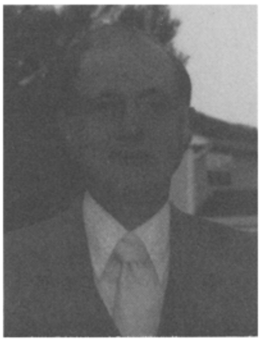

Formulation of Products from Soybean Oil

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ABSTRACT

High quality shortenings and margarines may be produced using soybean oil as the only fat source or using soybean oil as the primary fat source with the addition of a small amount of hydrogenated cottonseed or palm oil to provide crystal stability. These shortenings and margarines are manufactured by direct hydrogenation or by blending hydrogenated and/or unhydrogenated base stocks. The properties of soybean oil preclude the need for processes other than hydrogenation and blending to produce most margarine and shortening products. It is possible to design an integrated base stock program in which a limited number of base stocks may be used jointly in margarine and shortening formulations. This type of base stock program results in fewer hydrogenation department heels and simplifies scheduling of the hydrogenation department as well as scheduling of overall operations. Solid fat index (SFI) is the analysis used for final product consistency control. While base stocks are blended to meet a final SFI requirement, this analysis is too time-consuming to be used in hydrogenation control and individual hydrogenation batches are controlled using refractometer number and congeal points. Finished product characteristics are a result of decisions that must be made regarding characteristics such as plastic range and AOM stability, which are incompatible.

INTRODUCTION

Soybean oil is nearly an ideal oil as far as processing is concerned. It refines with relatively low loss. Soybean oil is a natural salad oil. The color pigments are so heat-sensitive that properly processed soybean oil deodorizes to a color of much less than 1.0 R (Lovibond) without bleaching; bleaching is performed for other reasons than color reduction. Soybean oil, when partially hydrogenated and winterized, forms large, easily filterable crystals. The high iodine value of the oil permits hydrogenation and blending to make a wide variety of products.

Two major deficiencies inherent in soybean oil are that the oil contains ca. 6–8% of linolenic acid and that the hydrogenated oil is a "beta crystal former" (1,2). Because of the high linolenic acid content, salad oil production requires partial hydrogenation followed by winterization to reduce the linolenic acid content. Shortenings which are packaged in a plastic form have ca. 10% fully hydrogenated cottonseed oil or palm oil added to maintain the product in the beta prime form.

The tendency of a shortening or margarine product to form beta crystals is accelerated by increases in temperature. Because shipping and storage practices in the U.S. keep margarine at a uniformly low temperature, the 5–10% hydrogenated cottonseed oil formerly required for crystal stability is no longer considered necessary and table-grade margarines often are formulated from all soybean oil bases. On the other hand, shortenings are stored ideally at temperatures of 70-75 F, and often are subjected to much higher storage temperatures. Therefore, those shortenings produced and used in the plastic state must contain hydrogenated cottonseed oil or palm oil. In specific shortening applications, such as fluid bread and frying shortenings, where the beta crystal state is desirable, the products are formulated from all soybean oil based fats.

A manufacturer may formulate products in such a manner that a special base fat or series of base fats is required for almost every product. Because individual orders rarely use exact multiples of hydrogenation batches, such systems result in a large number of heels. The purpose of this paper is to illustrate how a base stock system using a limited number of base stocks may be designed to formulate all or nearly all of the soybean oil based products that may be required. The base stocks and the formulations are within the quality control capabilities encountered in modern plant operations.

There are significant advantages to a base stock program. These are: (a) the number of heels of hydrogenation batches that must be reworked is greatly reduced; (b) by blending two or more batches of the same hydrogenated base stock, minor variations between individual batches tend to average; (c) scheduling of plant operations is greatly simplified because scheduling of hydrogenation involves keeping the base stock tanks full and does not begin with receipt of an order.

Quality Control

This paper does not present a complete discussion of edible oil quality control requirements. Quality control is reviewed only as it applies to consistency control and only in enough detail to indicate how the base stocks were prepared. Quality assurance or quality control, whichever system is used, also includes attributes other than consistency, including color, color stability, flavor, flavor stability, free fatty acid, peroxide value and AOM stability.

Finished product margarine and shortening consistency control is accomplished using solid fat index analyses obtained by standard AOCS methods. Individual customers may have iodine value, Wiley melting point or other required specifications in addition to solid fat index (SFI) to control the processing and formulation of the product but basic finished product control is done using SFI. However, SFI is too time-consuming for process control; hydrogenation control tests may be divided into one of three categories: (a) high iodine value base stocks. Base stocks above ca. 90 IV are adequately controlled using refractometer number alone; (b) intermediate iodine value base stocks. Base stocks from an IV of ca. 55–90 are controlled by a combination of refractomer number and AOCS congeal point. The oil is hydrogenated to a refractometer number and the congeal point is run. The congeal point is the controlling analysis. If the base stock is lower than the desired congeal point, hydrogenation is continued and the process repeated until the desired congeal point is obtained. Various mechanical devices have been developed which give a cloud point which is used instead of a congeal point. Whether these cloud point determinations are made manually or mechanically, their purpose is to reduce the time required for the official AOCS congeal point; (c) low iodine value base stocks. Low iodine value base stocks (normally 10 IV or less) are generally controlled by a quick titer determination. There are many versions of the test, but basically, the test involves dipping the bulb of a thermometer into the molten fat and rotating the stem of the thermometer between the fingers until the fat on the thermometer bulb clouds. A constant is added to the temperature obtained at this time to approximate the real titer. The AOCS titer determination requiring, e.g., saponification, acidulation and separation, is too time-consuming for hydrogenation control.

Shortening Formulation

Modern general purpose shortenings are formulated with a partially hydrogenated base oil and fully hydrogenated cottonseed oil or palm oil. Partial hydrogenation of the soybean oil base increases the oxidative stability.

As the iodine value of the base oil is lowered and the AOM stability continues to increase, the amount of hard fat required to yield the proper consistency decreases. This, in turn, decreases the plastic range. In other words, the increase in AOM stability is achieved at the expense of plastic range. This type of compromise is characteristic of all general purpose shortenings.

Base stocks #1 and #1A in Table I represent two soybean oil base fats that are used to make general purpose shortenings.

Base stock #1, with ca. 12% hard fat, will yield a shortening with ca. 65-hr AOM stability. Base stock 1A, with ca. 8% hard fat, will yield a finished product with over 100-hr AOM stability.

Figure 1 shows the effect of the hard fat addition on the slope of the SFI curves. While base fat 1A has a higher solids level than base stock #1, the slope of the base stock SFI curves are the same. The slopes of the finished shortening SFI curves are changed substantially, however, when differing amounts of hard fat are added to base stocks. The hard fat provides solids at the higher temperatures by flattening the SFI curve.

Figure 2 illustrates the effect on plastic range of using the two base stocks with differing amounts of hard fat. For each shortening, the midpoint of the SFI ranges were plotted. If we assume that a shortening is plastic and workable between SFI values of 15 and 25%, then shortening B, formulated with 12% hard fat, is plastic and workable at all temperatures from 50 to 92 F for a 42 F plastic range, and shortening A, formulated with 8% hard fat, is plastic and workable from 57 to 87 F for a plastic range of 30 F. These examples illustrate that, for given hydrogenation conditions, the softer the partially hydrogenated base stock, the lower the AOM stability and the greater the plastic range. Unhydrogenated soybean oil with added hard fat, represented in Figure 2 as shortening C, would have ca. 25-hr AOM stability but would be plastic and workable at all temperatures from 50 to 104 F.

It makes no difference at which SFI limits we arbitrarily determine a product to be plastic and workable. The less hard fat that is used, the steeper the SFI curve and the faster that curve will pass through the limits of plastic range.

Base stock #2 in Table I is used to make a high stability frying fat. It would not be uncommon to add ca. 2–5% hard fat to this base oil to produce a finished frying fat. On the other hand, it is not unusual for this type of shortening to be produced from a single, hydrogenated base oil having ca. 4-5% more solids at 50 F than base stock #2 by hydrogenating the oil an additional 2–5 IV. In any event, plastic range is of minor importance in this type of product and is sacrificed to achieve maximal frying performance.

Base stock #3 (Table I) is typical of the base stocks used

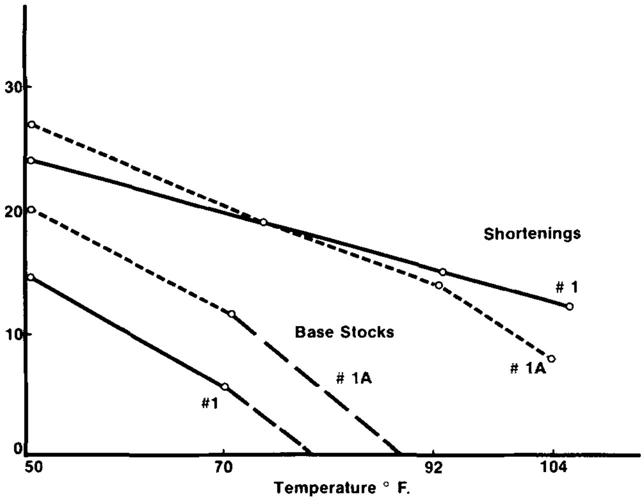

FIG. 1. Effect of hardstock on shortening SFI slope.

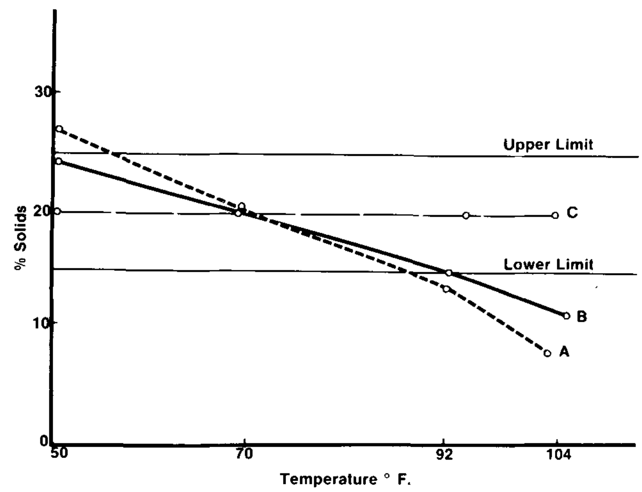

FIG. 2. Effect of hardstock on plastic range.

TABLE I

Shortening Base Stocks

Base stock no.	1	1A	2	3
Hydrogenation conditions				
Initial temp (F)	300	300	300	285
Hydro temp (F)	330	330	330	285
Pressure (psig)	15	15	15	40
Nickel (%)	.02	.02	.02	.02
Final IV	83-86	80-82	70-72	104-106
Final congeal (C)	—	—	—	—
SFI @ 50 F (10.0 C)	16-18	19-21	40-43	4 Max.
70 F (21.1 C)	7-9	11-13	27-29	2 Max.
92 F (33.3 C)	—	—	9-11	—

to produce fluid frying fats. Soybean oil hard fat is added to this base stock prior to crystallization to produce a fluid frying fat. The soybean oil hard fat is used because of the ease with which it will convert to the stable beta crystal form.

Margarine Formulation

Most finished table-grade margarine oils are a blend of one hydrogenated and one unhydrogenated oil or a blend of two or more hydrogenated oils. Table II lists margarine bases which can be used in margarines.

These bases include a very soft stock with ca. 4% solids at 50F, an intermediate stock with 36–38% solids at 50F and the hardest of the base oils with 58–60% solids at 50F.

Base stock #3A preferably should be hydrogenated to ca. 106–108 IV under selective conditions. However, in the interest of reducing base stocks, base stock #3, which was designed for a liquid shortening base may be used in place of soft margarine base #3A.

Base stock #4 should be hydrogenated under selective conditions to an endpoint of ca. 73–76 IV. This base stock must be hydrogenated selectively so that its addition to margarine base oil blends will not result in a precipitous increase in the Wiley melting point.

The hardest of the base oils to produce is base stock #5. The catalyst must be selective enough to maintain the necessary slope of the SFI curve. However, the IV of this base oil is low enough that, at the time the endpoint is being reached, the SFI at 92F is increasing rapidly. If the endpoint is exceeded, the SFI at 92F will be so high that it will not be possible to meet the final margarine SFI and melting point requirements. Four finished margarine oil specifications are listed in Table III (2, 3).

Margarine #1 very nearly represents the softest stick-type margarine that can be packaged. Modern packaging machines will deposit, wrap and carton product that is somewhat softer, but a product that is considerably softer does not have the structural rigidity to withstand deformation during handling and usage. This type of margarine contains the highest percentage of polyunsaturated acids of normal stick margarines.

Margarine #2 (Table III) typifies a stick margarine with relatively high SFI at 70F for the SFI at 50 and 92F. This type of formulation prints well, especially in packaging equipment which does not deposit the margarine into preformed quarters.

Margarine #3 (Table III) approaches the margarines that were produced before the so-called spreadable margarines were produced. This margarine oil can be produced by straight hydrogenation of soybean oil. It also can be produced by blending the base stocks that have been presented, obviating the necessity for a special hydrogenation.

Margarine #4 in Table III represents a typical tub-style margarine.

Specialty Products

A large number of specialty products are used in various food operations. While it is true that a few of these products require some special processing or special hydrogenation, the quality standards of the most can be met by blending base stocks.

An experienced formulator will determine first which of available base stocks approximates the desired specification. If the desired product is harder or softer than the nearest base stock, an appropriate blend is made. Of course, this presupposes that the proposed specification has an SFI slope that is similar to existing base stocks. If not, it already has been shown that the slopes of SFI curves can be significantly changed by the addition of hard fats and that the crystal behavior of the resulting product may be controlled by the type of hard fat that is added. The number of products that can be formulated from a minimal number of base fats is governed largely by the skill and ingenuity of the formulator.

In this discussion, the use of base stocks to meet consistency limits has been discussed. It must be emphasized that all of the other possible specifications also must be met. Base stocks may not be blended with a total disregard for AOM stability, for instance. In short, to maintain product integrity, blending of base stocks should be closely controlled by the one person within the company who is in charge of formulation. Individual batches of product formulated by plant personnel should be within the percentage guidelines established by the formulator.

TABLE II

Margarine Base Stocks

Base stock no.	3A	4	5
Hydrogenation conditions			
Initial temp (F)	300	300	300
Hydro temp (F)	350	425	425
Pressure (psig)	15	15	5
Nickel (%)	.02	.02	.02
Final IV	106–108	73–76	64–68
Final congeal (C)	—	24.0–25.0	33.0–33.5
SFI @ 50 F (10.0 C)	4 Max.	36–38	58–61
70 F (21.1 C)	2 Max.	19–21	42–46
92 F (33.3 C)	–	2.0 Max.	21 Max.

TABLE III

Typical Margarine Formulae

Formula number	1	2	3	4
Type	Soft Stick	Stick	Stick	Tub
SFI @ 50 F	20–24	27–30	28–32	10–14
70 F	12–15	17.5 min	16–18	6–9
92 F	2–4	2.5–3.5	1–2	2–4
Base #1 or 1A (%)	—	—	60	—
#3 or 3A	—	42	—	80
#4	—	20	25	—
#5	50	38	15	20
Liquid oil (%)	50	—	—	—

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