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Consistency of Mixtures of Cottonseed and Paraguayan Palm Kernel Oils[1]

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MBOCAYA OIL, the kernel oil from the Paraguayan palm, *Acrocomia Totai Mart (Fam. Palmae)*, is used for edible purposes and in the preparation of high-grade soaps. Production of the oil could be increased greatly if it were economically advantageous. However the physical characteristics of the oil are such that in the unmodified state it is not suitable for use either as salad oil or shortening.

Mbocaya oil resembles that from the kernel of the more generally known oil palm, *Elaeis guineenis Jacq*, but there are some differences. It has been reported (6) that the iodine value of mbocaya oil ranges between 28.0 and 30.2, about twice that for the usual palm kernel oil; and the melting point is correspondingly low, 20.0 to 23.0°C. The saponification value lies between 239 and 246, slightly less than the value of 244 to 254 for the usual palm kernel oil but still indicating the presence of a considerable proportion of glycerides of short chain fatty acids.

As in all palm kernel oils, the proportion of linoleic acid and other polyunsaturated fatty acids among the component fatty acids of mbocaya oil is very low. The composition of the component fatty acids has been reported (7) to range as follows: saturated acids, 67–68%; oleic acid, 29–31%; and linoleic acid, 2–4%. The content of unsaponifiables in the oil (6) is low, 0.25 to 0.40%. Also in common with ordinary palm kernel and coconut oils, the oil in the crude state contains practically no coloring matter, and the flavor is mild and nut-like. Refining, bleaching, and deodorization produce a bland, water-white product.

The above-described properties indicate that mbocaya oil should be suitable for use in a blended or compound-type of shortening in which the other component is hydrogenated cottonseed oil. Because of the apparently relatively high content of oleins, mbocaya oil should yield a compound-type of shortening superior to that obtained with coconut oil. On the other hand, the shortening should be substantially free of linoleins and hence more resistant to oxidation than are the ordinary compound-type of shortenings. It might also be possible to produce mixtures having suitable consistencies by interesterifying hydrogenated cottonseed oil and mbocaya oil or by blending hydrogenated mbocaya oil with cottonseed oil. To evaluate these possibilities various mixtures and products were prepared and subjected to consistency measurements. The results which were obtained will be presented and interpreted.

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Materials and Procedures

The cottonseed oil, C-1, used in the tests was a refined and bleached oil of good quality obtained from a commercial source. It had an iodine value of 108.3. A portion of this oil was hydrogenated in the laboratory to obtain a product, C-2, having an iodine value of 9.8 and a capillary melting point of 61.4°C., determined according to the official methods of the American Oil Chemists' Society.

The hydrogenated cottonseed oil identified as C-3 was also prepared from a commercially refined and bleached oil and possessed an iodine value of 1.8.

The mbocaya oil identified as M-1 was a refined and bleached product possessing an iodine value of 29.5, a melting point of 22.4°C., and a saponification value of 242.8. It was prepared from a crude oil received

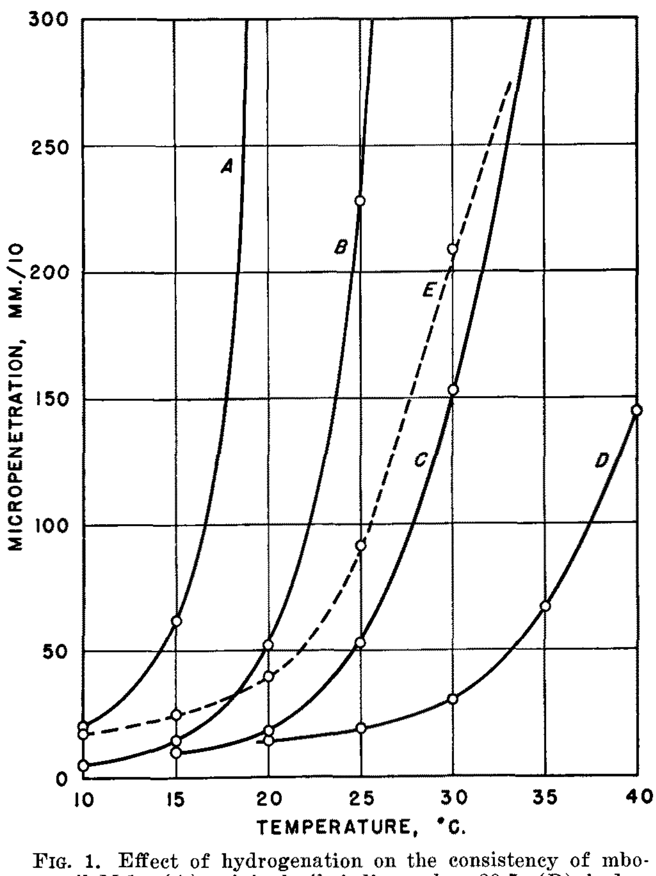

FIG. 1. Effect of hydrogenation on the consistency of mbocaya oil M-1: (A) original oil, iodine value, 29.5, (B) hydrogenated to an iodine value of 19.2, (C) hydrogenated to an iodine value of 11.2, and (D) hydrogenated to an iodine value of 0.2. Curve E represents a shortening of the all-hydrogenated type.

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Portions of M-1 were hydrogenated to iodine values of 19.2, 11.2, and 0.2.

Mbocaya oil M-5 was a refined and bleached product, possessing an iodine value of 32.6 and a melting point of 21.1°C. Product M-6 was prepared by hydrogenating a portion of M-5 to an iodine value of 0.4 and a melting point of 58.1°C.

Interesterification of mbocaya and hydrogenated cottonseed oil was accomplished by using the general method of undirected interesterification described by Eckey (3).

Consistency measurements were made with a falling needle type of penetrometer. The apparatus and technique described by Feuge and Bailey (4) were used.

Mbocaya Oil, Hydrogenated Mbocaya Oil, and Their Mixtures

Batches of the oil were hydrogenated to different iodine values and their consistencies were measured. As might have been predicted from the composition of the oil, these products did not have the plastic range required for a good shortening. The consistency *vs.* temperature curves obtained are reproduced in Figure 1, together with curves for the unhydrogenated oil and a commercial shortening of the all-hydrogenated type.

It is evident that the hydrogenated oils are somewhat firmer than a typical all-hydrogenated shortening when compared at temperatures below about 17°C. From the general shape of the set of curves the conclusion can be drawn that the hydrogenation of mbocaya oil to a shortening-like consistency at room temperature (about 100 at 25°C.) would result in a product which would soften at a more rapid rate than does shortening as the temperature is increased above 25°C., *i.e.*, the plastic range of the hydrogenated mbocaya oil would be shorter. Increasing the amount of hydrogenation of the oil increases the plastic range, but it simultaneously greatly affects the temperature at which the desirable consistency of 100 units is obtained. On hydrogenating the oil from an original iodine value of 29.5 to one of 0.2, the temperature at which a consistency of 100 units is obtained is shifted from about 16.5°C. to 37.5°C. It must be concluded that any shortening made from hydrogenated mbocaya oil would be somewhat inferior to current all-hydrogenated shortenings insofar as plastic range is concerned.

Consistency measurements were made on mixtures of hydrogenated and unhydrogenated mbocaya oil. As might be expected on the basis of the probable glyceride configurations in the unhydrogenated oil, mixtures containing up to 25% of hydrogenated oil of iodine value 0.4 yielded consistency curves similar to those obtainable with an all-hydrogenated oil. Unlike semi-drying oils, mbocaya oil probably contains little or no di- and triunsaturated glycerides which can be partially hydrogenated.

Mixtures Containing Hydrogenated Cottonseed Oil

Consistency *vs.* temperature curves for simple mixtures consisting of mbocaya oil and hydrogenated cottonseed oil are reproduced in Figure 2. From this set of curves it is evident that such mixtures can be prepared to duplicate the characteristics of the compound-type of shortenings at temperatures above about 20°C. For the particular components used in the compounds represented in curves A through D a content of hydrogenated cottonseed oil slightly above 10%, probably 12%, would be required to give an acceptable compound-type shortening. A product having a suitable consistency above 20°C. would be somewhat firmer than a typical blended-type of shortening (curve E, Figure 2) below 20°C., yet for practical purposes it would not be firmer than an all-hydrogenated type shortening (Curve E, Figure 1).

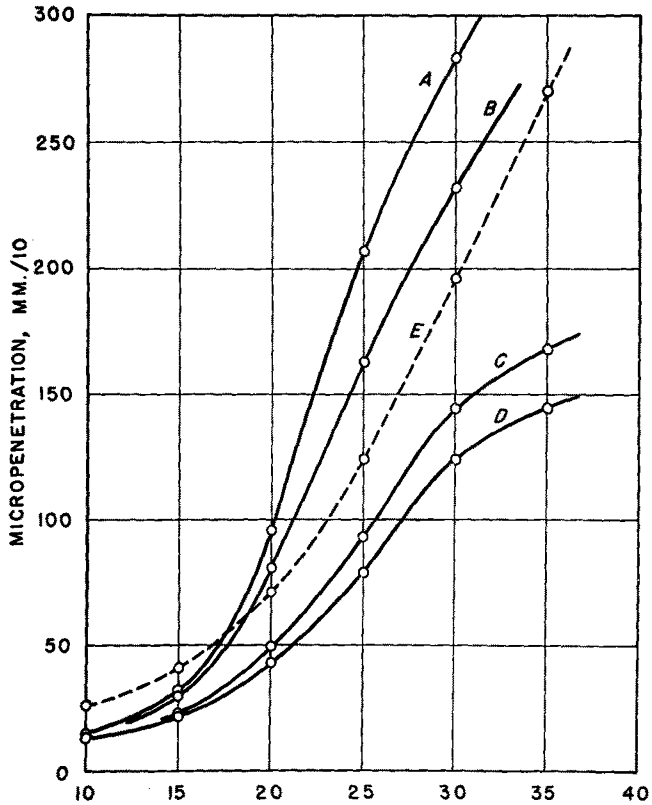

FIG. 2. Consistency of mixtures of mbocaya oil M-5 and hydrogenated cottonseed oil C-3 (iodine value, 1.8) in which the contents of hydrogenated oil are: (A), 8%; (B), 10%; (C), 16%; and (D), 18%. Curve E represents a blended-type of shortening.

In the formulation of blended shortenings containing the coconut type of oils several variations are possible. One of these commonly practiced in the preparation of shortening containing a large proportion of coconut oil is to add cottonseed oil or other liquid oil so as to improve consistency at low temperatures. On adding up to 8% of cottonseed oil to mbocaya oil-containing mixtures no improvements in consistency were observed, partly because the percentage added was small and partly because mbocaya oil is not as brittle at lower temperatures as is coconut oil. In view of the fact that the simple blends represented in Figure 2 already have a consistency at lower temperatures comparable to that of an all-hydrogenated shortening, the addition of larger percentages of cottonseed oil was not investigated.

Small variations in the amount of hydrogenation of the cottonseed or other oil used in blends would be expected to have an effect on their physical characteristics. Quantitatively, it was found that the substitution of 8% of hydrogenated cottonseed oil C-2 (iodine value, 9.8) for 8% of hydrogenated cottonseed oil C-3 (iodine value, 1.8) in a mixture with

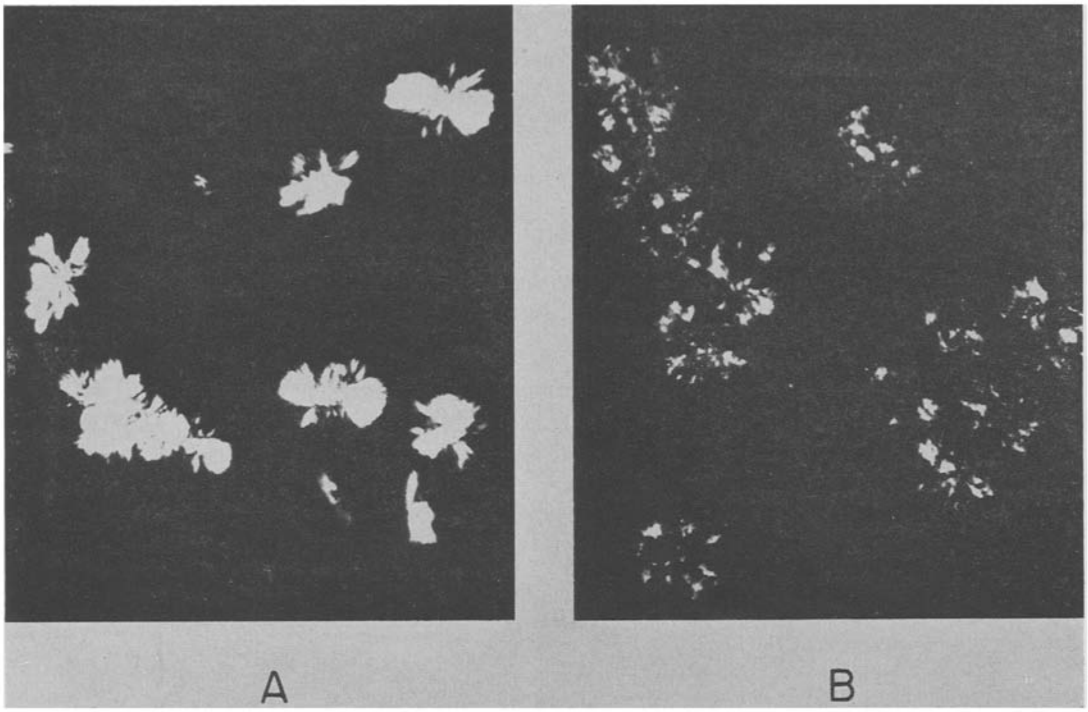

FIG. 3 Photomicrographs (X 850) of crystals obtained on cooling to room temperature solutions containing (A) 12% of hydrogenated cottonseed oil C-2 and 88% of mbocaya oil M-5, and (B) 12% of hydrogenated cottonseed oil C-2 and 88% of cottonseed oil C-1.

mbocaya oil changed the consistency value of the mixture at 25°C. from 207 to 234. At higher levels of hard fat and at lower temperatures the differences between the two hydrogenated cottonseed oils tended to be less marked.

In other tests the consistency of a given mixture of mbocaya oil and hydrogenated cottonseed oil was always found to be softer than that of a comparable mixture made with cottonseed oil, that is, the hydrogenated cottonseed oil had a greater stiffening effect on cottonseed oil than on mbocaya oil. In the temperature range of 2.0 to 30°C. and with 12% of hydrogenated cottonseed oil C-2 the micropenetrations for the mbocaya oil mixtures were about 50% greater than those obtained with comparable mixtures containing cottonseed oil.

When the various mixtures were melted and resolidified by cooling to room temperature at a moderate rate, differences in physical structure could be observed with the naked eye. The hydrogenated cottonseed oil in the mbocaya oil formed relatively coarse clusters of crystals which gave the mixture a grainy appearance. A tendency of the mixture to bleed was observed. On the other hand, the crystals in the hydrogenated and unhydrogenated cottonseed oil mixture appeared to be much finer, and the mixture had a smoother texture. The photomicrographs reproduced in Figure 3 show in more detail the differences in the crystals formed in the two oils under identical conditions of thermal treatment.

Presumably the differences in the structure of the crystals can be attributed to differences in the chain lengths of the fatty acids in the glycerides of cottonseed and mbocaya oils. In the latter a large proportion of the component fatty acids are of short chain length, probably C_{12}, while in the former chain lengths of 16 and 18 carbon atoms predominate. Hence when hydrogenated cottonseed oil crystallizes from solution in mbocaya oil, there is little tendency for solid solutions to form. Only the hydrogenated cottonseed oil separates, and its crystals are relatively pure and large. When hydrogenated cottonseed oil crystallizes from unhydrogenated cottonseed oil, the situation is different. The glycerides of the two oils are so much alike that some of those from the unhydrogenated oil are incorporated in the crystals, and solid solutions are formed. Because of their heterogeneity these crystals tend to be less perfect and smaller in size. While the above explanation of the differences observed may be somewhat simplified, it is believed to be substantially correct.

A concomitant result of the formation of solid solutions in mixtures of hydrogenated and unhydrogenated cottonseed oils is that the total amount of solids formed exceeds the amount which might be expected on the basis of the content of hydrogenated cottonseed oil. This is one reason why these mixtures are firmer than are comparable mixtures in which mbocaya oil forms the liquid phase; the other two reasons are that the crystals are smaller and that they are more irregular in shape.

The probability that the explanations offered above are correct is well supported in the literature. Bailey (1) has reviewed evidence indicating that solid solutions are factors in the consistency of plastic fats. Kerridge (5) and Craig *et al.* (2) have presented data showing that solid solutions occur when certain mixtures of glycerides are cooled.

Other Products from Cottonseed Oil and Mbocaya Oil

It might be expected that interesterification of hydrogenated cottonseed oil and mbocaya oil would produce mixtures suitable for use as shortenings. Such mixtures were prepared and examined. The consistency curves obtained are reproduced in Figure 4.

It is evident that if interesterification is to produce suitable products, quite large proportions of hydrogenated cottonseed oil will be needed. At levels of 16 and 24% of hydrogenated cottonseed oil the interesterified mixtures are too soft at a temperature above 20°C. and too firm below this temperature. Undoubtedly interesterified products having suitable consistency characteristics can be prepared, but large proportions of hydrogenated cottonseed oil with an iodine value greater than that of hydrogenated oil C-2 would have to be employed. Economically this might not be attractive in areas where mbocaya oil is the more readily available.

Interesterification has a desirable effect upon the crystal habit of the finished products made from hydrogenated cottonseed oil and mbocaya oil. Before interesterification the solid phase of plastic mixtures at room temperature consists of more or less spherical granules. After interesterification the crystals which form are rod-like in shape and relatively small in size, which tends to result in an improved texture.

One acceptable type of formulation which cannot be duplicated with coconut oil appears to be possible with mbocaya oil. On hydrogenation the melting point of the latter can be raised to about 58°C., which makes it suitable for use as the solid phase in blended type shortening. Completely hydrogenated coconut oil, on the other hand, possesses a melting point of only about 43°C. As shown in Figure 5, a blend of hydrogenated mbocaya oil and cottonseed oil can be prepared which has consistency characteristics superior to those of a typical shortening of the all-hydrogenated type with regard to plastic range. The blend represented by Curve B, Figure 5, is similar to an all-hydrogenated shortening below 20°C. and somewhat firmer at higher temperatures.

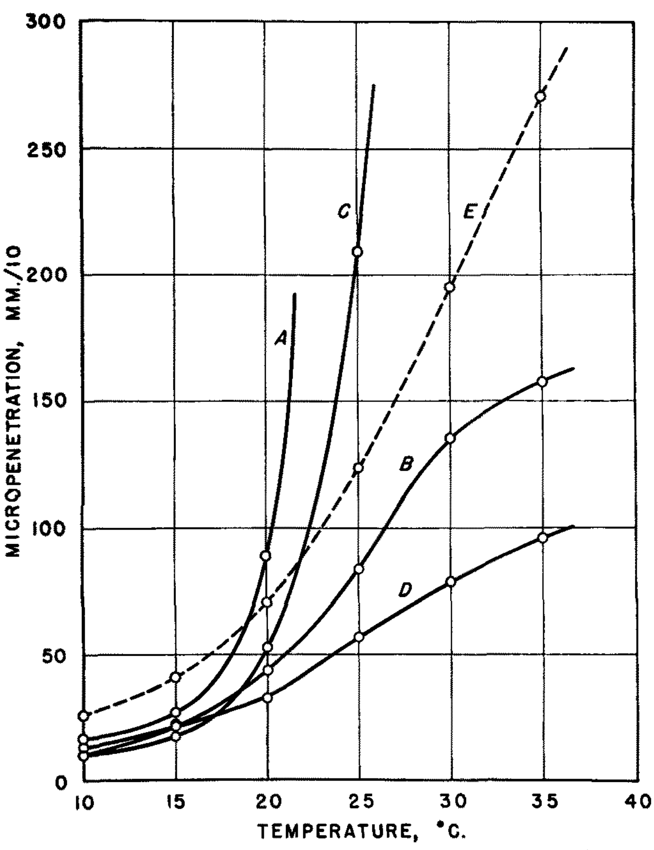

FIG. 4. Effect of interesterification on consistency: (A) mixture obtained by interesterifying 16% of hydrogenated cottonseed oil C-2 and 84% of mbocaya oil M-1, and (B) the same mixture before interesterification; (C) mixture obtained by interesterifying 24% of cottonseed oil C-2 and 76% of mbocaya oil M-1, and (D) the same mixture before interesterification. Curve E represents a blended-type shortening.

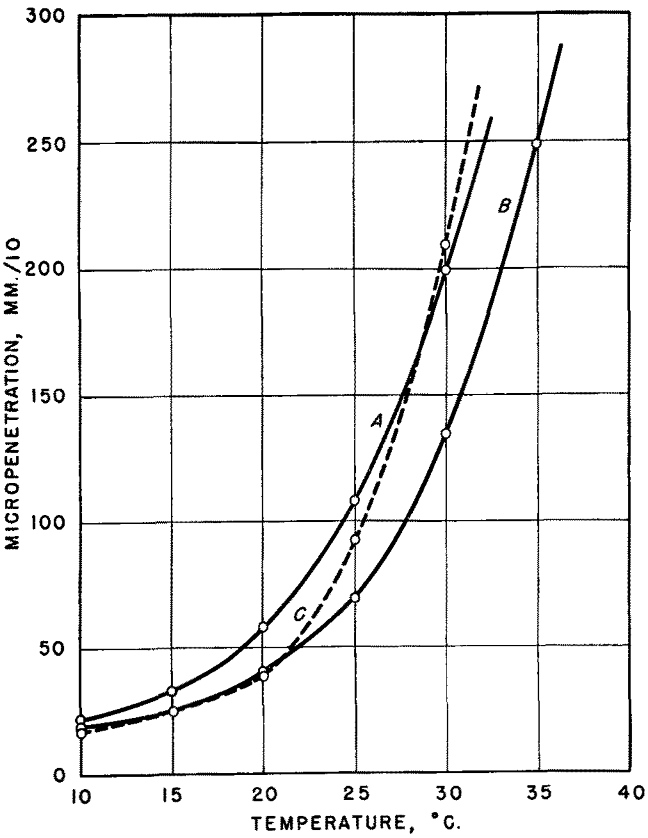

FIG. 5. Consistency curves for (A) a mixture containing 30% of hydrogenated mbocaya oil M-6 and 70% of cottonseed oil C-1, (B) a mixture containing 40% of hydrogenated mbocaya oil M-6 and 60% of cottonseed oil C-1, and (C) a commercial shortening of the all-hydrogenated type.

Summary

A palm kernel oil, mbocaya, possessing a relatively high iodine value, approximately 30, is being produced in Paraguay. Production can be expanded. One possible use for the oil is as a component of shortenings.

As expected, consistency measurements showed the oil to be unsuited for conversion to shortening of the all-hydrogenated type. Blends with hydrogenated cottonseed oil yielded products having acceptable consistency characteristics. However, for a given consistency, the proportion of hydrogenated cottonseed oil needed was greater than that needed for a comparable blend with cottonseed oil. The difference was attributed to the formation of solid solutions or mixed crystals in the latter blend.

A mixture of hydrogenated palm kernel oil and cottonseed oil was prepared and found to possess consistency characteristics better than those of a typical shortening of the all-hydrogenated type.

Acknowledgment

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