.04±0.01d | 0.05±0.01e | 0.05±0.01f |
| C22:1         | 0±0     | 0.01±0    | 0.01±0    | 0.01±0    | 0.01±0    | 0.01±0    |
| C24:0         | 0.02±0.0a | 0.04±0.01b | 0.01±0.01c | 0.02±0.08d | 0.02±0.0b | 0.03±0.01c |
| others        | 0.47±0.19a | 0.59±0.15b | 0.43±0.13c | 0.51±0.2d | 0.6±0.22e | 0.56±0.12f |
| Σ saturated   | 61.75±0.15a | 61.27±0.17b | 60.94±0.08c | 61.07±0.13d | 61.11±0.2e | 60.98±0.1f |
| Σ monounsaturated | 35.02±0.04a | 35.31±0.04b | 35.12±0.05c | 35.65±0.06d | 35.48±0.07e | 35.6±0.07f |
| Σ polyunsaturated | 2.76±0.07b | 2.83±0.05c | 3.51±0.03d | 2.77±0.03e | 2.81±0.06f | 2.86±0.03g |

Values are expressed as the means ± SD. Different letters in the same row indicate significantly different (p < 0.05).

4. Conclusions

The present study was successfully to extract crude cocoa butter from whole cocoa beans by mechanical press. CB5 had the highest oil yield of 79.9%, obtained from fermented beans roasted at 130°C for 25min, while CB1 had the lowest oil yield of 57.9%, obtained from unfermented and unroasted beans. The extraction yield is influenced by fermentation degree and roasting conditions. There were statistical differences in the physicochemical properties and fatty acid composition among the studied cocoa butters. The physicochemical parameters of six extracted cocoa butters were within the norms. Fermentation and roasting steps induced minor change in the composition of fatty acids of tested cocoa butter samples. To sum up, CB1 possessed characteristics of the highest melting point, the lowest iodine value, and the highest saturated fatty acid content among the tested cocoa butters, implying CB1 could be a high quality of cocoa butter. Furthermore, the valuable byproduct cocoa powder obtained from the production of CB1 by mechanical press was expected to be rich in polyphenol compounds, which are certainly beneficial to human health.

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Conflicts of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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