Lipid and Hardness Characteristics of Cocoa Butters from Different Geographic Regions

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Twenty-four commercially pressed cocoa butters and 39 laboratory solvent extracted cocoa butters were evaluated. A rapid method using differential scanning calorimetry (DSC) was used to evaluate the hardness of small quantities of cocoa butter. In the DSC thermogram of a quenched sample, the percentage area under the polymorph II endotherm had a positive correlation (r = 0.74) with the mechanical hardness. Soft cocoa butters were characterized by high POO, SOO content (P = palmitic acid, O = oleic acid, S = stearic acid), high iodine value, low percentage area under the polymorph II endotherm from the DSC scanning, and low SOS. Hard cocoa butters displayed opposite characteristics. In general, South American cocoa butters were the softest and had a 37.03 iodine value, a total of 9.1% POO and SOO, and a 26.4% area under the polymorph II endotherm. Cocoa butters from Asia and Oceania were the hardest and had a 34.74 iodine value, a total of 4.1% POO and SOO, and a 35.65% area under the polymorph II endotherm. North and Central American and African cocoa butters were intermediate in hardness characteristics.

Cocoa butter, which amounts to 25–36% in finished chocolate, is responsible for the smooth texture, contractability, flavor release, and gloss of the product. However, differences in physical characteristics, such as crystallization behavior and hardness of cocoa butters from various origins, have been observed. Generally, Malaysian cocoa butter is hard and has low iodine value (1), whereas Bahian (Brazil) cocoa butter is the opposite (2–5). Most cocoa butters were reported to have similar triacylglycerol compositions (4), but a variation in SOS content (S = stearic acid, O = oleic acid) has been reported (5). The differences in physical and chemical characteristics of cocoa butters could be caused by the climatic variation of cacao growing areas. Cocoa butter obtained from fruits grown at low temperature is soft and contains high diunsaturated triacylglycerols (6) and high unsaturated fatty acids, i.e., oleic and linoleic acid (2). Rainfall caused high concentrations of stearic acid, oleic acid, C56 triacylglycerol, and free fatty acid (7), but did not shown an effect on the iodine value (3). Sunlight, on the other hand, increased the palmitic acid content (7) and the iodine value of cocoa butter (3).

Cocoa butter exhibits six polymorphs in which polymorph I has the least stability and the lowest melting point. Stability and melting points of the polymorphs increase with transformations from polymorph I to VI. It is believed that these transformations occur in the liquid state except for the V → VI, which occurs in a solid state (8). Some evidence indicates that only four cocoa butter polymorphs actually occur. Polymorph III is believed to be a mixture of polymorph II and IV (8,9), with polymorph VI only a phase differing in composition (8,10). Differential scanning calorimetry (DSC) has been used to study polymorphic transitions of cocoa butter not only because it can measure changes in enthalpy during crystallization and melting, but also because it can monitor the tempering process. This is important because slight differences in tempering procedures, such as cooling rates, can effect the melting point of certain cocoa butter polymorphs due to a phase separation (8).

Hardness of cocoa butter is directly related to its melting properties. Cocoa butter hardness has been directly measured using a penetrometer (11). Indirect hardness determination can be performed using dilatometry, nuclear magnetic resonance (NMR), and DSC. Results are expressed as solid fat index (SFI) for the dilatometry and as solid fat content (SFC) for the NMR and DSC (12). Since hardness is an important characteristic for the final chocolate product in which the butter exists in polymorph V, cocoa butter has to be tempered to obtain this polymorph prior to the hardness test. The tempering process takes about 30 hr at 20–25°C (13), and takes for up to a month at 15°C (14). Therefore, it would be beneficial if other characteristics related to hardness could be determined without the time consuming tempering step.

In this study, cocoa butters from various origins were analyzed for triacylglycerol composition using HPLC, and hardness using penetrometry and a rapid DSC method.

EXPERIMENTAL

Sample preparation. Cocoa butters from different geographic regions used in this study were obtained by two methods—commercially pressed from roasted beans (n = 24), and laboratory extracted from unroasted beans (n = 39). The solvent extracted samples were obtained by refluxing the ground cocoa nibs with certified grade hexane for 20 hr. Nibs were obtained by deshelling the fermented and dried cocoa beans by hand. Hexane was removed using a rotary evaporator followed by a nitrogen stream to evaporate the solvent residue. It is necessary to ensure that the characteristic variations that were observed were due to regional differences and not to treatment differences.

To study the effect of extraction treatment, roasted (150°C/30 min) and unroasted cocoa bean samples from eight different origin countries were pressed and solvent extracted to obtain cocoa butter. Pressing was performed using a laboratory scale-hydraulic press at 60°C. Further analyses, including triacylglycerol composition and hardness of cocoa butter obtained from different extraction methods were conducted using the methods described below.

Refractive index (IUPAC 2.102). The n_D^{40} of commercial cocoa butters were read on an Abbé Refractometer (15).

Free fatty acid (IUPAC 2.201). Cocoa butter was weighed (10 ± 0.05 g) and titrated with standard 0.1 N ethanolic KOH (15).

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Iodine value (IUPAC 2.205). Iodine value was determined on 0.8 ± 0.001 g of commercial cocoa butter by the Hanus method (15).

Saponification value (IUPAC 2.202). Saponification value was determined on 2 ± 0.005 g of sample by refluxing the sample with 0.5 N ethanolic KOH and titrating with the standard 0.5 N HCl (15).

Triacylglycerol composition. Triacylglycerols of cocoa butters were evaluated according to the method previously described (16). Analyses were conducted with a HPLC pump and differential refractometer (Waters Assoc., Milford, MA, Model 401). The mobile phase, acetonitrile-chloroform 6:4 (v/v), was pumped at 0.7 ml/min through an Adsorbosphere C-18, 5 μm reverse phase column (Alltech Assoc., Deerfield, IL). A 10% (w/v) cocoa butter solution in chloroform was prepared for analysis. Standard SOO, POP, POS, and SOS (Supelco, Inc., Bellefonte, PA) were used for qualitative and quantitative purposes. Other triacylglycerols were identified by their retention volumes and comparison of chromatographic data with previous studies (4,17).

Differential scanning calorimetry (DSC). Five grams of laboratory solvent extracted samples and 30 g of commercial cocoa butters were melted at 60°C. Molten samples were mixed and 2-3 mg of the butter were transferred to DSC aluminum pans using a micropipet. The samples were tempered on the DSC-4 (Perkin Elmer Co., Norwalk, CT) head using a programmed temper cycle. The cycle consisted of melting the sample at 60°C for 2 min, quenching to 0°C, and holding at this temperature for 2 min. Analysis was conducted immediately by heating the sample from 0°C to 50°C at the rate of 20°C/min. The tempering step caused cocoa butters to crystallize in polymorph I and II. The area under the polymorph II endotherm was measured using a partial area program.

Penetrometry. The commercially pressed cocoa butters were completely melted at 60°C and dynamically crystallized using a magnetic stirrer at room temperature. After the slurry was formed, cocoa butters were poured into 7.5 × 7.5 × 2 cm^3 molds. The samples were then immediately cooled to 4-6°C for 1 hr before the temperature was alternated between 27°C and 31°C every 24 hr for a week, and then maintained at 31°C for another week. The tempered samples were tested for hardness using a Precision penetrometer (GCA Co., Chicago, IL) with a Precision 35 g-aluminum cone. The weight applied to the sample surface was 320 g for 12 sec at room temperature (25°C). The penetration depth was compared with the DSC data.

RESULTS AND DISCUSSION

Refractive index and chemical characteristics. Commercially pressed cocoa butters were analyzed for refractive index, percent free fatty acid (FFA), iodine value and saponification value. The results are shown in Table 1. There was little difference in refractive indexes among the commercial samples. The values ranged from a low of 1.4572 for the Panamanian sample to a high of 1.4580 for the Costa Rican butter. Average percent FFA of the commercial samples from different countries varied from 0.42% for the Mexican butter to 3.11% for the Peruvian sample. Most of the values of individual samples were less than 1.75%, which is the maximum value recommended by The Codex Alimentarius Commission of FAO/WHO. Only three individual samples from Ecuador, Malaysia and Peru had percent FFA above the limit, i.e., 1.94, 2.02, and 3.11%, respectively. High FFA can be caused by hydrolysis by lipase from mold contamination and an extended fermentation (5). The Mexican cocoa butter had

TABLE 1

Refractive Indexes (n_D^{40}) and Chemical Characteristics of Commercially Pressed Cocoa Butters from Different Origin Countries

Country	Number of samples	Refractive index (n_D^{40})	Free fatty acid (% oleic acid)	Iodine value	Saponification value
Bolivia	1	1.4576	0.84	36.02	195.43
Brazil	4	1.4578[a] ±0.0002	0.91[a] ±0.05	37.46[a] ±1.31	195.07[a] ±1.47
Colombia	2	1.4579 ±0.0001	1.07 ±0.29	36.56 ±2.20	195.75 ±0.04
Ecuador	2	1.4579 ±0.0001	1.42 ±0.73	36.68 ±0.04	195.85 ±0.45
Peru	1	1.4577	3.11	37.94	195.92
Costa Rica	1	1.4580	0.72	36.64	195.27
Dominican Republic	2	1.4578 ±0.0001	0.88 ±0.01	36.72 ±0.07	194.92 ±0.32
Mexico	1	1.4576	0.42	35.79	193.72
Panama	1	1.4572	1.07	36.86	196.71
Ivory Coast	5	1.4577 ±0.0004	1.36 ±0.18	35.54 ±1.15	193.58 ±1.16
Nigeria	1	1.4579	1.21	37.33	193.62
Malaysia	3	1.4579 ±0.0005	1.44 ±0.42	34.74 ±0.34	194.36 ±0.12

[a]Mean ± S.D. where more than one sample available.

0.42% FFA which was significantly lower than other samples and could be a result of under fermentation.

Iodine value is useful in determining degree of hardness, since high iodine values indicate high content of unsaturated fatty acid components which contribute to the softness in cocoa butter. Iodine values of individual commercial samples varied from 34.40 to 38.65. Cocoa butters from Peru, Brazil, and Nigeria had significantly higher iodine values, i.e., 37.94, 37.46, and 37.33, respectively. Hence, these latter samples had a tendency to be softer than the others. Malaysian cocoa butter, on the other hand, had the lowest iodine value of 34.74. Cocoa butters from Ivory Coast, Mexico, and Bolivia were also low in iodine value.

Individual samples had saponification values ranging from 192.47 to 197.09. Cocoa butter from Panama had a significantly higher saponification value (196.71) than the others, whereas those from Ivory Coast, Mexico, Malaysia, and Nigeria had significantly lower values, i.e., 193.58, 193.72, 194.36 and 193.62, respectively.

Triacylglycerol composition. Both commercially pressed cocoa butters and laboratory solvent extracted bean samples were analyzed for their triacylglycerols. Nine triacylglycerols, namely, PLiP, POO, PLiS, POP, SOO, SLiS, POS, SOS, and SOA (P = palmitic acid, Li = linoleic acid, A = arachidic acid) were quantified (Fig. 1). The chromatogram shows trace amounts of PLiO, OOA + PPS, and PSS. Triacylglycerol compositions of cocoa butters from different countries are listed in Table 2. The major triacylglycerols, POP, POS, and SOS, ranged between 17.5-22.6%, 35.8-41.4%, and 22.8-31.3%, respectively. The amounts of POO, SOO, and SLiS varied among the samples from different countries, whereas PLiP, PLiS, and SOA were constant.

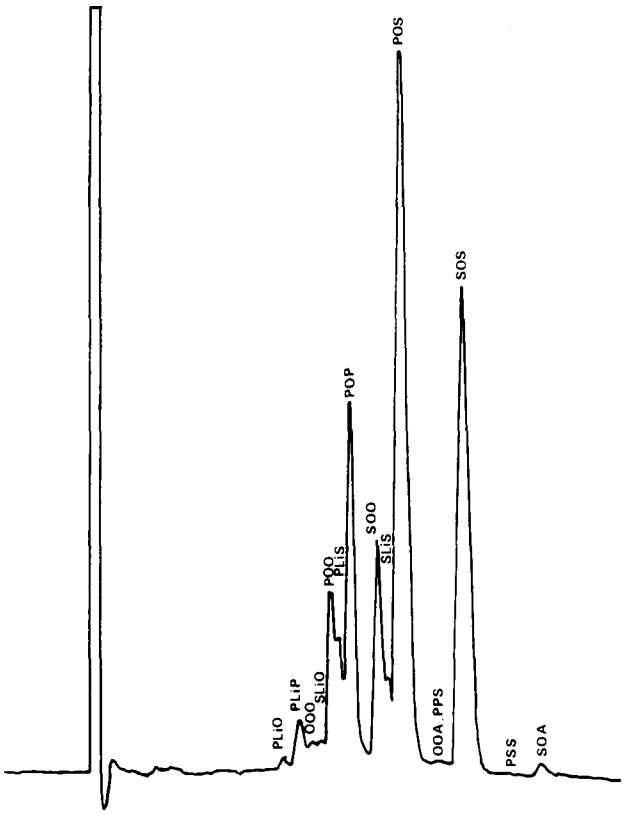

FIG. 1. HPLC chromatogram of cocoa butter triacylglycerols.

Cocoa butter with a high concentration of diunsaturated triacylglycerols have been shown to be soft (6). Double bonds in the fatty acids in the Sn-3 position of diunsaturated triacylglycerols cause extra kinking in the structures that interrupt molecular packing of the major components, monounsaturated triacylglycerols (18). In this experiment, Bahian cocoa butters, which are known for their softness (2,3,6), contained an average of 15% POO and SOO combined. Other soft cocoa butters which contained high POO + SOO (>8%) were from Brazil, Peru, Dominican Republic, Cameroon and Gabon. Hard butters with less than 5.2% POO + SOO were from Venezuela, Indonesia, Malaysia and Solomon Islands. It should be noted that cocoa butters which were low in POO + SOO were concomitantly high in POS and SOS, especially cocoa butters from Malaysia and Solomon Islands.

Hardness. Cocoa butter hardness has been determined by means of solid fat content (SFC) using nuclear magnetic resonance (NMR) and differential scanning calorimetry (DSC) (12). In this experiment, cocoa butter hardness was determined by a mechanical method using a penetrometer on tempered samples, and the SFC was determined by DSC. The results indicate that there was low correlation (r = 0.62) between SFC at 20°C of the tempered sample and the penetration data. A similar study was also performed on quenched cocoa butters. In the quenching procedure, cocoa butters were melted at 60°C and then rapidly cooled to 0°C on the DSC head. This rapid cooling resulted in crystallization of cocoa butter in polymorph I. Holding a quenched cocoa butter at 0°C for 2 min allows polymorphic transition of the fraction from form I to form II. The DSC thermograms (Fig. 2) show that hard butters had higher percentage area under the polymorph II endotherm than those of the soft butters. This was supported by a correlation (r = 0.74) between the percentage area of polymorph II endotherm of the quenched samples and the penetration data of the tempered samples (Fig. 3). The correlation indicated that the hard cocoa butters had a faster transformation rate from polymorph I to polymorph II. Evaluation of hardness using rapid quenching of the cocoa butter on the DSC head permitted short tempering time, small sample size, and better correlation with the mechanical hardness than SFC at 20°C. This method would be useful in evaluating hardness of cocoa butters due to its rapidity, and where small amounts of samples are available.

Table 2 shows the average percent area under the polymorph II endotherms of cocoa butters from different countries. The higher percent area under the polymorph II endotherm represents the harder cocoa butter. Data suggest that cocoa butters from Bolivia, Solomon Islands and Malaysia, which had percent areas under polymorph II endotherm of 44.91, 42.93, and 36.02%, respectively, were significantly harder than the others. Cocoa butters from Venezuela and Mexico with the values of 32.15% and 32.12% were also considerably harder. Brazilian, Costa Rican, Nigerian, and Gabonese cocoa butters had low percent areas, i.e., 22.13, 21.89, 21.71, and 16.60%, respectively. These samples were softer. Hardness of cocoa butters from Ecuador, Dominican Republic, Cameroon, Peru, and Guatemala was intermediate with the

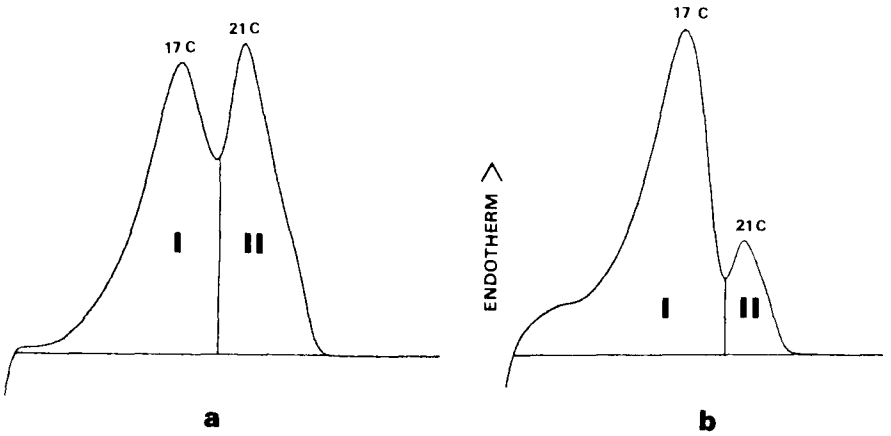

FIG. 2. DSC thermograms of hard cocoa butter (a) and soft cocoa butter (b) tempered on the DSC head and scanned from 0 to 50°C at 20°C/min. Polymorph I and II show peak maxima at 17°C and 21°C, respectively.

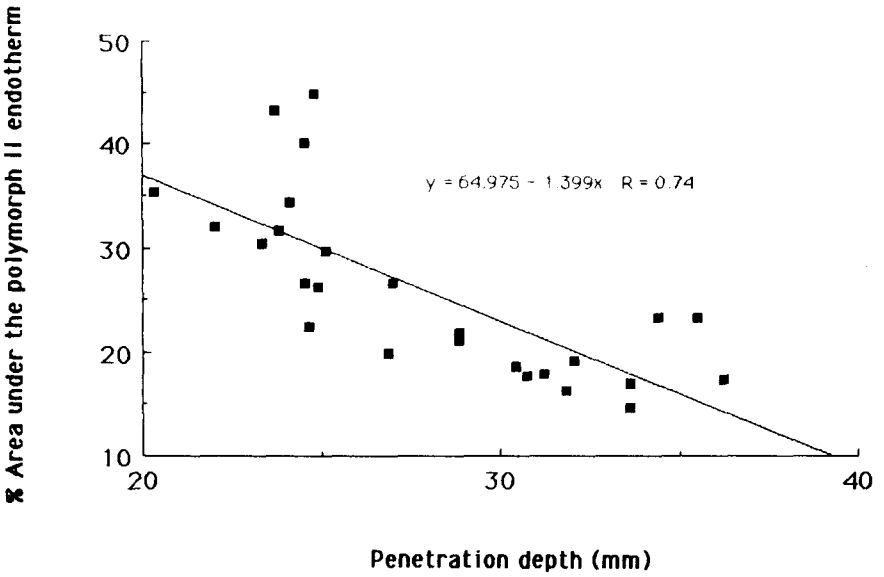

FIG. 3. Relationship between penetration depth and percent area under the polymorph II endotherm.

TABLE 2

Triacylglycerol Compositions of Cocoa Butters from Different Origin Countries

Cocoa butter	Number of samples	Triacylglycerol (%)									Percent area of the polymorph II endotherm
		PLiP	POO	PLiS	POP	SOO	SLiS	POS	SOS	SOA	
Bolivia	1	1.1	3.3	3.5	22.6	4.0	2.1	40.4	22.8	0.5	44.94
Brazil	6	0.9	3.9	3.7	17.9	6.7	3.2	37.1	26.0	0.04	22.13 ± 8.88[a]
Colombia	2	1.1	3.3	3.6	20.4	4.4	2.3	39.4	25.0	0.6	28.93 ± 7.83
Ecuador	3	1.2	3.0	3.2	19.2	5.4	2.3	38.4	26.9	0.4	26.14 ± 0.64
Peru	1	1.5	4.3	3.9	18.3	7.4	3.7	35.8	24.6	0.4	23.48
Venezuela	1	0.9	1.0	3.1	20.4	2.8	1.9	40.4	28.8	0.8	32.15
Costa Rica	1	1.0	2.6	3.5	17.8	5.5	3.0	38.7	27.4	0.4	21.89
Dominican Republic	4	1.1	3.3	3.2	18.4	6.1	2.7	38.2	26.5	0.6	24.99 ± 4.36
Guatemala	1	1.0	2.3	3.4	19.3	4.9	2.2	39.0	27.5	0.4	23.46
Mexico	1	1.1	2.4	3.5	19.1	4.1	3.0	38.8	27.8	0.6	32.12
Panama	1	1.0	1.5	3.0	19.1	3.1	2.7	41.4	27.3	0.8	30.41
Cameroon	2	1.0	3.0	3.4	17.9	5.8	2.5	38.3	27.7	0.5	24.32 ± 1.00
Gabon	1	0.9	3.7	3.5	17.5	7.3	3.0	37.1	26.5	0.4	16.60
Ghana	3	1.2	2.2	3.4	17.8	4.9	2.2	39.0	27.5	0.4	30.29 ± 9.29
Ivory Coast	9	1.0	1.9	3.0	19.0	3.9	2.5	39.6	28.5	0.6	31.79 ± 7.83
Nigeria	2	1.0	2.3	3.6	17.9	5.2	3.0	38.8	27.8	0.5	21.71 ± 5.35
Indonesia	2	1.1	1.6	3.0	19.9	3.6	1.7	40.6	28.1	0.5	28.38 ± 12.23
Malaysia	20	0.7	1.2	2.8	18.4	2.9	2.2	40.0	31.1	0.8	36.02 ± 5.34
Solomon Islands	1	1.0	0.9	3.0	19.3	2.8	2.0	40.7	29.5	0.7	42.93

[a]Mean ± S.D. between samples of the same country.

percent areas under the polymorph II endotherm ranging from 23.46–26.14%. However, there was a wide variation among samples from the same country, especially those from Brazil, Colombia, Ghana, Ivory Coast, and Indonesia. The variation of hardness within the same country could be caused by the different ambient temperature in the production area and the different varieties of cacao trees. The other possible causes of variation could be the difference in degree of moldiness which may affect the free fatty acid and diacylglycerol content of cocoa butter.

Effect of extraction method. Both roasted and unroasted beans of eight different samples were subjected to pressing and solvent extraction. Triacylglycerol compositions and hardness of cocoa butters obtained from different treatments are shown in Table 3. The results indicate that there were little differences in triacylglycerol compositions among treatments. The hydraulically pressed cocoa butters from unroasted beans were significantly higher in POS and SOS when compared to the solvent extracted butters from roasted beans. Concomitantly with higher POS and SOS content, the pressed cocoa butter from unroasted beans were lower in POO and SOO, although not significantly. The data also confirm that pressed cocoa butter from roasted beans and solvent extracted butters from unroasted beans had no major differences in triacylglycerol composition in this study. Only 0.1% difference in PLiP content was observed. In addition, treatments such as roasting and solvent extraction showed no effect on hardness evaluated by the rapid DSC method.

Regional differences. Cocoa butters from the same region were similar in characteristics. The results from Table 4 showed that refractive indexes were constant among cocoa butters from different regions. South American, African, and Asian cocoa butters were similar in their FFA contents which were 1.25, 1.27, and 1.44, respectively. On the other hand, North and Central American cocoa butters were significantly low in FFA ($P<0.05$) with an average of 0.79%. In this case, FFA could be low due to the fact that Central American cocoa beans had lower degree of fermentation than the beans from other regions (19).

Cocoa butters from South America also showed the highest iodine value (37.03) which was the result of their highest diunsaturated triacylglycerol content (Table 5). Cocoa butters from Asia and Oceania had significantly lower iodine values due to their low diunsaturated triacylglycerol content. Table 5 shows triacylglycerol composition of cocoa butters from each region. South American cocoa butters had the highest POO and SOO content (9.1% combined). They were concomitantly the lowest in POS, SOS and SOA. In contrast, cocoa butters from Asia and Oceania had the lowest POO and SOO content (4.1% combined), but had the highest amount of POS, SOS and SOA.

Table 5 shows the percent areas of the polymorph II endotherm obtained from DSC thermograms of cocoa butters from different regions. The significantly higher area of the polymorph II endotherm of cocoa butters from Asia and Oceania implies that cocoa butters from this region

TABLE 3

Triacylglycerol Composition and Percent Area Under the Polymorph II Endotherm of Cocoa Butters Obtained from Roasted and Unroasted Beans Using Hydraulic Press and Solvent Extraction Methods

Treatment	Triacylglycerol (%)									Percent area of the polymorph II endotherm
	PLiP	POO	PLiS	POP	SOO	SLiS	POS	SOS	SOA	
Unroasted										
Pressed	1.0A[a]	1.9A	2.3A	17.9A	3.4A	2.3AB	41.5A	29.4A	0.6A	29.89A
Solvent extracted	1.1B	2.6A	3.4B	18.5A	4.3A	2.4AB	39.4AB	27.6B	0.6A	29.85A
Roasted										
Pressed	1.0A	2.4A	3.3B	18.1A	4.7A	2.1B	40.1AB	27.5B	0.6A	28.25A
Solvent extracted	1.1B	2.5A	3.5B	18.7A	4.9A	2.6A	38.9B	27.3B	0.6A	28.11A

[a]Means of eight samples followed by different capital letters are significantly different in the same column ($P < 0.05$).

TABLE 4

Refractive Indexes (n_D^{40}) and Chemical Characteristics of Commercial Cocoa Butters Classified by Region

Region	Number of samples	Refractive index[a]	Free fatty acid[a] (% oleic acid)	Iodine value[a]	Saponification value[a]
South America	10	1.4578 A ± 0.0002	1.26 A ± 0.71	37.03 A ± 1.16	195.48 A ± 0.97
North and Central America	5	1.4577 A ± 0.0003	0.79 B ± 0.23	36.54 AB ± 0.62	195.11 AB ± 1.12
Africa	6	1.4578 A ± 0.0004	1.27 A ± 0.30	35.84 BC ± 1.59	193.59 C ± 1.15
Asia and Oceania	3	1.4579 A ± 0.0004	1.44 A ± 0.38	34.74 C ± 0.32	194.36 BC ± 0.58

[a]Mean ± S.D. followed by different capital letters are significantly different in the same column ($P > 0.05$).

TABLE 5

Triacylglycerol Composition and Percent area of the Polymorph II endotherm of Cocoa Butters Classified by Region

Region	Number of samples	Triacylglycerol (%)[a]									Percent area of the polymorph II endotherm
		PLiP	POO	PLiS	POP	SOO	SLiS	POS	SOS	SOA	
South America	15	1.1A[a]	3.4A	3.5A	19.0A	5.7A	2.8A	38.0A	26.0A	0.5A	24.40 ± 8.46A
North and Central America	8	1.0A	2.7B	3.3AB	18.6A	5.3AB	2.7A	38.9B	26.9A	0.6AB	25.98 ± 4.35A
Africa	17	1.0A	2.2C	3.2B	18.4A	4.7B	2.5A	39.1B	28.2B	0.6B	28.51 ± 8.03A
Asia	24	0.8B	1.2D	2.9C	18.6A	2.9C	2.2AB	40.0C	30.8C	0.8C	35.65 ± 6.60B

[a]Mean within the same region followed by different capital letters are significantly different in the same column ($P < 0.05$).

were harder than those of the other regions. There was no significant difference in areas of the polymorph II endotherm of the samples from South America, North and Central America or Africa. This was the result of wide variations among samples from the same regions.

Overall, cocoa butters from South America had characteristics and compositions close to those of the North and Central American butters except for higher percent FFA, POO, and lower POS content. They were significantly different from Asian and African cocoa butters in saponification value, iodine value, hardness and triacylglycerol composition. African samples had compositions similar to the North and Central American cocoa butters, except for higher SOS and lower POO concentrations.

Generally, hard cocoa butter originates from beans grown in the Far East and Oceania. This characteristic is fairly consistent due to the uniform climate. In this region, rainfall is evenly distributed and temperature is consistent throughout the year. More important, monthly mean maximum temperatures remain high at 30–33°C, whereas monthly mean minimum temperatures seldom fall below 20°C (20). It has been reported that cocoa pods developed at high temperatures contain less unsaturated fatty acids than those grown at lower temperatures (6). As a result, there is less diunsaturated triacylglycerols to interrupt the molecular packing of the monounsaturated types. Cocoa butters from South America, especially those from Bahia, Brazil, were softer. In Bahia, average minimum temperatures usually fall into the teens during June through September. Other countries in South America, e.g., Colombia, Ecuador, and Peru also have a period where temperatures are in the teens during the night (21). Temperatures are low enough to promote a high unsaturated fatty acids content and cause softness in cocoa butters from this region. Hardness of cocoa butters from Africa is intermediate. Average minimum temperatures in West Africa are fairly constant at 20–22°C, but the average maximum can fall to 27–29°C during the wet season (20). In South America and West Africa, cacao trees are cultivated in more expanded areas and different altitudes resulting in large temperature variations. Hence, greater variations in cocoa butter hardness may be expected. Although it seems that cocoa butter hardness is affected by climate, different cacao varieties may also result in different cocoa butter hardness (7). There are many hybrid varieties that are developed to suit local growing conditions. However, there are no conclusive hardness characteristics of cocoa butters from different subspecies or varieties.

In this study, a rapid method using DSC to evaluate cocoa butter hardness was used. This method provided a better correlation with the mechanical hardness than the SFC at 20°C, required only 2–3 mg sample and could be conducted in less than 10 min; hence, it is useful where an estimate of hardness is needed.

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