Confectionery Fats from Palm Oil and Lauric Oil

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ABSTRACT

In the search for economical cocoa butter alternatives, palm and lauric oils have emerged as important source oils in the development of hard butters. Based on the method presented for categorizing hard butters, the lauric oils, primarily palm kernel and coconut, can be modified by interesterification and hydrogenated to yield lauric cocoa butter substitutes (CBS) which are both good eating and inexpensive. Fractionation, although adding to the cost of production, can provide lauric hard butter with eating qualities virtually identical to cocoa butter. Unfortunately, one factor identified with the lauric oils is their very low tolerance for cocoa butter.

Palm oil, on the other hand, has been identified as a valuable component in all types of cocoa butter alternatives. It is a source of symmetrical triglycerides vital in the formulation of a cocoa butter equivalent (CBE). It can be hydrogenated or hydrogenated and fractionated to yield hard butters with a limited degree of compatibility with cocoa butter, allowing some chocolate liquor to be included in a coating for flavor enhancement. Palm oil is used with lauric oils as a minor component in interesterified lauric hard butters, as well as functioning as a crystal promoter in coatings formulated with a fractionated lauric CBS. While palm oil's importance and flexibility have been duly noted, some important concerns remain from a market perspective. The fact that the CBE fats are very expensive suggests they offer limited cost savings compared to cocoa butter. The potential for CBE products is still questionable in those countries where chocolate labeling standards preclude the use of vegetable fats other than cocoa butter. The nonlauric CBS products, while cheaper than the CBE types and able to tolerate limited levels of cocoa butter, do not exhibit the level of eating quality characteristics present in the lauric hard butters.

Some challenges remain for today's oil chemists. An economical nonlauric CBS, made predominantly from palm oil, possessing the eating quality of a fractionated lauric CBS and exhibiting good compatibility with cocoa butter would be met with considerable interest by the chocolate and confectionery industries. As for the lauric oils, it would seem reasonable to assume that greater cocoa butter compatibility, if attainable, could enhance their potential for gaining even greater acceptance by confectionery manufacturers currently using pure chocolate. As for the CBE products, the major issue is cost. If the cost of a CBE could be reduced to a level which would allow a CBE to compete with the nonlauric and lauric cocoa butter substitutes, a major advancement in the evolution of cocoa butter alternative fats will have been achieved.

INTRODUCTION

Fats and oils from various sources are important ingredients in the manufacture of many confectionery products. While fats and oils serve a variety of purposes in the production of chocolate and confectionery items, no application for fats and oils has received more attention than the development of vegetable fats for use as cocoa butter replacers.

The opportunity for vegetable fats to replace cocoa butter in chocolate and confectionery applications exists due to the volatility in cocoa butter prices brought on by an uncertain availability of cocoa beans from year to year. While the supply of cocoa beans is difficult to predict, demand is not. The world demand for chocolate and chocolate-type products does not appear to be diminishing. To the contrary, demand is expected to grow in the years and decades ahead (1). Therefore, one could conclude that the need for economical cocoa butter alternative fats appears to be assured.

As oil chemists continue to search for raw materials and processing methods which can be used to produce fats with characteristics similar to cocoa butter, it is apparent that palm and lauric oils are among the vegetable oil sources of significance in the formulation of cocoa butter alternatives currently available. These cocoa butter replacement fats are commonly called "hard butters" (2).

APPLICATIONS

Hard butters are well suited for a variety of confectionery applications. Specialty fats formulated from palm and lauric oils are used in cream centers where the fat provides "stand-up" properties to the confection, while maintaining good eating quality due to its narrow melting range. Hard butters are also used as binders in the formulation of granola bars. In taffy and caramel, the hard butter performs a lubricating function which prevents the confection from sticking to teeth and dentures (3). However, the primary application for hard butters is in the formulation of coatings for use on confections, bakery products and other snack foods (4). Because of the significant size of the coating market and the future potential it represents, most of the effort relative to the formulation and processing of hard butters has been concentrated on the development of products with comparable physical and/or functional characteristics to cocoa butter.

Coatings formulated with a fat system other than cocoa butter are called confectionery coatings or compound coatings. Compound coatings may be formulated with a combination of cocoa butter and compatible hard butter as the fat phase, or with hard butter as a total replacer of cocoa butter in the coating. Hard butters are also used in the formulation of nonchocolate coatings, available in various colors and flavors, called pastel coatings. While compound and pastel coatings are most often used to enrobe confections and bakery products, coatings are also molded or deposited, as in the production of baking chips or "cookie drops" (5). In the United States, unlike some other countries, no vegetable fats other than cocoa butter may be present in a coating labeled "chocolate." Sweet chocolate and milk chocolate are protected by specific standards of identity established by the Federal Food and Drug Administration (6).

CHARACTERISTICS

Of all the ingredients included in a coating, none has a greater influence on the characteristics of a coating than the fat phase. The function of the coating fat is to provide the continuous matrix that holds the other ingredients and contributes to flavor, aroma and color in an acceptable form prior to consumption. This fat matrix must be firm and dry to the touch at ambient temperatures, not greasy or sticky. Upon consumption, this fat matrix should melt away quickly and completely at or near body temperature. Failure of the coating fat to melt rapidly will result in poor flavor release and probably a waxy aftertaste (7).

Cocoa butter is characterized by high solid fat content at ambient temperatures as indicated by the solid fat index (SFI) as shown in Table I. However, cocoa butter has a very sharp melting curve. The Wiley melting point of cocoa butter is below body temperature, typically about 34 C (8). In addition, it is resistant to oxidation (9). Therefore, it is the cocoa butter that gives chocolate its excellent eating quality, brittleness or "snap" at ambient temperature, excellent molding characteristics and long shelf life. In addition, when properly tempered, chocolate exhibits excellent gloss and gloss retention. Several types of hard butters have

TABLE I

Comparison of Cocoa Butter to Lauric and Nonlauric CBS

Solid fat index	Cocoa butter	Nonlauric CBS Hydrogenated	Nonlauric CBS Fractionated	Lauric CBS Interesterified			Lauric CBS Fractionated	
10.0 C	76	60	70	66	68	70	72	77
21.1 C	73	48	60	54	55	58	70	75
26.7 C	62	39	54	38	42	46	54	68
33.3 C	10	18	24	8	14	20	2	11
37.8 C	0	4	3	0	3	8	0	–
Wiley melting point	34 C	39 C	38 C	35 C	39 C	43 C	34 C	36 C

been developed which duplicate the characteristics of cocoa butter to a greater or lesser degree.

TYPES OF HARD BUTTERS

Much has been written about the proper classification of hard butters. In fact, entire articles have been written on this subject, and classification models have been presented in the context of other topics (10). While all classification models have been based on acceptable rationale, the issue can be confusing, if not for the oil chemist, often for the coating manufacturer or the coating user.

Categorizing hard butters based upon the dominant properties of the source oils present in each is a meaningful approach to establishing an understanding of the various hard butters being manufactured and marketed. Applying this method, three major categories emerge: lauric cocoa butter substitutes (lauric CBS), nonlauric cocoa butter substitutes (nonlauric CBS), and cocoa butter equivalents and extenders (CBE). These categories may be further subdivided to reveal a wide variety of hard butter products. Palm oil and/or lauric oils are important raw materials in the formulation of all types of hard butters.

CBE

Cocoa butter equivalents are reported to be completely compatible with cocoa butter and therefore may be combined with cocoa butter in any ratio in the formulation of a coating (11). Cocoa butter extenders are also highly compatible with cocoa butter. Extenders are generally used at a legislated maximum allowable level in countries that allow the use of vegetable fats other than cocoa butter in products labeled "chocolate" (12). By definition, equivalents may also be used as extenders. To best understand the CBE fats, a review of the basic chemistry of cocoa butter is desirable as a point of reference.

Cocoa butter is composed of three predominant fatty acids: palmitic, stearic and oleic. As shown in Table II, these fatty acids combined typically account for over 95% of the fatty acids present in cocoa butter (13). It is the unique symmetrical positioning of these fatty acids that is attributable for cocoa butter's desirable characteristics (13). An analysis of the triglyceride composition of cocoa butter indicates the presence of approximately 74% symmetrical triglycerides with saturated fatty acids in the one and three positions, and an unsaturated fatty acid in the center, or two position (11). These mono-oleo disaturates are predominantly stearic-oleic-stearic (SOS), palmitic-oleic-palmitic (POP), and palmitic-oleic-stearic (POS).

From this evaluation of cocoa butter, it is logical to assume that if vegetable fats possessing significant levels of identical or very similar symmetrical triglycerides could be identified, and a procedure could be employed to isolate these components, then these cocoa butter-like triglycerides could be combined in appropriate proportions to yield a vegetable fat with a chemical composition extremely close to the triglyceride composition of cocoa butter. The CBE hard butters are the result of this logic (11).

TABLE II

Cocoa Butter Compared to CBE Source Oils

Fatty acid	Typical fatty acid composition (percent) Cocoa butter	Shea	Illipe	Palm
C-12:0	trace	0.5	trace	0.1
C-14:0	0.7	0.6	0.3	1.2
C-16:0 (palmitic)	25.2	4.2	17.5	46.8
C-18:0(stearic)	35.5	40.6	45.8	3.8
C-18:1 (oleic)	35.2	47.3	35.2	37.6
C-18:2	3.2	5.4	0.7	10.0
C-18:3	0.2	trace	trace	trace
C-20:0	trace	trace	trace	trace

Triglycerides	Typical triglyceride composition (percent) Cocoa butter	Shea	Illipe	Palm
P-O-P	12.0	0.3	6.6	25.9
P-O-S	34.8	6.4	34.3	3.1
S-O-S	25.2	29.6	44.5	nil
Other	2.2	nil	nil	1.3
Total symmetrical mono-oleo disaturates	74.2	36.3	85.4	30.3

Source oils identified as having significant levels of the desired symmetrical triglycerides include palm, illipe, shea, sal, kokum and allanblackia. As shown in Table II, palm oil is particularly rich in POP (approximately 26%) and contains lesser amounts of POS (approximately 3%). Modification of palm oil by double fractionation yields a palm mid-fraction (PMF) with concentrated levels of POP and POS. In commercial practice, it is not practical to produce a palm mid-fraction containing only symmetrical triglycerides. Typically, palm mid-fraction contains undesirable triglycerides such as PPP, PPO and POO. These undesirable triglycerides, if retained with the palm mid-fraction at significantly high levels, will adversely affect the melting point and solid fat content of the fraction and the quality of the CBE. Care must be taken during fractionation to minimize these undesirable triglycerides in the palm mid-fraction (13).

In the formulation of a cocoa butter equivalent, the POP rich palm mid-fraction is blended with vegetable fats rich in SOS and POS fractions. Typically, illipe and shea are used as sources of SOS and POS. Table II shows the typical SOS and POS content of these oils. Illipe shows very high levels of mono-oleo disaturated symmetrical triglycerides and may be blended with other components without modification. Shea, on the other hand, requires fractionation to provide a source rich in SOS and POS. By carefully blending these various sources, it is possible to produce a cocoa butter equivalent that may be combined with cocoa butter in any ratio in the formulation of a compound coating.

A typical dark sweet chocolate might be formulated by blending 32% chocolate liquor, 14.6% cocoa butter, 53% sugar and 0.4% lecithin. The chocolate liquor is approximately 52% cocoa butter and 48% cocoa solids. Thus the total fat content of the coating would be approximately 31.2% (14.6% cocoa butter plus 16.6% contributed by the chocolate liquor). A completely compatible cocoa butter equivalent could be used to replace the 14.6% cocoa butter in the formula. The resulting coating would function essentially the same as chocolate. However, the coating containing the CBE could not be labeled chocolate in most cases. The term "supercoating" has been used to describe such a coating. Proponents of this approach suggest that cocoa butter varies in its quality and that a CBE of consistent quality could be advantageous to the chocolate manufacturer since the performance of a "supercoating" would be very predictable.

A cocoa butter extender is formulated from the same components as a cocoa butter equivalent. However, the extender may not require the same ultimate level of compatibility with cocoa butter. For example, a higher portion of palm mid-fraction might be used to formulate a cocoa butter extender (12,13). Because of the more economical nature of palm oil due to its much greater availability than shea fraction and illipe, it is possible to produce an extender at a marginally lower cost than an equivalent. A cocoa butter extender may be used at a 5% maximum level in coating and still be labeled "chocolate" in the United Kingdom, Ireland, Denmark and Japan. The European Economic Community (EEC) countries of West Germany, France, Luxembourg, Italy, Belgium and Holland have recently received a proposal defining the chemical composition limitations for cocoa butter extenders which, if adopted, would allow up to 5% CBE in products labeled "chocolate" (11,12).

While the use of cocoa butter equivalents and extenders has been well documented in some countries, it is still very questionable, if not doubtful, that CBE hard butters will be widely accepted in the United States in the near future, regardless of the outcome of the proposal before the EEC (8). Certainly, examples of their use in the United States can be cited. However, there does not appear to be strong support among the chocolate manufacturers in the United States to embrace a change in the current chocolate standards of identity. While the "supercoatings" are recognized as very high-quality compound coatings, they are also very expensive even though they may cost slightly less to produce than chocolate (see Table III). Apparently, in the United States manufacturers are not ready to pay a relatively high price for a coating which cannot be labeled chocolate, when compound coatings formulated with other hard butters are less costly and are apparently well accepted by consumers (14).

NONLAURIC CBS

Nonlauric cocoa butter substitutes are made from partially hydrogenated nonlauric source oils. In the United States, these source oils are predominantly soybean and cottonseed oils. However, partially hydrogenated palm oil may be used in these hard butters, normally at relatively low levels blended with partially hydrogenated soybean and cottonseed oils. Nonlauric hard butters can be segmented into two types: hydrogenated nonlauric CBS, and hydrogenated and fractionated nonlauric CBS.

Nonlauric cocoa butter substitutes produced by hydrogenation only fall far short of meeting the physical and functional properties of cocoa butter. As seen in Table I, a typical hydrogenated nonlauric CBS exhibits much lower solid fat content, as indicated by the solid fat index, at ambient temperatures compared to cocoa butter. Unfortunately, at temperatures near and above body level, this type of hard butter exhibits solid fat content substantially above cocoa butter. This difference can also be ascertained by comparing the typical Wiley melt points. The solid fat index and Wiley melt point of a typical hydrogenated nonlauric CBS indicated a hard butter that is soft at ambient temperatures and exhibits a wide melting range as opposed to the narrow melting range of cocoa butter (see Fig. 1).

When a hydrogenated nonlauric CBS is used in a compound coating as a total substitute for cocoa butter, the coating is characterized by poor flavor release and mouth feel. In addition to poor eating quality, compound coatings formulated with this type of hard butter exhibit poor "snap" due to their characteristically low solid fat content at ambient temperatures. Hydrogenated nonlauric cocoa butter substitutes also display a low coefficient of contraction resulting in poor mold release and may exhibit a tendency to stick to conveyor belts.

However, these hard butters do have some redeeming features. They have fair to good gloss, and are resistant to oxidation, which accounts for their good shelf life. An

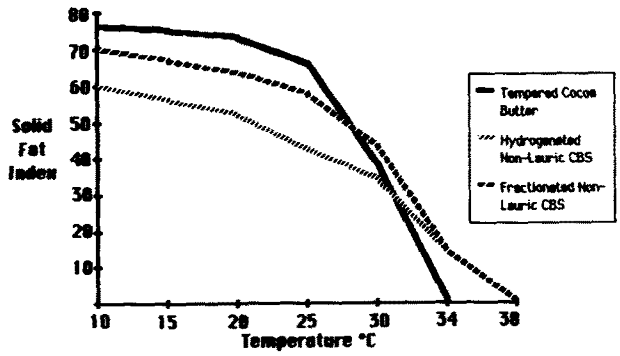

FIG. 1. Dilatation curves of cocoa butter and typical nonlauric CBS.

TABLE III

Properties of Coatings Made with Cocoa Butter Alternatives

Properties	Chocolate	Cocoa butter equivalent	Cocoa butter extender	Hydrogenated nonlauric CBS	Fractionated nonlauric CBS	Interesterified lauric CBS	Fractionated lauric CBS
Flavor release	excellent	excellent	excellent	poor	good	good	excellent
Mouth feel	excellent	excellent	excellent	poor	fair	good	excellent
Texture "snap"	excellent	excellent	excellent	poor	fair	good	excellent
Mold/belt release	excellent	excellent	excellent	poor	good	good	excellent
Gloss	excellent	excellent	excellent	fair	good	good	good
Oxidative stability	excellent	good	good	good	good	excellent	excellent
Temper/nontemper	temper	temper	temper	nontemper	nontemper	both	both
Cocoa butter compatibility		complete	very high	limited	25% max.	6% max.	6% max.
Relative cost		very expensive	expensive	very inexpensive	moderate	inexpensive	moderate

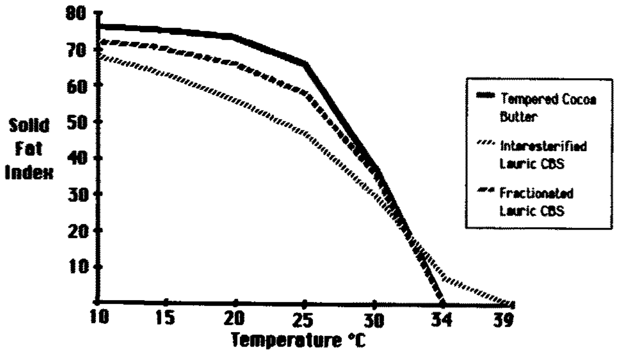

FIG. 2. Dilatation curves of cocoa butter and typical lauric CBS.

advantage in using a compound coating formulated with a hydrogenated nonlauric CBS is the elimination of the tempering step required with chocolate in order to achieve coating gloss. These fats exhibit little tendency to undergo polymorphic changes in crystal structure (15). As a result, these coatings tend to retain an acceptable appearance, even when exposed to temperature fluctuation which could cause the hard butter to melt and recrystallize. Chocolate and other compounds when subjected to fat liquification and recrystallization may develop visible surface distortions called "bloom."

Undoubtedly, the most attractive positive aspect of hydrogenated nonlauric cocoa butter substitutes is the very low cost compared to other types of hard butters. In certain compound coating applications where the coating's eating quality is relatively unimportant to the overall product appeal and cost is extremely important, these hard butters represent a very desirable cocoa butter alternative. An example of such a product would be a bakery product with sufficient bulk to offset and minimize poor eating quality of the coating (5,16).

While the hydrogenated nonlauric CBS are considered to be the lowest quality cocoa butter alternatives, nonlauric CBS can be significantly improved by the modification of hydrogenated nonlauric oils by fractionation. An example of a fractionated nonlauric CBS is hydrogenated and fractionated palm oil. As shown in Figure 2, a typical fractionated nonlauric CBS exhibits substantially improved solid fat content at ambient temperatures and a much narrower melting range than is the case with a nonlauric CBS produced through the use of hydrogenation alone. By subjecting the partially hydrogenated source oils to fractionation, the solid fat index improvements are accomplished while effecting a marginal reduction in the Wiley melt point of the hard butter, as shown in Table I.

With the improvements in solid fat content, and partly due to the fact that nonlauric source oils, such as palm, have fatty acid chain lengths similar to cocoa butter (see Table II), the fractionated nonlauric cocoa butter, or cocoa butter and butter fat, substitutes are reported to tolerate up to 25% cocoa butter in the total fat phase of a compound coating (17). This fact suggested that an improvement in the eating quality can be achieved by including a limited amount of chocolate liquor in the compound coating. As shown in Table III, such a coating compares favorably to a coating formulated with a hydrogenated nonlauric CBS. Compound coatings formulated with a fractionated nonlauric CBS are typically used for enrobing better quality bakery products and, in some cases, high bulk candy bars as well as in the formulation of cookie drops.

LAURIC CBS

Lauric cocoa butter substitutes offer a wide range of hard butters with different ranges of physical properties. These confectionery fats are made primarily from palm kernel oil and coconut oils (18). Lauric hard butter generally contains 40% to 50% lauric fatty acids (C-12) in combination with lesser amounts of relatively low molecular weight fatty acids. Therefore, lauric CBS are particularly resistant to oxidative rancidity (19). Modification techniques, including hydrogenation, interesterification and fractionation, are used to enhance the solid fat content and melting properties of palm kernel oil, and blends of palm kernel, coconut and palm oils. Depending upon the type of modification technique used, lauric cocoa butter substitutes can be formulated which closely match the Wiley melt point and solid fat index of cocoa butter, as shown in Table I.

Two factors concerning lauric cocoa butter substitutes used in the formulation of compound coatings are their incompatibility with cocoa butter (5,18,20), and their potential for developing "soapy" flavors if hydrolilic rancidity occurs. Because the fatty acid composition of lauric oils is made up of predominantly short chains, mixing with cocoa butter in the formulation of a compound coating can result in a eutectic, or softening effect of the fat phase of a coating. This incompatibility may also lead to discoloration or a hazing effect on the surface of the coating, often referred to as bloom. Therefore, compound coatings formulated with a lauric CBS may contain no more than approximately 6% cocoa butter as a portion of the total fat phase. This is accomplished by replacing chocolate liquor with low-fat cocoa powder containing only about 10% to 12% cocoa butter. While this may limit the major flavor component in the coating, the narrow melting range of lauric hard butters provides a rapid melting and concomitant flavor release at body temperature.

Regarding the development of soapy flavors, it is often stated that moisture will cause a lauric fat to "split" (5). The free fatty acids resulting from this splitting have strong soap-like flavor notes. While moisture is a contributing factor, the important issue contributing to hydrolilic rancidity is not as strongly emphasized. Enzymes from mold or bacteria in the presence of what is called "free moisture" can result in soapy flavors. Since enzymes are readily destroyed by the heat present in the formulation of coatings, it is easy to avoid hydrolysis by simply maintaining good manufacturing practices and using reasonable sanitary precautions. If moisture alone were the only issue regarding hydrolysis, then lauric oils could not be used in high moisture applications such as whipped toppings, coffee whiteners and other imitation dairy products, all of which are being succesfully marketed and often contain lauric oils. The presence of enzymes is the important issue concerning lauric hard butter decomposition (18).

Lauric cocoa butter substitutes can be divided into two categories based on the modification techniques used and the resulting hard butter's similarity to the physical properties of cocoa butter. These two categories are interesterified lauric hard butters and fractionated lauric hard butters.

The interesterification process is the rearranging of the naturally occurring triglycerides into a random distribution. Combined with hydrogenation, the interesterification of palm kernel oil results in a lauric CBS with an acceptable solid fat content at ambient temperatures, while achieving a Wiley melt point below body temperature (see Fig. 1). By blending palm kernel oil and coconut oil along with lesser amounts of a nonlauric oil such as palm prior to interesterification, a wide variety of lauric cocoa butter substitutes may be produced. Hard butters of this type are being formulated with Wiley melting points ranging from approximately 33 C to above 40 C. Examples of three typical interesterified lauric cocoa butter substitutes are shown in Table I.

The flexibility in solid fat index and Wiley melt point achievable by varying the proportions of the lauric oils and palm oil in the formulation of interesterified lauric cocoa butter substitutes provides the ability to produce compound coating suitable for almost any climate or season. In the United States, it is not uncommon for a bakery item to be enrobed with a compound coating containing an interesterified lauric CBS with a Wiley melting point of approximately 40 C during the summer.

In general, compound coatings formulated with an interesterified lauric CBS exhibit good mouth feel and flavor release due to their characteristic narrow melting range. They are hard and dry to the touch at ambient temperatures, which is attributable to the hard butter's adequate solid fat content at ambient temperatures. The coating exhibits good gloss, and good mold and belting release. In addition, the lauric hard butter displays excellent resistance to oxidation. Generally, the interesterified lauric hard butters are also inexpensive when compared to a CBE or a fractionated nonlauric CBS. Compound coatings formulated with interesterified lauric cocoa butter substitutes are typically applied to bakery products and confectionery products where the coating is important, but not the dominant factor in the eating quality of the product, or when cost is a major factor.

The ultimate lauric cocoa butter substitutes are those made from fractionated palm kernel oil. Palm kernel stearins have physical characteristics very similar to cocoa butter. Table I provides a comparison of the Wiley melt point and solid fat index of two typical fractionated lauric cocoa butter substitutes to cocoa butter.

Fractionation separates the whole palm kernel oil into two fractions: an olein or soft fraction, and a stearin or hard fraction. By properly controlling the fractionation process, stearin fractions may be produced which nearly duplicate or even exceed the steep melting curve of cocoa butter (see Fig. 2). The fractionation procedure is typically performed either by a solvent crystallization method or by cold pressing. The hard fraction shows a concentration of lauric, myristic and palmitic fatty acids. Thus the result of fractionation is a fat that is much harder than the starting oil because the softer triglycerides have been substantially removed (21). By combining fractionation with subsequent partial hydrogenation, extremely high solid fat content levels may be achieved while keeping the melting point at or below body temperature, as shown in Table I.

Compound coatings formulated with a fractionated lauric CBS exhibit excellent eating qualities in terms of mouth feel and flavor release, and excellent texture due to the extremely steep melting curve of the fat phase. These coatings also possess excellent mold and belt release as a result of the lauric hard butter's high coefficient of contraction. Other characteristics include excellent oxidative stability and very good gloss (18). The fractionated lauric cocoa butter substitutes are normally moderate in cost compared to cocoa butter.

While some users of this type of compound coating find it desirable to perform a tempering procedure to help ensure gloss retention for the anticipated shelflife of the product, many users find tempering unnecessary when a crystal promoter is included in the coating formula (15). Hydrogenated palm oil will perform this function when incorporated at a level of approximately 1% by weight of the coating. Coatings formulated with a fractionated lauric CBS and hydrogenated palm oil for crystal promotion have reportedly exhibited gloss retention of six months to more than a year (18).

Compound coatings formulated with a fractionated lauric CBS are used for enrobing high-quality bakery goods and candy bars when the quality of the coating is vitally important to the eating quality of the finished product. The fractionated lauric cocoa butter substitutes are also typically the hard butter of choice in the formulation of pastel coatings for molding and enrobing, as well as in the formulation of coconut, butterscotch, peanut butter and chocolate-flavored baking chips (18).

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