Blending, Chilling, and Tempering of Margarines and Shortenings

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ABSTRACT

The preparation of the milk and fat phase of margarine, which is a milk-in-fat emulsion, is discussed. Refined and deodorized fats are blended to meet constraints in regard to price, solid fat index, taste stability, and crystallization behavior. The milk phase is prepared according to specifications and concerning protein content, salt concentration, and other ingredients, and adjusted to the pH. The flavored fat and the milk are then dosed in the proper ratio and processed by means of scraped coolers in which the mixture is emulsified, cooled, and crystallized. High speed machines pack the product in tubs or wrappers.

The processing of shortenings is roughly the same, but no water phase is used. Occasionally, tempering, which is a hold of several hours at elevated temperature, is applied to improve the plasticity of the product, its creaming properties, and overall baking performance.

INTRODUCTION

Margarine is a water-in-fat emulsion in which the water droplets are kept separated by the fat crystals. These crystals may vary in shape and appear in the form of needles or platelets with lengths ranging from < 0.1 μm to 20 μm or more. They do not behave as individual particles, and can grow together, forming a strong network (Fig. 1A). They may also show a tendency to agglomerate, forming tiny porous crystal clusters with considerably fewer contact points (Fig. 1B). This difference in behavior is reflected in the spreadability and oil exudation of margarines even if they have the same percentage of solids; the one in Figure 1A will be hard and brittle, the one in Figure 1B soft, sloppy, and oily. Good margarines take a position in between these two extremes and are neither too brittle nor too soft. When the fat crystals melt on raising the temperature, the network weakens and the product becomes softer. Ideally, all crystals should melt some degrees below body temperature, resulting in a total breakdown of the emulsion *in the mouth.*

The spreadability of margarines is controlled by two dominating factors: the amount of solid triglycerides, i.e., the Solid Content Index (SCI), which depends on the choice of the fat blend, and the processing conditions during production, i.e., the degree of cooling and working. When the processing conditions are constant, a strong correlation is expected between the solid content of the blend and the spreadability of the margarine.

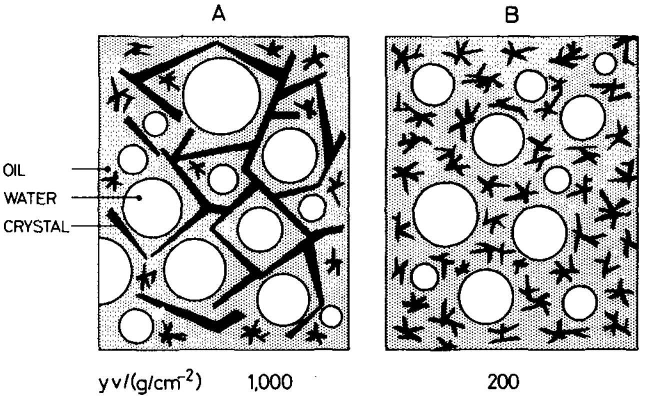

FIG. 1. Structure of two margarines containing 10% solid fat: (A) yield value 1,000 g/cm2; (B) yield value 200 g/cm2.

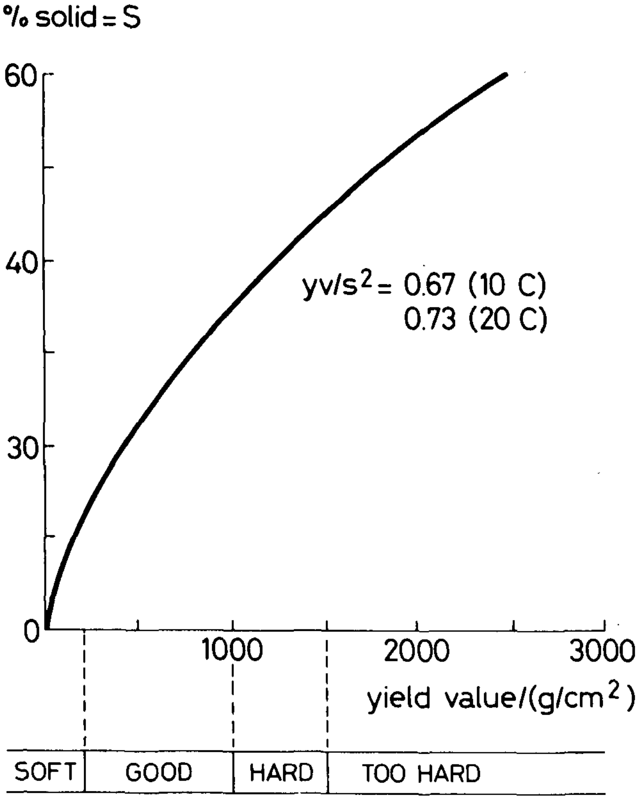

FIG. 2. Hardness of margarine vs. percentage solid in fat.

TABLE I

Calculation of the Percentage Solid in Mixtures of Raw Materials

Fat	Contribution (% solid/% fat) to % solid 10 C	15 C	20 C
Liquid oil	-0.13	-0.15	-0.13
Hydrogenated soybean oil (HSBO)	0.71	0.56	0.36
Palm oil	0.42	0.29	0.19
Coconut oil	0.46	0.15	-0.13

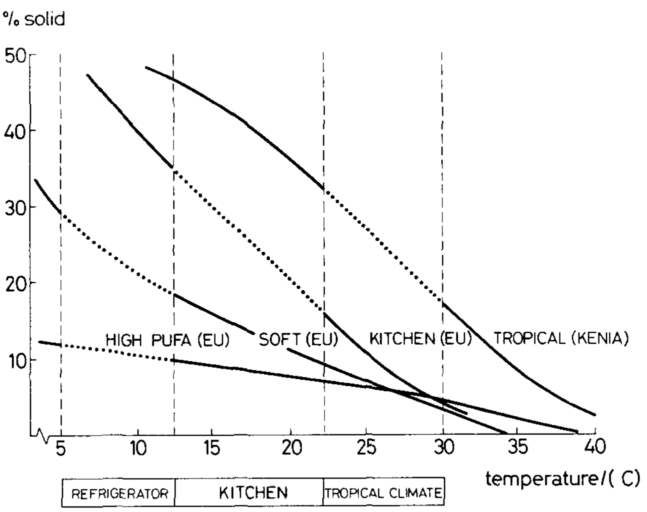

FIG. 3. Percentage solid vs. temperature for some margarines. PUFA = polyunsaturated fatty acids; EU = Europe.

Figure 2, in which the yield value is used as a measure of the spreadability, shows the importance of mixing the blend components in such a ratio that the required solid content is obtained.

SOLID CONTENT INDEX

Calculation of the SCI of a blend from its components is possible on the assumption that each component, in relation to its amount, yields a linear contribution to the solid content. These contributions or Statistical Dilatation Equivalents must be computed first, using the dilatations of a known mixture of the components. One example is given in Table I for a product consisting of four components: a liquid oil such as soybean oil, a hydrogenated soybean oil, palm oil, and coconut oil. The SCI at 15 C is then equal to

$$0.15 \times \%\ \text{liquid} + 0.56 \times \%\ \text{HSBO} + 0.29 \times \%\ \text{palm oil} + 0.15 \times \%\ \text{coconut oil}$$

By introducing several characteristics of each raw material, such as dilatation specifications, the best possible blend can be obtained.

The types of margarines sold vary from very soft products spreadable from the refrigerator to products with a high-temperature stability for tropical conditions. Typical percentage solid vs. temperature lines are shown in Figure 3. Both the soft and the kitchen margarine melt below body temperature, which, as said before, is a requirement for good meltdown characteristics in the mouth. The dietary, high polyunsaturated fatty acid margarine is soft at all temperatures and, due to the solids remaining above 35 C, a bit slow melting. Tropical margarines must have sufficient body up to 35 C but, consequently, are very "thick" in the mouth.

CRYSTALLIZATION

An important factor in the production of margarines is the rate of crystallization of the fat blend. If it is low, the margarine will be too soft and cannot be packed, or only with great difficulty. The fat will continue to crystallize in the pack or tub. This post-crystallization, in the absence of agitation, favors the formation of a strong network; consequently, severe post-hardening will occur. High crystallization speeds are not desired either, as they give rise to too soft and overworked products by lack of sufficient body.

Fats crystallize slowly and may need hours to reach complete crystallization. In Figure 4, the increase in the amount of solids is shown when fats are cooled quickly by transferring a dilatometer from a 60 C bath to a 0 C bath. For these experiments, hollow stopper dilatometers were

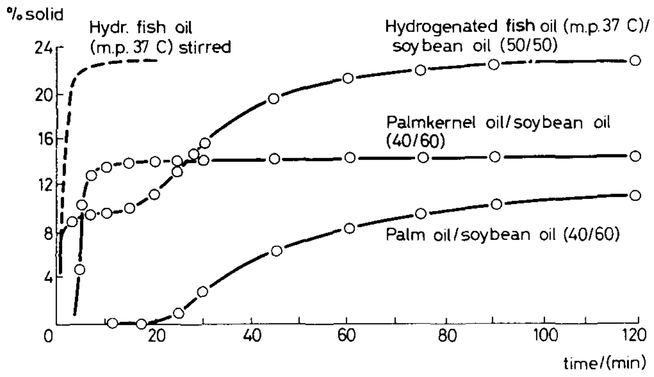

FIG. 4. Cooling curves of various fat samples transferred from 60 to 0 C.

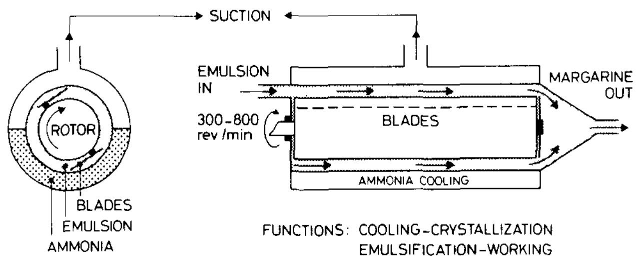

FIG. 5. Girdler A-unit.

used with internal water circulation. In this way it is possible to cool a fat layer at ca. 3 mm thickness to the required temperature within ca. 2 min. Three fats with different rates of crystallization were diluted with soybean oil in the ratios given. The palmkernel fat is a fast crystallizer, as contrasted with the palm oil, which is a slow one. The hydrogenated fish oil crystallizes in two steps: first, probably, the saturated and later the unsaturated glycerides. The picture changes drastically when stirring is applied, as is shown by the dashed line; now the fat is fully crystallized within ca. 7 min. To study the crystallization rates under stirred conditions, metal dilatometers with scraper blades were made to imitate factory conditions.

The high shearing and scraping actions which occur in a Girdler A-unit, combined with its high cooling capacity, make this unit ideally suitable for the production of margarine. This scraped-surface tube cooler (Fig. 5) consists of a steel rotor, rotating in a tube which is cooled externally by boiling ammonia. The annular space between rotor and cooling tube is ca. 5-10 mm. The rotor carries from 2 to 6 rows of scraper blades. The high rotation speed presses the blades against the cooled inner surface by centrifugal force. High local pressures and shearing actions induce fast nucleation and crystallization during the short residence time of ca. 5-10 sec.

In general (Fig. 4) fats require crystallization times of ca. 5-7 min. This time is provided in crystallizers, tubes of large diameter with pins on wall and rotor (Fig. 6). The volume varies from 50 to 100 liters, allowing the fat or emulsion a resting period of a few minutes while it is constantly being worked.

The margarine or shortening production line consists of a combination of A-units and crystallizers (B-units) (Fig. 7). The emulsion is formed in the first A-unit with moderate cooling. The A-unit is followed by a crystallizer in which the temperature is 2 C higher due to the heat of crystallization. Two other coolers bring the emulsion to 15 C. The total residence time is now 2.5 min, which, as we have seen, is still too short; therefore, the margarine passes another 2.5 min in a resting tube in which it sets to a hardness sufficient for it to be packed in wrappers. Various arrangements of A-units and crystallizers can be applied for the production of margarines with different temperature

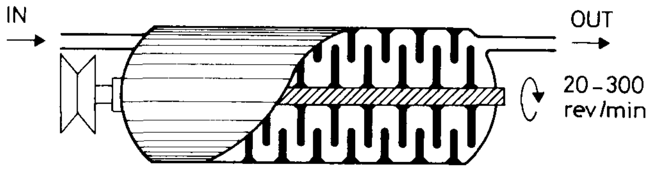

FIG. 6. Crystallizer.

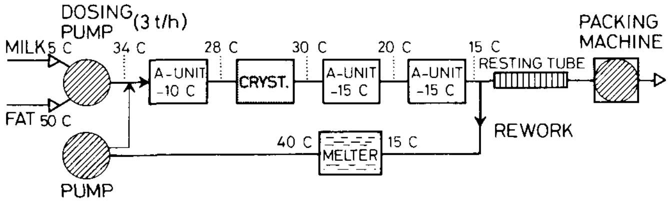

FIG. 7. Production of margarine.

profiles and degrees of working for packs or tubs.

WATER PHASE

So far, we have mainly dealt with the crystallization behavior of the fat phase and not touched upon the ingredients added to the fat phase, such as emulsifiers (mainly monoglycerides), lecithin, coloring matter, and vitamins, or upon the milk phase. The latter constitutes an important part of the margarine (up to 20%). The use of milk offers a number of advantages over the use of plain water. Milk (a) increases taste stability, (b) develops the natural butter flavor, and (c) improves the frying properties (browning of proteins).

The main disadvantage of using milk is the highly increased sensitivity of the margarine to spoilage by microorganisms. The means available in a margarine factory to inhibit the growth of bacteria, molds, and yeasts are (a) good emulsification—small water droplets below 5 μm do not contain sufficient nutrients and are too small for microorganisms to grow-in; (b) addition of salt, so that the water activity of the milk phase is decreased; (c) adjustment of pH, as bacteria cannot live at a low pH; (d) addition of preservatives, such as benzoic and sorbic acid; and (e) keeping the initial infections low.

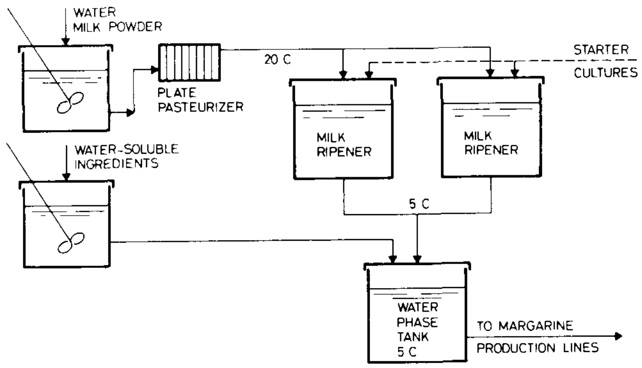

FIG. 8. Preparation of water phase.

Preparation of the water phase is shown in Figure 8, using skim milk powder; whole sweet milk, whey, or other milk products can also be used. After pasteurization, the "milk" is pumped to a milk ripener in which it is inoculated with ca. 1% of a starter culture mainly consisting of *Streptococcus lactis, Streptococcus cremoris,* and *Betacoccus cremoris* for the production of lactic acid, diacetyl, and other flavors. Ripening is continued until the proper pH is reached or the required amount of flavor has developed. After addition of the water soluble ingredients, the water phase is kept at ca. 5-8 C, ready for being mixed with the fat phase.

TEMPERING

Table and kitchen margarines are usually sold without any heat treatment after production. Margarines and shortenings used for baking are often tempered, i.e., placed at an elevated temperature for 2 or 3 days. The temperature varies between 25 and 35 C, depending on the type of product and the tempering time. Tempering improves the plasticity, creaming properties, and baking performance, especially of products containing lard and tallow. The slow crystallization occurring during tempering favors the crystal growth, which in its turn improves the creaming, i.e., the uptake of water and air in batters.