Fats and Processes Used in Manufacturing Chocolate and Confectionery Coatings[1]

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ABSTRACT

The basic requirements of the confectioner for fats to be used in chocolate are briefly reviewed. The melting properties of the polymorphs of cocoa butter and variation in them are outlined together with methods of measuring them. These properties govern two important steps in the manufacture of chocolate—tempering and cooling. The tempering process and methods for determining the state of temper in a sample are noted. The main types of chocolate in common use are described along with two main processes used for their manufacture. The polymorphic forms commonly found in commercial operations are discussed. The discussion on chocolate and cocoa butter leads to reasons for the interest of confectioners in so-called coating fats or cocoa butter substitutes. The various classes of fat which have been tried so far for this use are briefly reviewed along with their limitations from the viewpoint of the confectioner and his consumers. Desirable specifications for a coating fat and possible future developments in their use in the candy industry are discussed briefly.

INTRODUCTION

Fundamentally, for the candy maker, cocoa butter has only two important technical properties—its melting behavior and its flavor. While the latter is of importance to the candy industry, it will not be discussed much further here. It is included as an aside because it is frequently completely overlooked. However, depending on the intended use, cocoa butters or coating fats may be rejected by the confectioner because they possess a flavor which is undesirable for his particular purpose (although it might suit another admirably), or because they lack a flavor which he considers essential for his product. It is also true that the confectioner expects the flavor of his products to be stable over a considerable period of time. It is widely known that cocoa butter is sufficiently saturated to exhibit excellent resistance to oxidation and does not contain fatty acids which are likely to contribute off-flavors as a result of the activity of fat-splitting enzymes. But it is worth bearing in mind that the same will be expected of coating fats in general. Coatings with oxidative, and others with hydrolytic, off-flavors developing early in life have been observed. However, at present, actual or potential flavor problems with coating fats are overshadowed by the physical properties, and it is the latter which are mainly to be discussed in the following.

Polymorphism of Cocoa Butter

Cocoa butter, like many fats, can solidify in a number of different crystal forms, depending on the conditions of cooling. Each form or polymorph has its own melting range, rather than a sharp melting point, due to the mixture of triglycerides composing the fat. All forms except the highest melting are relatively unstable. Stability increases from the lowest through the highest melting forms. The number of recognized forms has increased through the years and the current total is six, although the existence of a seventh is suspected.

Earliest recognition of these forms came in the 1920's by Fincke (1), Whymper and Bradley (2), and Abers (3), and revealed three crystal forms with final melting points of 24, 29 and 34 C, respectively. The existence of a lower melting (18 C) form was discovered by Vaeck (4) between 1948-51. The fifth form was demonstrated by Duck (5,6). The existence of the sixth form is suspected by Wille and Lutton (7) who supply the most complete description to date of the polymorphic states; it has been confirmed by Huyghebaert and Hendrickx (8). Because of piecemeal discovery by different workers, the nomenclature for these forms has been somewhat confused. Currently the most widely accepted names among candy technologists are γ, α, β'', β' and β (in ascending order of melting), but Wille and Lutton have understandably and wisely proposed I-VI (or 1-6). In addition to eliminating some confusion, general adoption of this nomenclature should be a boon to typists and typesetters as well as to those increasing numbers who have not received an education in Greek alphabet.

TABLE I

Melting Data[a]

Type of cocoa butter	Slip Points, C					Clear melting points, C					Melting range[c]
	1st det[b]	2nd det	3rd det	X	R	1st det	2nd det	3rd det	X	R	
Mixed	33.2	33.3	33.2	33.23	0.1	34.1	34.0	34.0	34.05	0.1	0.82
Java	33.5	33.45	33.4	33.45	0.1	34.4	34.45	34.5	34.45	0.1	1.00
Venezuela	33.2	33.3	33.2	33.23	0.1	34.0	34.15	34.2	34.12	0.2	0.89
Arriba	33.0	33.15	33.15	33.1	0.15	34.5	34.6	34.55	34.55	0.1	1.45
Lagos	33.65	33.6	33.6	33.62	0.05	34.25	34.3	34.2	34.25	0.1	0.63
Accra	33.2	33.15	32.9	33.08	0.3	34.25	34.1	34.05	34.14	0.2	1.05
Cameroon	33.0	33.1	33.0	33.03	0.1	34.1	34.1	34.1	34.10	0	1.07
Ivory Coast	33.2	33.25	33.25	33.23	0.05	34.25	34.2	34.1	34.13	0.1	0.90
Bahia, not refined	32.9	32.75	32.85	32.83	0.15	33.80	33.8	33.85	33.82	0.05	0.99
Bahia, fully refined	32.55	32.50	32.40	32.48	0.15	34.25	33.9	34.0	34.05	0.35	1.57
Total				331.28	1.25				341.65	1.30	

[a] Determined on a mixed commercial cocoa butter and on several laboratory pressed cocoa butters. Experiments carried out by three investigators working independently.

[b] Determination.

[c] (Clear mp-slip point) calculated from the means.

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[1] One of seven papers presented in the symposium "Fats and Oils in the Food Industry," Atlantic City, October 1971.

The picture is complicated by the fact that cocoa butter is not a unique triglyceride mixture. Its composition can vary depending on the origin of the cocoa beans and the processes used to extract fat from them. The effect of this on melting point is exemplified in Table I (9). Melting ranges found by individual workers can therefore be only approximate, and each polymorph is likely to exhibit a range of final melting points from sample to sample.

The melting properties of the polymorphs showing this variation, as derived by various workers (4,6-10, also private communications from H. Humecki, 1967, and H.P. Adams, 1970) appear in Table II. This table also shows the correlation between the two main systems of nomenclature.

Figures 1 and 2 confirm the variation in melting points and demonstrate the melting of some form or fraction of cocoa butter at temperatures above 36 C.

A number of techniques have been used to study the melting ranges of these polymorphs and to distinguish them from each other. They include hot stage microscopy (10) in which crystals are seen to melt as the sample temperature is raised; thermo-penetrometry (10) in which breaks are seen in penetration-temperature curves; X-ray diffraction analysis (7); and calorimetry (11)—particularly, recent use of the Differential Scanning Calorimeter which gives a direct trace of changes (+ or −) in insensible heat content (enthalpy) of a sample as its temperature is raised or lowered at a constant rate. The curves of Figures 1 and 2 were derived by the latter method.

The melting properties of cocoa butter and chocolate are clearly very dependent on the polymorphs present, and their proportions, and the unique advantages of the β or VI form of cocoa butter in this respect have been discussed (12). In order to control these properties, the confectioner tempers his chocolate and controls his coating conditions.

Tempering

This is a process whereby the confectioner attempts to control the proportion and type of solid fat present in his fluid chocolate at the enrober or molding plant. A number of methods and apparatuses are commercially available for this purpose, and all of them have been successfully used. Space does not permit a description of them here, other than to say that they all depend on controlled temperature cycling of the chocolate from a temperature at which it is completely liquid to the temperature at which it is to be used, without ever reaching a temperature at which it is completely solid. The cycle may or may not include constant temperature holding stages long enough to permit the fat to come into thermodynamic equilibrium at various temperatures. More detail is available in Reference 10.

Two methods are available for investigating the condition of temper in a sample of fluid chocolate. One involves plotting the temperature of a sample with time as it cools under standardized conditions (10), and a commercial apparatus called the Temper Meter for this purpose has been marketed by Greer Division of Columbia Precision. The second method derived by Duck (13) uses the viscosity of the tempered sample at the use temperature, compared to its viscosity at the same temperature but untempered to calculate the per cent solid fat in the sample. We have also found a cooling curve, obtained from the Differential Scanning Calorimeter, useful for demonstrating differences in temper.

The same processes and methods can be used to temper cocoa butter and to estimate the state of temper in it.

It should be clear from the foregoing discussion that the confectioner has to be selective in his choice of cocoa butter, for his purpose and his choice may be based on knowledge of the origin of the beans (country, grade) and the processes used in preparing the butter (per cent shell left after decortication, method used to extract fat, deodorization, alkalization, etc.). The properties of the

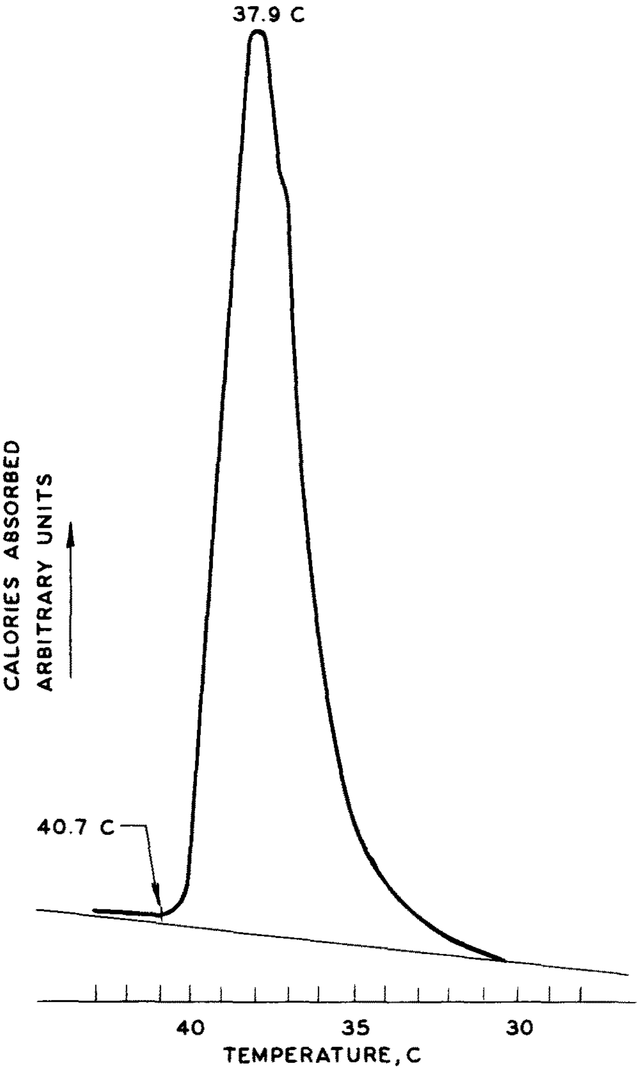

FIG. 1. Differential Scanning Calorimeter melting curve of a typical cocoa butter pressed from shell-free West African cocoa.

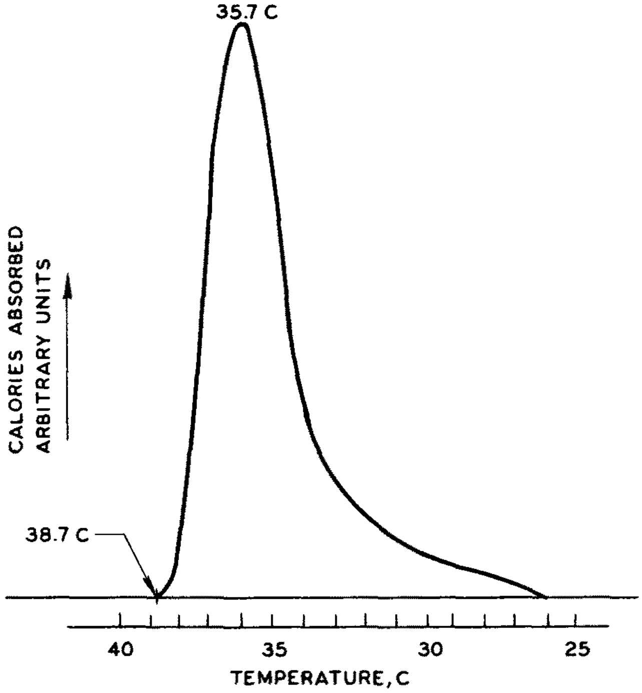

FIG. 2. Differential Scanning Calorimeter melting curve of a typical cocoa butter pressed from shell-free Brazilian cocoa and then deodorized.

TABLE II

Melting Ranges of Polymorphs of Cocoa Butter

Name of form		Mean melting range, C	Range of final melting points, C
a	b		
γ	1	4-17	16-18
α	2	14-23	21-24
—	3	17-27	25.5-27.1
β''	4	12-28	27-29
β'	5	24-32	30-33.8
β	6	25-35	34-36.3
—	7?	?	38-41

solid fat will then depend on how it is tempered and cooled. Thus, in preparing a sample of cocoa butter for the determination of melting properties with which the properties of other cocoa butters or other fats can be compared, it is necessary to specify all of these things.

Chocolate

In the U.S., chocolate is of three main types, shown in Table III: "chocolate," which is the milled, shelled cocoa bean; "sweet chocolate," which is prepared from "chocolate" with the addition of sugar, cocoa butter and, optionally, certain other specified ingredients, but must contain at least 15% of "chocolate" and less than 12% of milk solids; and "milk chocolate," which is similar but must contain at least 10% of "chocolate" and at least 12% of whole milk solids. Both in the U.S. and abroad, there are a number of alternative names, e.g., chocolate liquor or cocoa mass for "chocolate," for these types and for subclasses within them. Outside the U.S., different standards apply, e.g., in many countries milk chocolate need not contain as much as 10% of chocolate liquor.

In practice, sweet chocolate will typically contain from 20-50% of chocolate liquor and less than 5% of milk solids, most of the balance being sugar and cocoa butter to give a total fat content of 30-36%. Milk chocolates will mostly cover the range 10-20% chocolate liquor, 12-30% whole milk solids; the balance being mainly sugar and cocoa butter as before.

Processes for preparing chocolate from the ingredients are greatly varied but fall into two main types: (a) The so-called dry mix process in which the milk, if used, is in powder form. Typically all of the chocolate liquor, dry milk, sugar and other dry ingredients (if used), such as butter oil, nut pastes, flavors, etc., will be mixed with enough cocoa butter in a suitable mixer to form a soft, putty-like paste of suitable consistency. This paste is refined mechanically in a roller mill, typically with five rollers. This process is carried out by different manufacturers to various degrees from exceedingly fine (seems to be liquid when melting in the mouth) to perceptibly coarse or "sandy." Degree of refining can be measured in many ways. A simple way is by direct micrometer measurement on the melted material (usually dispersed in a little oil). The micrometer reading is very dependent on the amount of oil used and is not related in any simple way to actual particle size distribution. With oil used at the level of one-third the weight of chocolate, fineness in practice will mostly cover the range from 10-60 μ by micrometer; (b) The second type of process differs from the first in that the milk is premixed with sugar, possibly also with some or all of the chocolate liquor and dried, with or without prior concentration, and with or without vacuum, depending on the form of milk received (liquid, condensed, sweetened condensed, etc.). A variety of drying processes is used and the dried product is known as "crumb." The milled crumb is then mixed with the other ingredients necessary to form a paste for refining as before.

Not surprisingly, the flavor of the eventual chocolate is very dependent on the precise process used, especially in the case of crumb process chocolates.

After refining, the addition of further cocoa butter and possibly emulsifiers is usually necessary to reduce the chocolate to a workable viscosity. A somewhat esoteric process known as "conching" may or may not be used, but space forbids elaboration on this topic here.

The chocolate then requires tempering by one of the methods mentioned earlier and, after coating onto candy or depositing into molds or forming into some shape by other methods, needs to be solidified under conditions which will promote the formation of the more stable polymorphs—preferably Form VI—rather than the less stable forms (I-IV). It is inappropriate here to discuss this vexed question in detail other than to say that, in my experience, most (but not all) commercial tempering processes produce Form V rather than Form VI fat in fluid chocolate; and many commercial cooling tunnels produce mostly Form V in the solid chocolate. With suitable storage conditions, transition to the Form VI can occur fairly rapidly and harmlessly after the candy is packed out. However there is commonly an easily observed change in the texture of chocolate occurring some months after manufacture when stored under good conditions (say 70 F., 50% relative humidity). This *may* be associated with transition to a form melting higher than Form VI, if it exists and is a polymorphic form rather than the result of fractional crystallization or recrystallization. If so, it might be of benefit if one were able to induce this condition in the chocolate at the time of manufacture. This is, of course, speculative.

Coating Fats

It has been stated earlier that, contrary to common expectation, cocoa butter can be quite variable in its flavor and physical properties. Historically, it has also been quite volatile in price. Successful selection of purchases can be advantageous for the confectioner but introduces considerable complication. This has led to a long established desire on the part of the candy maker to find a fat other than cocoa butter which would be constant (and equivalent to the best cocoa butter) in its properties and in its price. The name "coating fats" has been given to fats designed for this use.

Initially, attempts were made to replace cocoa butter with vegetable oil stearines of various types which had a Wiley melting point or slip point similar to that of cocoa butter (ca. 92-95 F if much Form VI is present). These stearines were prepared by fractional crystallization of the oil from the melt under controlled conditions, the still liquid fraction being removed by pressing. The resulting coatings (often referred to as confectionery coatings to distinguish them from those in which cocoa butter is the predominant vegetable fat) proved to be softer than was desired, because of the formation of eutectic mixtures with any cocoa butter present. The stearines themselves were physically similar to cocoa butter, except that they exhibited a lesser degree of supercooling (Fig. 3). This of course has a profound effect on the process for tempering coatings containing stearines.

It should be pointed out that the presence of some cocoa butter in coatings is unavoidable to date, since the desired flavor can so far only be achieved by the use of either chocolate liquor or cocoa powder, both of which contain cocoa butter. It is also well recognized that the best flavor coating can only be achieved by use of liquor rather than powder. Since liquor contains over 50% of cocoa butter and sweet chocolates contain mostly at least 20% of liquor and about 35% total fat, it is clear that comparable confectionery coatings would contain cocoa butter at a level of at least 30% of the total fat present. Similarly, a typical milk coating made from chocolate liquor would have to contain cocoa butter at a level of ca. 17% or more

TABLE III

Types of Chocolate

Names		
U.S. standard	Alternate	Ingredients (U.S. Standard)
Chocolate	Chocolate liquor Cocoa mass Baking chocolate Bitter chocolate	Milled flesh of roasted cocoa bean (shell removed after roasting)
Sweet chocolate	Semisweet chocolate Bittersweet chocolate	Chocolate liquor ≮ 15% Sugar Cocoa butter (optional) Specified flavorings (optional) Emulsifiers (optional) Milk products (optional) < 12%
Milk chocolate	Sweet milk chocolate Dairy milk chocolate, etc., e.g., buttermilk chocolate (if buttermilk is used)	Chocolate liquor ≮ 10% Whole milk solids ≮ 12% Sugar Cocoa butter (optional) Flavorings (optional) Emulsifiers (optional)

of the total vegetable fat present.

Coatings could be made from these stearines, but all of them showed excessive softening at temperatures of ca. 70 F. Additionally, to avoid softness even at 70 F, it was necessary either to restrict cocoa butter to less than 10% of total vegetable fat or to restrict stearine to less than 10% (14). The former restriction eliminates the use of chocolate liquor with a consequent effect on flavor while the latter offers little benefit over 100% cocoa butter. Either type also proves difficult to temper as discussed earlier.

Attempts were also made to use hydrogenated vegetable oils in place of cocoa butter. These also proved to be incompatible with cocoa butter, as the stearines were, in the sense that eutectic effects were observed imposing severe limits on the proportions of the two fats permissible in admixture. Similar difficulties were experienced in tempering, and additionally these fats and their mixtures with cocoa butter have much wider melting ranges than cocoa butter itself. Therefore, depending on the extent of hydrogenation of the fat used, such coatings tend either to be soft at room temperature or to be "waxy" in the mouth (because the melting range extends too far above body temperature), or both.

Stearines can also be prepared by fractional crystallization of hydrogenated fats, and these of course have a much narrower melting range. The best of them have a melting range very close to that of cocoa butter but still a few °C wider, and our mouths and fingers are very sensitive to those few. These fats also exhibit very little in the way of supercooling effects, and therefore tend to solidify fairly readily into a stable condition without tempering (15) or to be relatively unaffected by wide variations in the tempering conditions. Whether the resulting solid is in the most stable or a completely stable condition is not certain. Eutectic effects are also observed in mixtures of these fats with cocoa butter. In other words, they are not fully compatible. However they are more compatible than the unfractionated hydrogenated oils or the stearines from unhydrogenated oils, to the extent that with the very best of them a coating of fair physical properties and flavor can be made using chocolate liquor, provided that the proportions of liquor and whole milk (if any) in the coating are close to the minimum amounts permitted in the U.S. Standard of Identity for chocolate products.

A different approach was used by workers at the Unilever organization. Reasoning that the incompatibility of the other fats with cocoa butter must depend on the differences in triglyceride composition, they embarked on a considerable program to elucidate these differences. In the course of this work, they had to find out more about the triglycerides in cocoa butter itself and came to the conclusion that cocoa butter consists predominantly of symmetrical triglycerides having the monounsaturated oleic acid in the center or 2 position. Using the cooling curve of mixtures of various proportions of test fats with cocoa butter as the criterion, many fats and fractions thereof were examined for compatibility with cocoa butter. It appeared that only those fractions which contained predominantly symmetrical 2-oleo triglycerides exhibited the highest degree of compatibility.

As a result of this work a patented process (16) using the technique of Fractional Crystallization from a solvent and raw materials with relatively high proportions of the right type of glyceride was developed. The resulting fat has been named Coberine® and has a dilation curve very close to that of cocoa butter even in 50:50 blends (Fig. 4). However the same is not so true of its melting curve, which suggests a pronounced softening effect in 50:50 blend (Fig. 5). Thus even Coberine® is not quite completely compatible with cocoa butter, especially in milk chocolates which contain a high proportion of milk fat; and its use at too high a level in such formulations results in the softening effects with increasing temperatures above about 70 F which have always been observed in confectionery coatings although to

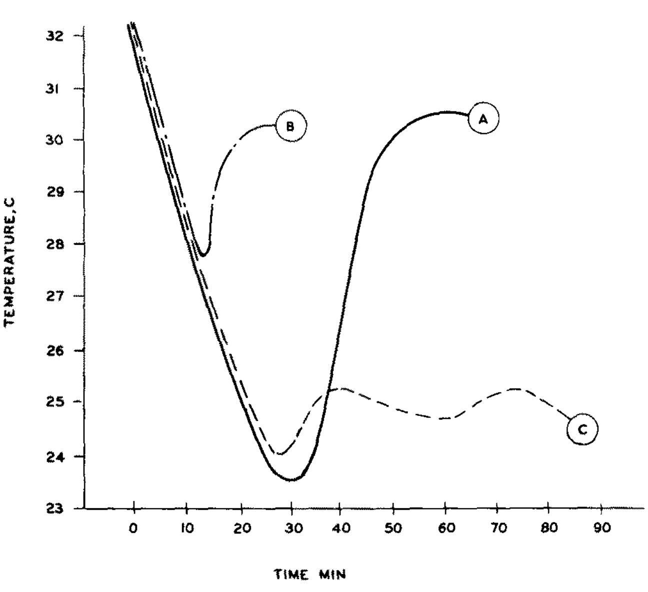

FIG. 3. Typical cooling curves; A. cocoa butter; B. palm kernel stearine; C. 50% cocoa butter/50% palm kernel stearine. The degree of supercooling is much less for B than A, while it is about the same for C and A. However note the apparent slow crystallization of C as shown by the low but extended temperature rise after the minimum.

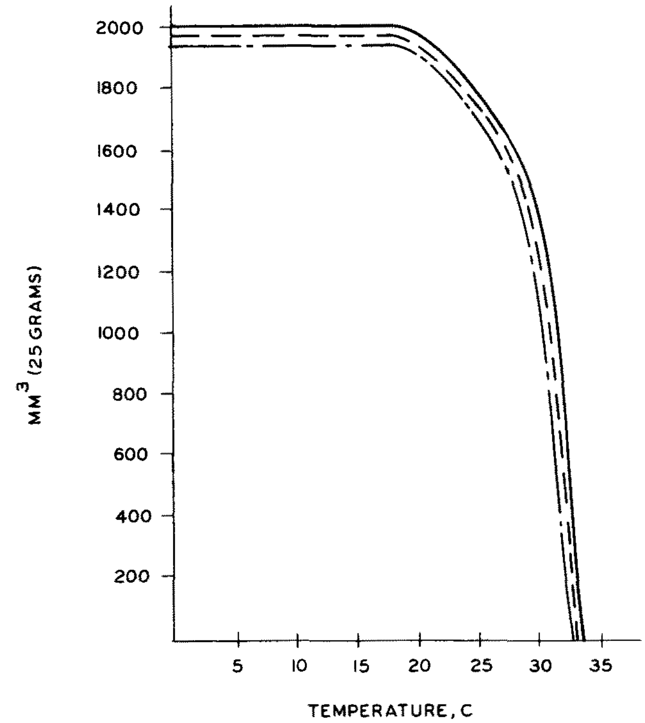

FIG. 4. Typical dilatation curves: upper, cocoa butter; lower, Coberine®; middle (dashed), 50% cocoa butter/50% Coberine®.

a much slighter degree. It is only fair to add that similar effects can be observed in chocolates which have been made with lower melting types of cocoa butter or which have been improperly processed; however textural effects will be observed at these high levels of cocoa butter replacement in such formulations, unless one can simultaneously be more restrictive in the type of cocoa butter used and improve process control, as the case may be.

One other fat should be mentioned in this context. Illipe Butter is the fat of *Shorea stenoptera*. It has a composition and melting propertes very similar to cocoa butter, although it is slightly harder. It is available in limited amounts. Its use in products which are described simply as "Chocolate" is not permitted in the U.S.

Desirable Specifications for All-Purpose Coating Fats

In view of space limitations, these specifications will be stated without elaboration. Hopefully the reasons will be apparent from the foregoing, or will be obvious.

The fat should either exhibit only one melting form or should have a form which is stable for at least a year at 10-25 C. In either case, the melting range of that form should extend from 25 ± 1 C to 35 ± 1 C.

It should be compatible with cocoa butter, preferably in all proportions, but at least in all proportions over the range 0-70% cocoa butter. Blends of the fat with cocoa butter in the range 0-50% cocoa butter should be similar to cocoa butter in their behavior toward milk fat. That is, when any such blend is mixed with milk fat in any proportion from 0-30% milk fat, the melting curve of the mixture should be similar to that of an equal mixture of milk fat and cocoa butter. It would be expected that such blends and mixtures in solid form would show penetration resistance similar to that of cocoa butter or equivalent cocoa butter-milk fat mixtures over the range 10-25 C, but this should be checked.

The viscosity of such blends and mixtures should be no higher than that of cocoa butter or equivalent mixtures over the range 25-35 C.

The fat should be bland in flavor, and its flavor should not change over at least a year in storage at 10-25 C. In particular, it should have an AOM value of at least 200 hr and should not develop undesirable flavors in the presence of lipolytic organisms. For this reason, it is probably preferable that it contain little or no lauric acid, free or bound.

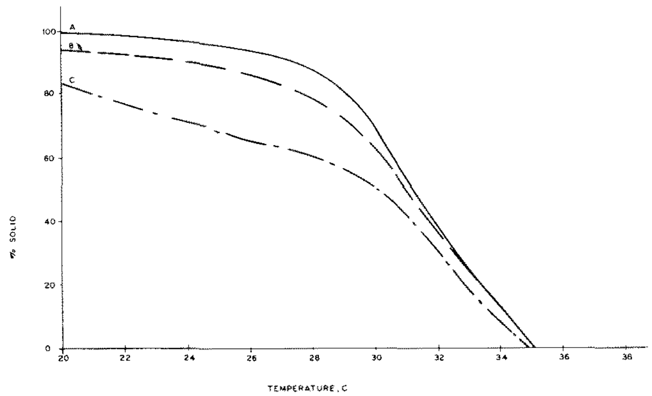

FIG. 5. Melting curves (% solid vs. temperature) of cocoa butter and mixtures with Coberine®: A. cocoa butter alone; B. 5, 10 or 20% Coberine®, balance cocoa butter; C. 50% Coberine®/50% cocoa butter. Per cent solid determined by calorimetry. The cocoa butter was tempered and stored to produce Form 6. The other samples were treated identically.

The fat should be produced with a total plate count as low as possible, certainly below 50,000/g, and should not contain pathogenic organisms.

Some of these may be unreachable specifications, but it is re-emphasized that such a fat could be expected to be capable of replacing cocoa butter for all purposes. Fats which go some way towards meeting these criteria can replace and are replacing cocoa butter for some purposes.

In the end, raw material specifications are drawn up by each individual user. Other users may have different ideas, but it seems to me that these are likely to be acceptable to most, and would leave the user free to maintain or improve his product quality by application of his own technology without imposing possibly unachievable specifications on his other ingredients.

Future Trends

There can be no doubt that the use of confectionery coatings is increasing in spite of the limitations of current coating fats. This is occurring under the pressures of increasing competition in the marketplace and fluctuations in the price of cocoa products, the reasons for which I am not qualified to discuss. However it seems unlikely that either competition or the price of cocoa can be expected to stabilize in the future. The trend towards confectionery coatings is restrained at present by the reluctance of many manufacturers to accept the limitations I have discussed. In this we believe ourselves to be acting in the interests of our consumers.

This trend is also restrained by legislation in many countries, including the U.S., which does not permit one to describe a product or a component of a product as "chocolate" without qualifying phrases, if so-called coating fats are added to that component. The whole subject of permissible ingredients to be used in chocolate is currently under international discussion under the aegis of the Codex Alimentarius Commission. This Commission is seeking to draw up standards for food products which could apply in all countries. If successful, this might involve changes in the standards which currently apply to chocolate products in the U.S. and elsewhere. Some delegates to the Commission have argued that since there are various types of cocoa butter, the use of some should be excluded. It has recently been agreed by the delegates to the committee on chocolate products to define three types of cocoa butter depending on the processes used to derive fat from the cocoa bean. All of these have been used widely and interchangeably in chocolate making in various parts of the world for years, and there is no reason why this practice should cease. Some delegates argue for the inclusion of coating fats up to a certain amount in products to be described as chocolate. This too has been a fairly widespread practice in places where it has not been prohibited, and there is no reason why it should cease. Depending on the eventual outcome of this argument, the usage of coating fats may accelerate.

It seems unlikely, as well as unjustifiable, that the description "chocolate" will ever be permitted to apply to products in which cocoa butter has been substantially replaced with other fats. Such products are no more chocolate than margarine is butter. However that need be no deterrent to expanding use of such products. It can hardly be coincidence that expansion in the use of margarine has accompanied an improvement—a better approximation to butter—in its quality.

In the end, then, the trend in the candy industry will be in step with the wishes of its consumers. It is my belief that they will accept confectionery coatings, whatever they are called, in increasing amounts, somewhat in proportion to the extent to which the quality of the coatings approximates that of chocolate, without their price reaching that of chocolate. The candy technologist can contribute to this improvement, but it cannot be achieved without improvement in the properties of the available fats—and this must be left to the oil chemists.

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