INTRODUCTION

Fats and oils play an important role in the human diet. They improve the palatability of foods, are a concentrated source of calories, and supply certain components vital to the human diet such as essential fatty acids and fat-soluble vitamins.

The per capita consumption of visible fats and oils in the U.S. during several years for several types of food-fat products is given in Table 1. The usage of margarine, baking and frying fats, salad and cooking oils has increased while that of butter and lard has decreased.

Culinary practices have a strong influence on the particular form in which fat is consumed. For example, in 1972 in Europe, countries in the Mediterranean region (namely Portugal, Spain, Italy, Greece, and Yugoslavia) consumed 78% of their fat in the form of salad and cooking oils, 4% as margarine, 6% as butter, and 12% as other fat. The pattern changed gradually from liquid oils to margarine and butter in successive zones progressing towards Northern Europe. For the Scandinavian countries (namely Norway, Sweden, Finland, and Denmark) and the Netherlands, only 3% of the consumption was as salad and cooking oils, while 68% was as margarine, 23% as butter, and 6% as other fat (Lesieur, 1976).

Information is given in Table 2 on the various types of markets for edible oils in the U.S., their relative rank in 1978, and the types of food-fat products consumed in each market. Soybean oil is used in all of these markets. In a special report, Brody (1978) states that soybean oil in either liquid or modified form is suitable for use in each of
TABLE 1
Per Capita Civilian Consumption in U.S. of Visible Food Fats and Oils by Type of Product

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter c</td>
<td>8.6</td>
<td>6.0</td>
<td>4.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Margarine c</td>
<td>4.9</td>
<td>7.5</td>
<td>8.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Lard (direct use)d</td>
<td>12.6</td>
<td>7.6</td>
<td>4.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Baking and frying fats e</td>
<td>11.0</td>
<td>12.6</td>
<td>17.3</td>
<td>18.2</td>
</tr>
<tr>
<td>Salad and cooking oils f</td>
<td>---</td>
<td>9.2</td>
<td>15.5</td>
<td>20.5</td>
</tr>
<tr>
<td>Other edible uses g</td>
<td>8.6</td>
<td>2.3</td>
<td>2.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Total (fat content)</td>
<td>45.9</td>
<td>45.3</td>
<td>53.0</td>
<td>55.6</td>
</tr>
</tbody>
</table>

* Preliminary.
* Actual weight y .8 = fat content.
* Excludes quantity used in margarine, shortening and nonfood products.
* Data not available prior to 1959.

... the 11 markets. He gave two exceptions involving minor quantities of oil, namely when a dark oil is desired in some mayonnaises and similar products and when a stearine of the beta-prime crystal form is required for plasticizing a shortening.

Soybean oil is found in a variety of products, as illustrated by the partial listing given in Table 3. A reading of ingredient labels would reveal further uses. The oil is used in numerous and sometimes very inconspicuous ways such as spraying pieces of refrigerated dough so they will readily separate when the homemaker opens the package.

During the last four decades, U.S. usage of soybean oil in foods has increased about 34-fold, going from 256 million lb in 1938 (American Soybean Association, 1950) to 8,700 million lb in 1978 (preliminary figures) (U.S. Department of Agriculture, USDA, 1979b). Today, soybean oil is the leading edible fat source in the U.S. The same is true for Western Europe (Gander, 1976; Leysen, 1979).

Beginning with 1968, more than one-half the quantity of "visible" fats derived annually from both animal and vegetable sources has been supplied by soybean oil; in 1977, the proportion was 67% (USDA, 1979b). Table 4 lists for the period 1960-1978, the quantities of soybean oil used in the production of margarine, shortening, and salad and cooking oils. A significant portion of the latter apparently is used also by the wholesale baking industry for making bread and cakes, as will be discussed later. As shown in Figure 1, soybean oil supplied 61, 80, and 83% of the total fat required for the 1978 production of the three large volume...
<table>
<thead>
<tr>
<th>Market outlet</th>
<th>Type of fat product used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer products</td>
<td>Shortenings, margarines, and salad oils sold retail</td>
</tr>
<tr>
<td>Hotels, restaurants, and institutions—including fast-food operations</td>
<td>Mainly frying fats and some salad oils&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bakeries</td>
<td>Great variety of specialized fat products&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Salad dressings</td>
<td>Salad oils almost exclusively</td>
</tr>
<tr>
<td>Biscuits and crackers</td>
<td>Generally high stability fats&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Potato chips and other fried snack foods</td>
<td>Generally high stability fats&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Prepared mixes and refrigerated doughs</td>
<td>A variety of specialized shortenings&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Frozen foods—french fried potatoes, fish, chicken</td>
<td>Frying fats of several types</td>
</tr>
<tr>
<td>Canned and dehydrated foods</td>
<td>Good stability oil or fat</td>
</tr>
<tr>
<td>Confectionary coatings</td>
<td>Highly specialized fats</td>
</tr>
<tr>
<td>Imitation dairy products</td>
<td>From salad oil to highly specialized fats</td>
</tr>
</tbody>
</table>

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<sup>a</sup> Adapted from Brody, 1978.
<sup>b</sup> Given in approximate order of size.
<sup>c</sup> About 80% of usage is as frying fats.
<sup>d</sup> Often "tailor made" for a specific bakery product.
<sup>e</sup> To ensure long shelf life of the consumer product.
<sup>f</sup> Often "tailor made" to buyer's specifications.
Some Examples of Commercial Food Products That Contain Soybean Oil

<table>
<thead>
<tr>
<th>Product</th>
<th>Source oil</th>
<th>Fat content, wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salad oil:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brand A</td>
<td>pHSB</td>
<td>100</td>
</tr>
<tr>
<td>Brand B</td>
<td>pHSB, pHCs</td>
<td>100</td>
</tr>
<tr>
<td>Brand C</td>
<td>pHSB, pHCs</td>
<td>100</td>
</tr>
<tr>
<td>Shortening:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brand A</td>
<td>pHSB, pHF</td>
<td>100</td>
</tr>
<tr>
<td>Brand B</td>
<td>pHSB, pHF</td>
<td>100</td>
</tr>
<tr>
<td>Margarine:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stick</td>
<td>pHSB</td>
<td>80</td>
</tr>
<tr>
<td>Soft stick</td>
<td>pHSB, pHCs, SB</td>
<td>80</td>
</tr>
<tr>
<td>Fabricated sausage links</td>
<td>C, pHSB, CS</td>
<td>18</td>
</tr>
<tr>
<td>Coffee whitener</td>
<td>pHSB</td>
<td>14</td>
</tr>
<tr>
<td>Cheesecake mix</td>
<td>pHCn, pHSB</td>
<td>11</td>
</tr>
<tr>
<td>Egg noodles</td>
<td>CF, pHSB</td>
<td>8</td>
</tr>
<tr>
<td>Filled evaporated milk</td>
<td>SB</td>
<td>6</td>
</tr>
<tr>
<td>Instant pudding and pie filling</td>
<td>pHSB</td>
<td>4</td>
</tr>
<tr>
<td>Egg substitute</td>
<td>pHSB</td>
<td>3</td>
</tr>
</tbody>
</table>

a Mounts, 1979.

In order of decreasing amounts present as listed on product label: CF = chicken fat, Cn = coconut, C = corn, CS = cottonseed, P = palm, PK = palm kernel, SB = soybean. pH = partially hydrogenated. Other products of the same type may differ in both the source oils used and in fat content.

TABLE 4
Soybean Oil Usage in Manufacture of Three Major Food Oil Products

<table>
<thead>
<tr>
<th>Year</th>
<th>Salad and cooking oil</th>
<th>Shortening</th>
<th>Margarine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>887</td>
<td>1,169</td>
<td>1,105</td>
<td>3,161</td>
</tr>
<tr>
<td>1965</td>
<td>1,564</td>
<td>1,471</td>
<td>1,112</td>
<td>4,147</td>
</tr>
<tr>
<td>1970</td>
<td>2,471</td>
<td>2,182</td>
<td>1,410</td>
<td>6,063</td>
</tr>
<tr>
<td>1975</td>
<td>3,012</td>
<td>2,025</td>
<td>1,568</td>
<td>6,605</td>
</tr>
<tr>
<td>1978</td>
<td>3,825</td>
<td>2,479</td>
<td>1,593</td>
<td>7,897</td>
</tr>
</tbody>
</table>

a Source: U.S. Department of Agriculture, 1979c.
b Preliminary.

markets consisting of shortenings, salad/cooking oils, and margarines, respectively.

In a recent market survey based on in-home use of soy-
FOOD USES OF SOYBEAN OIL

Figure 1. Proportion of the U.S. market supplied by soybean oil in 1978 for production of margarines, shortenings, and salad/cooking oils. (Source: U.S. Dept. of Agriculture, 1979c).

Bean oil, homemakers rated soybean oil as essentially equivalent to corn and sunflower oils, two oils generally considered to be of top quality. In their comparative tests, most of the homemakers used the oils for frying and, to a somewhat lesser extent, for salads and baking (Erickson and Falb, 1980).

The large-volume usage of soybean oil within the U.S., and the widening acceptance of the oil in other parts of the world, is attributed to at least three factors: (1) a plentiful, dependable supply, (2) the oil's competitive price, and (3) the improvements made in the flavor and oxidative stability of both the unhydrogenated and the partially hydrogenated forms of the oil. Of course, the large-volume usage of soybean meal, an important animal feed, also has contributed considerably to the increased production of soybeans and of soybean oil. Improvements made in the oil's quality must be attributed, in a large degree, to the application by industry of the information developed in the research laboratories of industry, government, and universities.

By means of hydrogenation, the edible oil processor can harden vegetable oils and animal fats to most any desired degree. He can also employ other processes, such as winterization (see Chapter 12), solvent fractionation (Thomas and
Paulicka, 1976), and rearrangement of fatty acids on the triglyceride molecule by interesterification (Sreenivasan, 1978) to obtain fat fractions having improved or unique properties. Directed interesterification of lard to change the crystal habit from beta (β) to the preferred beta prime (β') form is one example. The interesterification process is used more often in Europe than in the U.S. to prepare suitable products from available oils. Interesterification is not permitted in France (Anonymous, 1979).

In the preparation of food products from soybean oil, several processing steps are used to produce different types of edible products. With rare exceptions, the oil will have been refined, bleached, and deodorized (RBD) to produce a high-quality food oil. Such oil, when unhydrogenated, typically has an iodine value (IV) of 120-140 and in the trade is often referred to as an RBD oil. Under the trading rules of the National Soybean Processors Association (NSPA, 1978), an RBD oil is designated as a fully refined oil. The various types of processed soybean oil used include but are not necessarily limited to those listed in Table 5.

### Table 5

Types of Soybean Oil Used in Various Food Products

<table>
<thead>
<tr>
<th>Type of Oil</th>
<th>Processing Steps</th>
<th>Typical Iodine Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBD SBO</td>
<td>Alkali refined, bleached, and deodorized, partial hydrogenation, winterization</td>
<td>126 (range 120-140)</td>
</tr>
<tr>
<td>Partial hydrogenation</td>
<td></td>
<td>105-115</td>
</tr>
<tr>
<td>Partial hydrogenation and winterization</td>
<td></td>
<td>105-115</td>
</tr>
<tr>
<td>Partial hydrogenation</td>
<td></td>
<td>80-100</td>
</tr>
<tr>
<td>Partial hydrogenation</td>
<td></td>
<td>60-79</td>
</tr>
<tr>
<td>Complete hydrogenation</td>
<td></td>
<td>6 (range 0-15)</td>
</tr>
<tr>
<td>Partial hydrogenation and winterization</td>
<td></td>
<td>60-100</td>
</tr>
<tr>
<td>Transesterification of pHSBO</td>
<td></td>
<td>60-80</td>
</tr>
<tr>
<td>Interesterification of pHSBO alone or in combination with another fat or oil differing in IV or fat composition</td>
<td></td>
<td>Varias</td>
</tr>
</tbody>
</table>

Paulicka, 1976), and rearrangement of fatty acids on the triglyceride molecule by interesterification (Sreenivasan, 1978) to obtain fat fractions having improved or unique properties. Directed interesterification of lard to change the crystal habit from beta (β) to the preferred beta prime (β') form is one example. The interesterification process is used more often in Europe than in the U.S. to prepare suitable products from available oils. Interesterification is not permitted in France (Anonymous, 1979).

In the preparation of food products from soybean oil, several processing steps are used to produce different types of edible products. With rare exceptions, the oil will have been refined, bleached, and deodorized (RBD) to produce a high-quality food oil. Such oil, when unhydrogenated, typically has an iodine value (IV) of 120-140 and in the trade is often referred to as an RBD oil. Under the trading rules of the National Soybean Processors Association (NSPA, 1978), an RBD oil is designated as a fully refined oil. The various types of processed soybean oil used include but are not necessarily limited to those listed in Table 5.
In addition to the mono- and diglycerides, other emulsifiers derivatized from monoglycerides or various fatty acids are also used.

In some food products, soybean oil is the sole edible oil and in others it is used in combination with one or several other oils and fats.

Unhydrogenated soybean oil has a higher P/S ratio than do the partially hydrogenated and winterized (HWSB) oils (Table 6). This ratio is of interest from the medical/nutritional standpoint and is the sum of the polyunsaturated fatty acids (i.e., linoleic and linolenic) divided by the sum of the saturated fatty acids, principally palmitic and stearic. As the degree of hydrogenation increases, the P/S ratio generally decreases although improved selectivity of the hydrogenation process can ameliorate this effect (see Table 6).

Soybean oil as well as other edible oils and fats often contain one or more additives, depending upon the intended use. The additives include metal scavengers, antioxidants, emulsifiers, coloring and flavoring agents, crystallization inhibitors, and antifoaming agents. Each additive improves the oil's ability to serve or perform in some specific manner. The additives are either generally recognized as safe (referred to as GRAS) or they have been specifically approved by a government agency.

Figure 1 of Chapter 5 depicts the various processing steps used to prepare the oil for each of the major food categories.

Further information about the major food products that use large volumes of soybean oil is given in the pages that follow.

MAYONNAISE, PREPARED SALAD DRESSINGS, AND SALAD OILS

TYPES OF OIL USED

Today, soybean oil is the major oil used in mayonnaise, prepared salad dressings, and salad or table oils. The types of processed soybean oil used include the following:

Unbleached but alkali-refined and deodorized oil. This is the simplest type and it meets U.S. Government specifications for oil exported under its Public Law 480 and Food-for-Peace programs. Little if any such oil is consumed in the U.S. in mayonnaise, and other food products.

Alkali-refined, bleached, and deodorized (RBD) oil. Bleaching improves the oil's color and flavor stability (see Table 1, Chapter 8). RBD oil is used with very acceptable results in mayonnaise, prepared salad dressings, salad oils,
### TABLE 6
Fatty Acid Composition of Soybean Oil and of the Fat in Some Soybean Oil Food Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Oils&lt;sup&gt;b&lt;/sup&gt; used</th>
<th>Fatty acid composition, g/100 g fat&lt;sup&gt;c&lt;/sup&gt;</th>
<th>P/s&lt;sup&gt;d&lt;/sup&gt; value</th>
<th>Iodine value, no.</th>
<th>Handbook&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Unhydrogenated soybean oil)</td>
<td>SB</td>
<td>Palmitic 4  Stearic 23  Oleic 51  Linoleic 7</td>
<td>4.0</td>
<td>126</td>
<td>50</td>
</tr>
<tr>
<td>Hydrogenated-winterized soybean oil&lt;sup&gt;e&lt;/sup&gt;</td>
<td>PHSB</td>
<td>10  5  42  35  3</td>
<td>2.5</td>
<td>104</td>
<td>51</td>
</tr>
<tr>
<td>Liquid margarine</td>
<td>PHSB, SB, CS</td>
<td>11  6  35  41  3</td>
<td>2.7</td>
<td>109</td>
<td>98</td>
</tr>
<tr>
<td>Soft (tub) margarine&lt;sup&gt;e&lt;/sup&gt;</td>
<td>SB, PHSB, pHCS</td>
<td>12  7  38  34  4</td>
<td>1.9</td>
<td>101</td>
<td>94</td>
</tr>
<tr>
<td>Regular (hard) margarine&lt;sup&gt;e&lt;/sup&gt;</td>
<td>PHSB, pHCS</td>
<td>11  7  59  17  1</td>
<td>1.0</td>
<td>83</td>
<td>75</td>
</tr>
<tr>
<td>Imitation margarine, about 40% fat</td>
<td>PHSB, pHCS</td>
<td>11  7  48  28  2</td>
<td>1.6</td>
<td>94</td>
<td>102</td>
</tr>
<tr>
<td>Vegetable oil spread (tub), about 60% fat&lt;sup&gt;e&lt;/sup&gt;</td>
<td>PHSB, pHCS</td>
<td>13  6  64  12  Tr</td>
<td>0.6</td>
<td>76</td>
<td>106</td>
</tr>
<tr>
<td>Household shortening&lt;sup&gt;e&lt;/sup&gt;</td>
<td>PHSB, pHCS</td>
<td>14  11  44  24  2</td>
<td>1.0</td>
<td>85</td>
<td>129</td>
</tr>
</tbody>
</table>

---continued
<table>
<thead>
<tr>
<th>Product</th>
<th>Oils</th>
<th>Fatty acid composition, g/100 g fat</th>
<th>P/S ratio</th>
<th>Value, page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial shortening&lt;sup&gt;a&lt;/sup&gt;</td>
<td>pHSB, CS</td>
<td>Palmitic 13, Stearic 12, Oleic 58, Linoleic 11, Linolenic 1</td>
<td>0.5</td>
<td>71</td>
</tr>
<tr>
<td>Special shortening for bread</td>
<td>pHSB, CS</td>
<td>Palmitic 10, Stearic 12, Oleic 53, Linoleic 17, Linolenic 4</td>
<td>1.6</td>
<td>97</td>
</tr>
<tr>
<td>Special shortening for cake mix&lt;sup&gt;c&lt;/sup&gt;</td>
<td>pHSB, pHC5</td>
<td>Palmitic 10, Stearic 9, Oleic 54, Linoleic 13, Linolenic 1</td>
<td>0.5</td>
<td>72</td>
</tr>
<tr>
<td>Special shortening for heavy duty frying&lt;sup&gt;g&lt;/sup&gt;</td>
<td>pHSB</td>
<td>Palmitic 11, Stearic 10, Oleic 74, Linoleic 74, Linolenic 74</td>
<td>1.8</td>
<td>98</td>
</tr>
<tr>
<td>Hard butter</td>
<td>pHSB</td>
<td>Palmitic 2, Stearic 6, Oleic 81, Linoleic 5</td>
<td>0.6</td>
<td>64</td>
</tr>
</tbody>
</table>


<sup>b</sup> CS = cottonseed oil; SB = soybean oil; PH = partially hydrogenated oil.

<sup>c</sup> Positional and geometric isomers may be present but are not indicated.

<sup>d</sup> Sum of linoleic and linolenic acids divided by sum of lauric, myristic, palmitic, stearic, and arachidic acids.

<sup>e</sup> Contained fractional percentage of one or more of the following fatty acids: lauric, myristic, palmitoleic, and oleic.

<sup>f</sup> Le = linoleic acid.

<sup>g</sup> Stabilized with silicones.
and margarines, and by the wholesale baking industry in the production of bread, buns, and cakes.

*Partially hydrogenated, winterized (HWSB) oil.* This is a dual-purpose oil sold in supermarkets for household use as a salad oil and as a cooking/frying oil. It is also used in the preparation of fluid margarines and shortenings.

The typical fatty acid compositions of RBD soybean salad oil and of HWSBO are given in Table 6.

The oils used in mayonnaise, prepared salad dressings, and salad oils must not solidify, cloud, or deposit a crystalline fraction at refrigerator temperatures; otherwise the emulsion will be broken. Both the RBD and HW soybean oils will remain clear after immersion for 5.5 hr in an ice bath held at 32°F (0°C), as specified in American Oil Chemists' Society (AOCS) method CC 11-53 (AOCS, 1974). Both oils will also pass when the test is extended to 24 hr as required by some manufacturers.

**MAYONNAISE**

Although the Standards of Identity require a minimum oil content of 65%, most mayonnaises contain 77-83% oil (Newkirk et al., 1978). A thicker product containing 80-84% oil is often used in institutions. Although oil is the major component, mayonnaise is an oil-in-water emulsion (oil is the dispersed rather than continuous phase) and is difficult to prepare (Weiss, 1970d).

Practically all mayonnaise produced commercially in the U.S. and West Germany is prepared exclusively with soybean oil (usually the RBD and HW types) as the oil component (Heckers et al., 1976; Newkirk et al., 1978). Until recently, cottonseed was the preferred oil because of the high flavor stability it imparted to the mayonnaise. The cottonseed oil emulsion in mayonnaise is rather weak, and sometimes it will break down at refrigerator temperatures or from mechanical shock during shipment. With the improved flavor stability, low cost and ready availability of soybean oil, plus the fact that it forms a stronger emulsion, this oil is now the choice of most manufacturers.

Weiss (1970d) provides information on the individual ingredients generally used, the usual formulation limits, and the manufacturing processes and equipment. Watanabe (1970) has also reviewed the subject.

**PREPARED SALAD DRESSINGS**

Prepared dressings such as Russian and Thousand Island use mayonnaise as the base and include one or more ingre-
FOOD USES OF SOYBEAN OIL

Ingredients from the following list: minced onions, minced green peppers, chopped stuffed olives, hard-cooked eggs, and chili sauce (Anon., 1963).

Imitation mayonnaises of U.S. manufacture contain 14 to 40% oil and considerably more water than do regular mayonnaises (Newkirk et al., 1978). Starch paste is used as a thickener in such dressings.

Other emulsified, semi-solid dressings of the spoonable type contain less salad oil than does mayonnaise and use starch paste as a thickener (Weiss, 1970d). U.S. Standards of Identity require that spoonable salad dressings contain not less than 30% vegetable oil.

Pourable salad dressings, of which French dressing is an example, contain oil, vinegar, spices, and other ingredients. These dressings may be of the emulsified type or they may require shaking before use to mix the oil and aqueous layers. Various types of gums as well as egg yolk are used as emulsifiers. The Standards of Identity specify a minimum oil content of 35% for French dressing, but most of the commercial products contain 55 to 65% (Weiss, 1970d).

Low-calorie dressings have a low oil content, typically 4 to 14% (Watt and Merrill, 1963). Salant (1968) and Weiss (1970d) give formulations for several low-calorie dressings, some of which contain no oil.

Soybean oil is now used almost exclusively in all prepared salad dressings and imitation mayonnaises sold in U.S. supermarkets.

SALAD AND COOKING OILS

Among the salad and cooking oils now marketed in the U.S., soybean is the more popular (Carpenter et al., 1976). The various types of oils used during the 5-year period, 1973-1978, in the commercial manufacture of salad and cooking oils, and the average percentage for each were: soybean (77%), cottonseed (10), corn (6), peanut (3), olive (1), safflower (under 1), and all other (2) (U.S. Department of Agriculture, 1979c). In West Germany, these oils, and also linseed and rapeseed, are used as table oils (Heckers et al., 1976). In both the U.S. and Germany, most brands contain a single type oil, but some brands are a blend of two types.

Partial, selective hydrogenation of soybean oil to lower its linolenic acid content to about 3% as in HWSB oil (Table 6) improves considerably the oil's flavor and oxidative stability (Cowan, 1965; Evans et al., 1964 and 1973).包装 of the oil under nitrogen and keeping the oil away from light also are important factors in maintenance of the oil's quality during storage (Evans et al., 1973).
Blending soybean oil with an oil containing little or no linolenic acid is also done to lower the linolenic acid content. Some commercial U.S. brands are a blend of soybean and cottonseed oils (Carpenter et al., 1976). Recently, a blend of sunflower and soybean oils appeared on the market.

The RBD and HW soybean oils are used also in margarines; in wholesale baking; in preparation of fried foods in the home, restaurants, and institutions; and in food processing.

Some salad oils and prepared salad dressings contain crystallization inhibitors (see Chapter 12) and some dual-purpose salad/frying oils contain an anti-foam agent, usually a silicone compound (Freeman et al., 1973; Howard and Martin, 1968; Lorenz, 1978; Martin, 1953).

MARGARINES

COMPOSITION, TYPES, AND OILS USED

Margarine was developed as a butter substitute in the late 1860's by the French chemist, Mége-Mouriés (Riepma, 1970; Vahlteich, 1967). Today, margarine is recognized in its own right as a high-quality, nutritious, manufactured product available in several forms for table use (Massiello, 1978) and is no longer considered a substitute. Regular margarine is prepared in part from partially hydrogenated vegetable oils and is a water-in-oil emulsion, in contrast to the oil-in-water emulsion found in mayonnaise. Bakery, puff-paste, and roll-in margarines often also include some animal fat.

In the U.S., regular margarine typically contains 80% fat as required by law, and about 16-18% as an aqueous phase. The latter may vary from cow's milk to pure water, or it may be water plus some edible protein such as nonfat dry milk solids or soybean protein (Code of Federal Regulations, 1977a, 1977b). The margarine also contains 2-3% salt (except for salt-free margarines), emulsifiers such as monoglycerides and/or lecithin, preservatives, flavoring, and coloring, usually beta-carotene. Each pound (0.45 kg) of margarine is fortified with 15,000 USP units of vitamin A as required by law and sometimes also with 2,000 USP units of vitamin D. Optional ingredients include butter, nutritive sweeteners, and fat antioxidants. Marine oils and vitamin E are not permitted under the U.S. Standards of Identity (Code of Federal Regulations, 1977a and 1977b). Other countries have legal requirements that differ somewhat from the above.

Regular margarine in stick or brick form was the only table-grade type available until 1955. But by 1976, 10 types of margarine and manufactured sandwich spreads were available
TABLE 7
Types of Table Margarines and Sandwich Spreads Available and Their Proportion of the Market in 1976*

<table>
<thead>
<tr>
<th>Type of margarine</th>
<th>Fat content, wt %</th>
<th>Market share, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stick margarine:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>80</td>
<td>22.0</td>
</tr>
<tr>
<td>Polyunsaturated</td>
<td>80</td>
<td>33.2</td>
</tr>
<tr>
<td>High polyunsaturated</td>
<td>80</td>
<td>13.0</td>
</tr>
<tr>
<td>Whipped</td>
<td>80</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Soft tub margarine:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>80</td>
<td>12.0</td>
</tr>
<tr>
<td>Premium</td>
<td>80</td>
<td>6.6</td>
</tr>
<tr>
<td>Whipped</td>
<td>80</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Other sandwich spreads:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable oil spreads</td>
<td>60</td>
<td>4.5</td>
</tr>
<tr>
<td>Diet imitation margarine</td>
<td>40</td>
<td>2.4</td>
</tr>
<tr>
<td>Liquid margarine</td>
<td>100</td>
<td>1.3</td>
</tr>
</tbody>
</table>


(Table 7). These include vegetable oil spreads having 60% fat and diet imitation margarines containing 40% fat. These products contain proportionately larger amounts of water along with the lower fat content. The various types of products were developed to meet consumer demands for margarines that are readily spreadable at refrigerator temperatures or have a higher P/S ratio or a lower fat content than the margarine manufactured before 1955.

Regular margarine is formulated from blends of one or more oil stocks, usually two or three, although the range can be one to four. Almost always, one or more of these stocks is an oil sufficiently hardened by hydrogenation to give margarine its semisolid form, and one stock is an unhydrogenated oil. These stocks can all be from one vegetable oil, e.g., soybean oil as described in Chapter 10, or from two or more oils. When two or more oils are used, soybean oil often is the predominant one; soybean oil supplied 80% of the oil used for U.S. production of margarine in 1976 and 1977. Other fats and oils in decreasing order of the amounts used in 1977 were: corn, lard and edible tallow, cottonseed, "all other," peanut, palm, and safflower (National Association of Margarine Manufacturers, 1978).

Soybean oil in partially hydrogenated or unhydrogenated form can be used as the predominant or sole oil in all the margarines listed in Table 7, except for the most highly
polyunsaturated products. In one study, soybean oil was present in regular stick margarines whose P/S ratios ranged from 0.7 to 3.1 and in soft tub margarines with P/S ratios of 1.5 to 3.4. For tub margarines with the higher P/S ratios, 3.6 to 4.7, and stick margarines with ratios of 2.3 to 3.1, liquid safflower oil was the predominant oil (Weihrauch et al., 1977). Moustafa (1979) reports P/S ratios are in the 2.5-3.0 range for the soft margarines now prepared from soybean oil. The fatty acid composition of three types of margarine, of an imitation margarine, and of a vegetable oil spread are shown in Table 6.

**PLASTICITY, SOLID FAT INDEX, AND PLASTIC RANGE**

The fat component of margarine consists of an intimate mixture of microscopic crystals of solid fat that hold the liquid oil. The spreadability of margarine at refrigerator temperatures is related to its content of solid fats at 36 to 50°F (2 to 10°C). The solids content at 77°F (25°C) influences plasticity at room temperature, and the solids content at 92 and 100°F (33 and 38°C) largely determines the mouth feel. If not completely melted at body temperature, the margarine leaves a "pasty" taste due to coating of the palate (Opfer, 1978). Regular stick margarine typically has 13 to 18% of the fat present as solids at 70°F (21.1°C).

Margarine manufacturers use the solid fat index (SFI) as a measure of the solid content of a fat. The index, which usually is expressed as percent of the total fat, represents relative values when determined by dilatometry (AOCS, 1974; Wiedermann, 1978) or absolute values if determined by proton pulsed nuclear magnetic resonance (Madison and Hill, 1978).

The SFI data for the oil component of several types of U.S. margarines are given in Table 8. Margarine oil must have an SFI of about 15-28 at 50°F (10°C) and 1.5-4 at 92°F (33.3°C) for the finished margarine to be a plastic solid (Weiss, 1970c).

Reference is often made to the plastic range of margarine oil and shortenings. When a fat product remains workable or plastic as the temperature range expands, the plastic range is said to widen. Graphically, the slope of the SFI curve decreases (See Fig. 2, Chapter 10). A wide plastic range is desirable for shortenings and margarines that are to be mixed in use or employed for their creaming ability--i.e., for their ability to entrain small air bubbles in an icing or batter.

Haighton (1976) discusses calculation of the SFI of an oil blend based upon the SFI's of its components. Wiedermann (1978) refers to the pitfall of relying on an SFI measurement.
TABLE 8
Typical Solid Fat Index (SFI) Values for the Oil Component in Several U.S. Margarines

<table>
<thead>
<tr>
<th>Type of margarine</th>
<th>Plastic range</th>
<th>SFI values at several temperatures, °F (°C)</th>
<th>Melting point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>50° (10°)</td>
<td>70° (21.1°)</td>
</tr>
<tr>
<td>Stick—prepared from 1 source oils</td>
<td>---</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td>Stick—containing 80% liquid oil</td>
<td>---</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Soft tub</td>
<td>---</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Liquid—containing 5% hard fat</td>
<td>Wide</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Puff pastry</td>
<td>Wide</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Roll-in</td>
<td>---</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Baker’s</td>
<td>Moderate</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>Table</td>
<td>Moderate</td>
<td>28</td>
<td>15</td>
</tr>
</tbody>
</table>

---

For note, from Wiedermann, 1978.

For note, from Carden and Meisner, 1970.
made at only one temperature. For control purposes, most margarine manufacturers determine the SFI at three temperatures. Both Wiedermann and Haighton discuss the various factors involved in the formulation of margarine and shortening oil blends.

CRYSTAL STRUCTURE

The triglycerides of soybean and a number of other oils can crystallize successively in the alpha (α), beta prime (β'), and beta (β) forms. When crystallized rapidly from a supercooled melt, the triglycerides generally form α crystals, an unstable waxy form that changes rapidly to β', the preferred form for plastic margarines and plastic shortenings. The β' form, which is fine grained, can in turn change to β, the coarsely crystalline and most stable form, but the transition does not take place readily. It may occur during prolonged storage or storage at elevated temperatures. Rapid supercooling helps stabilize the β' form. As the fat is hardened to an increasing degree, the crystal habit becomes more pronounced. Table 9 lists the crystal habit of a number of fatty hardstocks. Most fats that have the β' form apparently do so because their palmitic acid content is at least 20% and this acid is in the α or number 1 position on the glycerol molecule (Wiedermann, 1978).

It is important that the solid triglycerides in a margarine or shortening have the proper crystal structure. In general, the β form produces a margarine or plastic shortening that tends to be grainy or waxy in texture. The β' form gives a smooth texture and is preferred in margarines and plastic shortenings, particularly those used for cakes and icings.

When a molten fat mixture is chilled, the crystal structure of the entire fat composition can be controlled in three ways: (1) If a hardfat is present at a level of 5% or more, its crystal habit determines the crystal structure of the entire fat composition. (2) To obtain the β' form mixtures chilled without any hardfat must contain 20% or more of a fat that crystallizes in the β' form, and this fat must have a melting point higher than that of the other fat. For this reason, 20% of partially hydrogenated cottonseed oil is used in some margarines. Likewise, shortenings now often contain a similar amount of partially hydrogenated palm oil. (3) A common current practice in margarine formulation is to add a third fat of intermediate hardness. The use of a 3-component fat mixture not only controls the crystal structure but also gives improved product consistency and greater flexibility in formulation of the oil blend. This development has led to
TABLE 9
Classification of Fats and Oils According to Crystal Habit

<table>
<thead>
<tr>
<th>Beta type</th>
<th>Beta prime type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canbra</td>
<td>Cottonseed</td>
</tr>
<tr>
<td>Cocoa butter</td>
<td>Herring</td>
</tr>
<tr>
<td>Coconut</td>
<td>Menhaden</td>
</tr>
<tr>
<td>Corn</td>
<td>Milk fat (butter oil)</td>
</tr>
<tr>
<td>Lard</td>
<td>&quot;Modified&quot; lard</td>
</tr>
<tr>
<td>Olive</td>
<td>Palm</td>
</tr>
<tr>
<td>Palm kernel</td>
<td>Rapeseed</td>
</tr>
<tr>
<td>Peanut</td>
<td>Tallow</td>
</tr>
<tr>
<td>Safflower</td>
<td>Whale</td>
</tr>
<tr>
<td>Sesame</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
</tr>
<tr>
<td>Sunflower</td>
<td></td>
</tr>
</tbody>
</table>

a From Wiedermann (1978).
b Lard interesterified by itself or a blend of interesterified lard and regular lard in the proper proportions.

the successful production of margarine based entirely on soybean oil (Wiedermann, 1978; also see Chapter 10). Although the fat formulation strongly influences the crystal structure of the entire fat composition, the method of solidification and degree of mechanically working the supercooled fat also influence the rate at which the most stable crystalline form is reached (Thomas, 1978).

SOME ASPECTS OF MARGARINE MANUFACTURE

The basic steps in margarine manufacture are: (1) formulating the margarine oil blend, (2) preparing the aqueous phase, (3) preparing the emulsion, (4) solidifying the emulsion and controlling its plasticity, (5) packaging the margarine, and (6) tempering the packaged margarine, if necessary.

The oil formulation, the manner and degree of supercooling the emulsion, and the extent of mechanically "working" the supercooled emulsion during the crystallizing stage are all used to control the margarine's plasticity. If the fat composition is rapidly supercooled and allowed to solidify without agitation, the margarine will become quite firm and have a narrow plastic range. The plastic range is extended by mechanically working the emulsion while the fat is crystallizing from the supercooled state (Wiedermann, 1978).

The various factors that influence the plasticity or consistency have been summarized by Opfer (1978) as follows:

(1) Proportion by weight of the fat that is in cry-
TABLE 10
Types and Relative Amounts of Oil Stocks Blended According to the Type of Margarine Produced

<table>
<thead>
<tr>
<th>Oil type and relative amount</th>
<th>Margarine type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend of intermediate IV(^b) fats</td>
<td>Stick margarines containing only hydrogenated oils</td>
</tr>
<tr>
<td>Low level of a high IV oil and a high level of an intermediate IV fat</td>
<td>Soft tub margarines having low P/S(^c) ratio</td>
</tr>
<tr>
<td>Intermediate level of a high IV oil and intermediate level of an intermediate IV fat</td>
<td>Margarines with high P/S ratio such as soft tub margarines and stick margarines containing 50% liquid oil</td>
</tr>
<tr>
<td>High level of high IV oil and low level of low IV fat</td>
<td>Fluid margarines, stick margarines containing 75-80% liquid oil, and high P/S ratio soft tub margarines</td>
</tr>
</tbody>
</table>

\(^{a}\) From Wiedermann, 1978.  
\(^{b}\) Iodine value.  
\(^{c}\) Ratio of polyunsaturated to saturated fatty acids.

(2) Melting point of the crystals. Melting point of the triglycerides in all fats varies with (a) fatty acid chain length, (b) degree of unsaturation, (c) type of isomerism, and (d) crystal geometry.

(3) Crystal geometry. Ways for controlling the crystal structure of fats in margarine were discussed earlier.

(4) Formation of mixed crystals. In the rapid crystallization process used in manufacturing margarines and shortenings, the fat does not have time to form crystals containing only specific, pure triglycerides. Instead, mixed crystals develop that contain several triglycerides within the space lattice of one crystal. These crystals have melting points intermediate to the highest and lowest melting points of the individual triglycerides. Later, if the margarine is overheated slightly and allowed to cool slowly, some of the crystals will melt and then recrystallize in the highest melting form. Such recrystallization and alteration of the crystal network can adversely affect the margarine’s plasticity and mouthfeel (generally referred to as graininess) and lead to oil exudation (i.e., “weeping” or “sweating”). Similar changes can occur in plastic shortenings.

(5) Size of the crystals and extent of the crystal network. For a given solids fat content, a margarine having small crystals will be firmer than one with large crystals. Also, large crystals increase the margarine’s tendency to

\(\begin{align*}
\text{Blend of intermediate IV}^b \text{ fats} & \quad \text{Stick margarines containing only hydrogenated oils} \\
\text{Low level of a high IV oil and a high level of an intermediate IV fat} & \quad \text{Soft tub margarines having low P/S}^c \text{ ratio} \\
\text{Intermediate level of a high IV oil and intermediate level of an intermediate IV fat} & \quad \text{Margarines with high P/S ratio such as soft tub margarines and stick margarines containing 50% liquid oil} \\
\text{High level of high IV oil and low level of low IV fat} & \quad \text{Fluid margarines, stick margarines containing 75-80% liquid oil, and high P/S ratio soft tub margarines} \\
\end{align*}\)
exude oil. Rapid supercooling promotes the formation of numerous, small crystals.

According to Wiedermann (1978), the melting point, fatty acid composition, and structure of the individual triglycerides influence the structural, nutritional, and lubricity aspects of the margarine.

The types of oilstock and the relative amounts used for various types of margarine are given in Table 10. Stick margarines usually are made from a blend of two or three intermediate IV fats, or of a low IV fat and a liquid oil (see Table 6; also Table 6, Chapter 10). Soft margarines contain a high proportion of liquid oil; fluid margarines have the highest proportion. The SFI values in Table 8 reflect the respective proportions of solid and liquid phases.

PREPARATION OF THE MARGARINE EMULSION

The fats and oils selected for the margarine oil blend are mixed in the proper proportions and heated to 100°F (30°C) or more, and the oil-soluble ingredients are added. These additives include emulsifiers, usually mono- and di-glycerides and sometimes lecithin, plus specified amounts of the vitamins and desired flavoring and coloring ingredients.

The aqueous phase is prepared separately. Until recently, some form of milk was used as the aqueous phase; but today a "milk" phase is prepared by adding dried protein such as whey or non-fat dry milk solids to the water, then pasteurizing and cooling the mixture. The water-soluble ingredients, usually salt and preservatives, are added at this time (Wiedermann, 1978).

In the batch-continuous process, the oil and aqueous phases are prepared batch-wise in separate tanks, then the two phases are blended; the resultant emulsion is solidified on a continuous basis, as will be described later. Batchwise blending of the two phases is done in a premix tank that often is referred to as a churn. Holding time in the churn is kept to a minimum because the temperature is ideal for bacterial growth. If automatic proportioning equipment is used, the two phases can be prepared on a continuous rather than batchwise basis if proper temperature control is employed. Most margarine manufacturers in the U.S. prefer to weigh the major ingredients into the churn (Moustafa, 1979).

SOLIDIFICATION AND PACKAGING OF THE EMULSION

This discussion will be limited to the enclosed, tubular, scraped surface, continuous heat exchanger system of
which the Votator is one example. This system is widely used in the U.S. and other countries because of its flexibility, hygienic features, and economic advantages. Riepma (1970) estimated that about 90% of the American production is by this system.

The oil and aqueous phases are emulsified to the proper degree as or just before the blend enters the first chilling tube of the continuous processing unit (Figure 2). Water in the emulsion is dispersed as droplets of about five microns diameter and then kept from coalescing. Mono- and diglycerides help create and maintain an emulsion containing small droplets (Moustafa, 1979). The presence of large droplets would provide a medium for bacterial growth, particularly in low-salt margarines (Opfer, 1978). The emulsion is quickly cooled in a matter of seconds (5-10) by ammonia refrigerant vaporizing in the jackets of the heat exchangers. Scrapers continually remove solidified fat from the inner wall of the heat exchangers (often referred to as the A units) to promote rapid heat transfer. Small crystals form as the emulsion is supercooled (e.g., to 45-50°F or 7-10°C).

For regular (stick type) margarine, the supercooled,
Still-fluid melt is piped to either of twin crystallizers, referred to as B units. These are enlarged, empty cylinders wherein the emulsion remains stationary (typically, ca. 2 min) until crystal development proceeds to a point where the product is sufficiently firm to withstand the forces applied in extruding, shaping, and wrapping the margarine in high-speed automatic machinery. By use of twin crystallizers, the emulsion can remain stationary in one while the other is being filled. The temperature increases several degrees in the B unit because of the heat of crystallization.

Whipped margarines are produced by incorporating nitrogen into the margarine (Figure 2). The gas is introduced ahead of one of the heat exchangers or at the suction side of the feed pump. This type margarine requires vigorous mixing action in the B unit to limit the extent of crystal development; otherwise, the margarine becomes too firm. For this process, the B unit is a worker-type crystallizer. It has radial pins on a rotating central shaft, and these pins intermesh with stationary pins protruding from the cylinder wall. The agitation is controlled to allow crystal growth and yet prevent the formation of a firm crystal lattice. The soft, semi-fluid mass is packaged immediately in specially designed, print-forming (i.e., stick-forming) machines that squeeze little or no nitrogen from the margarine. The gas increases the margarine's volume by 50% (range can be 30 to 150% or more) and makes the margarine softer and easier to spread at refrigerator temperatures. Also, equivalent volume servings contain one-third fewer calories, which appeals to some consumers.

Soft tub margarines containing as much as 70-80% liquid oil are produced by chilling the emulsion in an A unit and then mixing the chilled mass in a large, agitated crystallizer (Figure 2). Again, working the chilled emulsion to a limited degree prevents the fat crystals from growing into a firm network. The soft, fluid margarine is packaged in plastic tubs by a liquid filling machine. Crystal development continues in the tub to give a soft, semi-solid product. If desired, nitrogen can be injected as shown in Figure 2. After packaging, soft tub margarines should be tempered by holding 24 hr or more at about 45°F (7°C) before shipping, so that the crystal structure can become fully developed and stabilized (Moustafa, 1979).

With the lower melting fats now used in most margarines, and also because of the water present, most margarines today require refrigeration both as they move through the marketing channels and in the home.

The manufacture of margarine has been described in detail by Anderson and Williams (1965) and by Crump (1958).
IMITATION DIET MARGARINES

These products contain no milk or milk protein in the aqueous phase because the protein adversely affects characteristics of the emulsion, which has a high water content (roughly 56-57%). A strong emulsification system is obtained by the use of a larger amount (0.5-1.0%) of the emulsifiers. More intensive mixing action than for regular margarine and very precise processing conditions are needed to prevent phase reversal of the water-in-oil emulsion. Diet margarines are manufactured and packaged only in the soft form; none of the harder fat blends are used because they promote water separation from the emulsion (Massiello, 1978).

VEGETABLE OIL SPREADS

They were first marketed in 1975 and have a fat content of 60%. They also require a stronger emulsifier system than does regular margarine and precise control of the processing conditions, because reversal of the water-in-oil emulsion can lead to water loss from the margarine and to possible microbial problems. These spreads are manufactured in soft form only and packaged in 1-lb (0.45 kg) tubs for household use (Massiello, 1978).

LIQUID AND FLUID MARGARINES

These margarines have found acceptance by both home consumers and commercial users because controlled amounts can be dispersed from a squeeze bottle taken directly from the refrigerator and large quantities can be easily pumped and metered. Liquid margarines remain limpid at refrigerator temperatures, whereas fluid margarines are opaque because of their content of minute, suspended fat crystals. These margarines are readily used for pan frying, or they can be spread on cooked foods and foods to be frozen (Massiello, 1978).

Liquid margarine is produced by either of two methods (Massiello, 1978). In one, a blend of liquid oil (nonhydrogenated or lightly hydrogenated) with a small amount (up to ca. 5%) of hardfat (typically ca. 8 IV) is chilled and crystallized in a Votator apparatus under conditions that produce 8' crystals. The chilled mass is held for several hours before it is combined with the milk phase and rechilled. The product is an emulsion that is very stable at all working temperatures.

In the second method, the oil and milk phases are blended directly, chilled, and packaged. The product has better
flavor characteristics than that produced by the first method but requires refrigeration at all times.

Fluid margarines can be produced either by the addition of 0.75-5% hardfat, preferably a β' type such as rapeseed or a rapeseed-cottonseed blend, to a salad oil (Pichel, 1967), or by addition of a liquid vegetable oil to regular margarine to give a 50:50 blend (Fricks, 1966, 1968).

BAKERY MARGARINES

Bakery margarines are designed for specific uses and rarely are aerated. In some ways, they can be considered as shortenings, but they do not contain sufficient emulsifier to be used in preparing most cakes and some icings. The same general principles apply in the formulation and production of bakery margarines as for regular margarines, with some differences occurring in some of the equipment used and in certain product characteristics.

One type of bakery margarine is table margarine packaged in large containers. The margarine is finished in a working type B Votator unit rather than in a static unit and is used primarily in the preparation of cream icings. Regular baker's margarine is made like table margarine but has 4-8% hardfat added as a plasticizer. It is used principally in baking cookies, pound cakes, and pastry. It can also be used as a roll-in margarine for Danish pastry preparation.

Special roll-in margarines for the preparation of Danish pastries are usually prepared from equal amounts of unhydrogenated tallow and soybean oil with about 8% hardfat added as a plasticizer. Such margarines are chilled on a flaking roll instead of in a Votator system.

General-purpose margarine consists of a blend of tallow and soybean oil, with or without hydrogenation, plus a small amount of hardfat.

Puff paste is used exclusively for making puff pastries such as turnovers, patty shells, and Napoleons. It contains 90% fat and usually is churned with water rather than milk. Vegetable puff paste is made by blending about 25% cottonseed oil hardfat with an unhydrogenated vegetable oil, usually soybean. Animal-vegetable puff paste contains approximately equal amounts of unhydrogenated tallow and soybean oil plus about 15% hardfat.

Weiss (1970c) should be consulted for further information on bakery margarines, their formulation, and manner of use.

MARGARINES WITH ZERO TRANS-ACID CONTENT

Partial hydrogenation of an oil or fat results in some
formation of fatty acid isomers in which the geometry (i.e., formation of trans-acids) or the position of the double bond (i.e., isomerization) has changed. The possible effect of such changes on nutritive value of the resultant oil product is discussed in Chapter 20. If a margarine of low trans-acid content is desired, a method is available for preparing such (List et al., 1977). The process involves interesterification of a non-hydrogenated soybean oil with about 20% of a soybean hardfat and then continuing with the usual steps of emulsion preparation and solidification. Yaron et al. (1973) concluded that margarine oils having suitable SFIs and of average nutritional value, based on the ratio of linoleic to total saturated fatty acids, can be prepared from blends of soybean oil alone when the interesterification process is used. Although the trans-acid content of their margarine oils was not given, some trans-acids were present.

PACKAGED MARGARINE MIX

With a recently developed mix packaged in small packets, the homemaker can readily prepare a spreadable, butter-substitute product (Hallstrom et al., 1979). The mix, which is shelf-stable, contains a water-in-oil emulsifier, a hardfat, and a vegetable oil, and may also contain artificial coloring and flavoring. To prepare the table spread, the homemaker adds cold water and salt to taste, blends the mixture for about 6 min in a conventional kitchen mixer, and refrigerates the product. Refrigeration helps form a stable emulsion and preserves the product during storage. By varying the relative amounts of mix and water, the product's fat content can be varied over the range typified by imitation diet margarine, vegetable oil spread, and regular margarine; namely, 40 to 80% lipid.

As an alternative, a pellet that contains no vegetable oil can be prepared. In this case, the housewife melts the pellet in a pan, adds warm vegetable oil of her own choosing, followed by ice water and salt and then emulsifies and refrigerates the mixture as above.

Advantages offered by the mix include no need for refrigeration until the margarine is prepared, and the margarine can be prepared daily in quantities that are quickly consumed when refrigeration is limited or unavailable.

SHORTENINGS

INTRODUCTION

Initially, shortening referred to lard used to make
tender, flaky pie crusts and in bread making. Later, the definition was extended to include cake baking and frying fats. Now all edible fats and oils of commerce usually are referred to as shortenings to differentiate them from oil-derived products such as margarines and other high fat-content products that contain various nonfat materials.

Thus, shortenings are edible fats used in baked goods, icings and fillings, and in the preparation of fried foods. Shortenings "shorten" or tenderize baked foods by preventing the cohesion of wheat gluten strands during mixing, thus literally shortening them. In icings and fillings, shortenings are used to entrain large volumes of air bubbles and thus produce a fine, delicate structure. Also, large quantities of shortenings are used in the preparation of fried foods both by deep fat and by pan and grill frying.

Lard and butter have long been used as shortenings. The first manufactured shortenings were prepared to resemble the plastic nature and performance of lard. Today, the shortening manufacturer can produce a number of shortenings that vary both in physical state and performance. He does this by proper selection of edible vegetable oils and animal fats, controlled hydrogenation, appropriate blending, plasticizing and tempering, and the incorporation of plasticizers, emulsifiers and antifoam agents as needed depending upon the product end use. The physical forms include the conventional plastic or semisolid shortening, pourable (liquid and fluid), and dry (powdered or pelletized) shortenings. The types can vary from the general-purpose shortening used by the housewife to the highly specialized bakery shortenings, such as those designed for icings and specific cake types, and thus have limited interchangeability.

Since 1961, plastic shortenings have been marketed with a higher content of polyunsaturated fatty acids (PUFA) than previously; e.g., 22-35% as against 6-15% (Institute of Shortenings and Edible Oils, Inc., 1974). Such shortenings have been developed and marketed in response to research findings which suggest the advisability of a greater intake of these fatty acids (see Chapter 20).

With the shift away from home baking and the small bakery to the production of baked goods in large-scale, largely mechanized operations, interest has increased in pourable-type shortenings, due largely to the ease in handling, pumping, and metering them. This interest has led to the development of improved pourable shortenings that find growing application in the preparation of both baked goods and fried foods.

Soybean oil is an excellent oil for preparation of the base stock (see Chapter 10) and is used in a number of shor-


TABLE 11

Classification of Shortenings

<table>
<thead>
<tr>
<th>Physical state</th>
<th>Functional requirements</th>
<th>General usage</th>
<th>Packaged form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>General purpose</td>
<td>Baking</td>
<td>Bulk</td>
</tr>
<tr>
<td>Fluid (contains suspended solids)</td>
<td>High stability (e.g., for frying and crackers)</td>
<td>Frying</td>
<td>Cubed</td>
</tr>
<tr>
<td>Liquid</td>
<td>Cake and icing</td>
<td>Household</td>
<td>Sheeted</td>
</tr>
<tr>
<td>Dry (pelleted and powdered forms)</td>
<td>Bread and sweet dough</td>
<td></td>
<td>Printed (e.g., sticks, bricks)</td>
</tr>
</tbody>
</table>

Soybean hardfat is used in pourable shortenings. It can also be in plastic shortenings in amounts up to 50% of the total hardfat content (Erickson, 1979). When used alone, soybean hardfat causes plastic shortenings to become brittle (Brody, 1978).

CLASSIFICATION OF SHORTENINGS

Shortenings have been classified in several different ways depending upon the purpose in mind. Several of these classifications are given in Table 11.

FUNCTIONAL ASPECTS OF SHORTENINGS

In baked goods, shortenings contribute to the finished products in a number of ways. For example, shortenings (1) impart tenderness and richness, (2) enhance the aeration of leavened products, (3) add to the flavor, (4) promote a desirable grain and flavor, (5) assist in the development of flakiness in products such as pie crusts, Danish and puffed pastry products, (6) modify the wheat gluten, particularly in the development of yeast-raised doughs, and (7) act as emulsifiers for the retention of liquids (Baldwin et al., 1972).

The contributions of plastic shortenings to baked goods as listed above arise from two chief functions performed by
the shortening; namely, a leavening and creaming action and a lubricating function. The description given below is based upon information provided by Black and Mattil (1951).

Leavening and creaming action. Microscopic examination of a cake batter made with a plastic shortening reveals that each particle of solidified fat contains small, entrapped bubbles of air. Incorporation of air into the batter in this manner is called creaming, and the more air dispersed in the fat within the batter, the better is said to be the shortening's creaming quality. There is a close correlation between volume and texture of the baked cake, dispersion of fat, and amount of air entrained within the fat.

When the batter is baked, the fat melts and the air particles are released from it. The increase in volume during baking results in part from expansion of the numerous entrapped air cells but more so from the carbon dioxide \( \text{CO}_2 \) generated by the baking powder and from the water vapor generated by the batter moisture. Linteris and Thompson (1958) state that the steam and \( \text{CO}_2 \) generate few new bubbles but rather these gases penetrate and greatly expand the fine air bubbles within the fat particles. The cake's final structure is fixed at the temperature at which the starch and proteins of the cake coagulate. If the shortening has entrapped many small air bubbles in the batter, the cake's texture will be finer than if there are relatively few bubbles.

Plastic shortenings used for cakes usually include several emulsifiers, one normally being mono- and diglycerides. The emulsifiers help disperse the fat as smaller particles and, in turn, the air is more finely dispersed within the cake. In such batters, a higher percentage of sugar and liquid ingredients can be incorporated and still produce a fine-textured cake of good volume and eating quality.

Lubricating function. When a shortening of proper consistency is mixed in the dough, the shortening becomes distributed very intimately among the other ingredients, but does not dissolve. During mixing, the shortening coats and lubricates fresh surfaces of the dough and thus prevents the particles of gluten and other materials from adhering together as intimately as they otherwise would. The shortening also penetrates between the starch granules. Thus, the shortening disperses what otherwise would be a continuous mass within the dough and serves as a separator or lubricant for the dough constituents.

Pastries are formed from stiff dough rolled into thin sheets without excessive prior mixing. If the sheets have been properly prepared, the shortening, which is quite firm,
is distributed throughout the dough in the form of thin layers. Then, after baking, the pastry readily breaks or separates along the planes where the fat was present.

PLASTIC SHORTENINGS

These shortenings are formulated from one or more partially hydrogenated vegetable oil basestocks or mixtures of such stocks with animal fat basestocks. The latter may have been partially hydrogenated. Hardfats, referred to as plasticizers, are often added to extend the shortening's plastic range. Optional ingredients include emulsifiers, antioxidants, metal scavengers, antifoam agents, pigments, and flavors. Proper amounts of the basestocks and hardfat are used to give a finished shortening having, within obtainable limits, the desired SFI values, oxidative stability, and melting point.

As with margarines, the crystal structure of shortenings is important. The β' form is preferred for plastic shortenings as the crystals tend to be small, uniform in size, and tightly knit. The shortenings then provide good aeration for cakes and icings. Shortenings with the β crystalline form are poor aerators, but they function well in pie crust applications.

By proper selection of fats, temperature control, and mechanical working, the fats and oils industry has learned to control fat crystallization in the manner needed to produce shortenings that have optimum creaming properties (Baldwin et al., 1972).

Information on the formulation of several shortenings is given in Chapter 10. The fatty acid composition of several types is given in Table 6.

The basic steps in shortening manufacture are: (1) preparation of the individual basestocks and hardfats, (2) formulation of the fat blend and other ingredients, (3) solidifying and plasticizing the fat blend, (4) packaging, and (5) tempering the shortening, when necessary. Tempering generally is limited to the plastic shortenings and margarines used for baking.

Tempering consists of holding the shortening for 24-72 hr in a room maintained at a constant temperature, usually somewhere between 80 and 90°F (27-32°C). The holding time is determined by factors such as container size and type of shortening. Crystallization continues slowly during the tempering step. Tempering stabilizes the crystal structure against changes that might otherwise occur during subsequent temperature variations encountered in normal handling and storage.
A tempered shortening will maintain its consistency and ability to perform satisfactorily in baked goods unless it has been heat abused, e.g., by storage at a temperature above that of the lowest melting polymorphic form of the crystalline fat. If such should occur, the shortening must be melted and reprocessed to restore its performance characteristics.

Plastic shortenings generally are solidified and plasticized in scraped surface, heat exchanger equipment similar to that used in the production of whipped or soft margarines (Figure 2). The melted fat plus optional ingredients are chilled rapidly from 115-120°F (46-49°C) to 60-65°F (16-18°C) in one or more A units to produce numerous nuclei for crystal formation. The supercooled melt then is piped to a worker-type B unit wherein the shortening is agitated as the crystals grow and the mass partially solidifies. From 10-20% air or an inert gas is added and dispersed in the shortening as small bubbles. In this form, the air improves the whiteness of the product and sometimes contributes to its creaming ability.

The plastic mass is pumped through a homogenizing valve and then to package fillers. The packages vary in size from 1-lb (0.45 kg) tins that are sealed after filling to open-end, 380-lb (172 kg) drums having removable covers. For bakery and institutional use, the shortening may be packaged in corrugated paper boxes of about 1 cu. ft. (28 L) volume, lined with a flexible, polyethylene liner. The liner is often blue for color contrast so it can be readily detected and quickly retrieved if, by chance, it should fall into the fry kettle.

The solidification process must be carefully controlled to avoid product defects such as streaking, alternate layering of hard and soft product, lumpiness, and shottiness (i.e., harder lumps about the size of buckshot) (Weiss, 1970a).

Large-volume users generally obtain their shortenings by bulk shipment as a liquid melt in tank wagons or railroad tank cars. The liquid is pumped into storage tanks and held at a temperature 5-10°F (3-6°C) above its closed capillary tube melting point (AOCS, 1974) until needed. When handled in this manner, plastic shortenings for bakery use are chilled and plasticized at the bakery. The melted shortening should be protected against oxidation by nitrogen blanketing and should also have a quick turnover (Weiss, 1970a).

Bulk handling is more typically used for frying and baking shortenings that can be used in the melted or liquid state without crystallization (Baeuerlen, 1973). Also, because frying shortenings have high oxidative stability,
they better lend themselves to handling at elevated temperatures (Thomas, 1978).

EMULSIFIERS

Emulsifiers have a number of functions in both plastic and pourable shortenings as well as in other lipid-containing food products. The functions include: stabilizing emulsions as in margarines and salad dressings; antispattering in margarines; texture control in bread and cakes; dough conditioning and antistaling in bread; aerating in cakes, toppings, and icings; plasticizing cake icings; and wetting in coffee whiteners and instant foods. Food emulsifiers probably are used in greater quantities than any of the other food additives (Nash and Brickman, 1972).

Although many emulsifiers are multi-functional to some degree, each usually has one predominant functional role. Therefore, two or more emulsifiers are often used in combination. The selection of emulsifiers and their level of use must be done carefully and is based to some extent upon "art" and experience. There is a definite optimum usage level for most emulsifiers and, with increasing dosage, the effect is not always the same. A number of factors influence emulsifier selection, including: ingredient formulation, flavor, type of homogenizing and heating equipment, product preparation technique, finished product form (e.g., liquid, powder, plastic solid), storage requirements, costs, and legal aspects (Nash and Brickman, 1972).

There now are seven, legally sanctioned emulsifiers that are widely used in yeast-raised bakery products. Each is fat-derived, and they include (Landfried, 1977): (1) mono- and diglycerides (40-50% a content), (2) distilled monoglycerides (90% a), (3) succinylated monoglycerides, (4) ethoxylated mono- and diglycerides, (5) polysorbate 60, (6) calcium stearoyl-2-lactylate, and (7) sodium stearoyl-2-lactylate. Several of the above as well as others are used in cakes and other chemically leavened baked goods. The mono- and diglyceride-type emulsifiers will vary in hardness with the degree to which the fatty acid portion has been hydrogenated.

A more complete listing of emulsifiers and recommended usage levels for a number of specific food applications are given by Nash and Brickman (1972). The topic is also discussed in some detail by Griffin and Lynch (1968).

POURABLE SHORTENINGS

The discussion on plastic shortenings used in baked
goods centered on the need for a certain amount of solid fat in the shortening and for these solids to have the proper crystalline form, but emulsifiers introduced since 1945 have changed the shortening technology considerably. Development of the continuous-mix method for bread making (Baker, 1960) created a demand for fluid and liquid shortenings that can be pumped, metered accurately, and conveniently handled and stored in large quantities.

With the development of successful emulsifiers, used singly or in combination, the wholesale baking industry is switching from animal fats and plastic shortenings to refined vegetable oils used in conjunction with the proper emulsifier systems. Proper use of oil and surfactants can provide a satisfactory, economical liquid shortening system for bread production by either conventional or continuous baking. In general, the more unsaturated oils are more effective shortening agents than their plastic counterparts (Hartnett and Thalheimer, 1979a and b; Landfried, 1977).

Soybean oil plus appropriate emulsifier systems is now being used by the wholesale bread baking industry (Baeuerlen, 1973; Baldwin et al., 1965, 1972; Hartnett and Thalheimer, 1979a).

Emulsifier systems have been developed that can do all of the aeration needed for bakery production of cakes made with fluid or liquid shortenings (Hartnett and Thalheimer, 1979b). A filled cake of good nutritional quality developed for the school lunch program is made with liquid soybean oil plus appropriate emulsifiers and a creamed filling made with a plastic shortening (Baldwin et al., 1972; Cotton et al., 1971).

Although the crystalline fats in plastic shortenings play a dominant role in the development of a fine-grained, cellular structure in cakes, the starch, protein, and emulsifiers take over this function when fluid or liquid shortenings are substituted, and crystalline fat is largely absent (Baldwin et al., 1972).

For icings and fillings, however, oil-based fluid shortenings have not been successful. Plastic shortenings with appropriate emulsifiers are needed to give icings and fillings the desired body or stiffness (Baldwin et al., 1972).

Pourable shortenings include fluid suspensions, fluid emulsions, and clear liquids. The latter include regular cooking oils, salad oils, and the liquid component resulting from the fractionation of partially hydrogenated oils and semihard fats. Simmons et al. (1968) prepared a liquid shortening by winterizing soybean oil that had been selectively hydrogenated at 356°F (180°C) to 81-84 IV. The winterized oil fraction (86-88 IV, 48-54% yield) remained free
of dispersed solid fat particles when stored at temperatures above 60°F (16°C) and contained less than 1% solid fat particles at 50°F (10°C).

Gooding (1972) described a method for preparing from a vegetable oil a liquid fraction that exhibits especially good stability at deep-fat frying temperatures. Soybean oil is the preferred starting oil, but others such as corn, cottonseed, safflower, and sunflower can also be used. The oil is partially hydrogenated with a nickel catalyst under mild conditions (220-225°F and 25 psig) to about 105 IV (100-120 range), winterized to remove the crystalline fat, then hydrogenated a second time at 245-255°F to 75-85 IV. This oil is cooled in two steps, first to 75°F and then more slowly to 65°F before filtering to remove the crystalline fat. No yield data were given.

Liquid, limpid shortenings often are not emulsified, because most emulsifiers are either not sufficiently soluble in the oils or sufficiently low in melting point to give a clear shortening at appropriate levels of use. However, one emulsifier, propylene glycol monostearate, properly designed, has the necessary solubility in vegetable oils for the levels required to provide adequate aeration of cake batters (Griffin and Lynch, 1968).

Fluid suspensions are opaque and consist of a base oil to which are added suspended solids in the form of hardfats or emulsifiers, depending upon whether the shortenings are to be used for frying or baking. The size of these solid particles is a critical factor. Because of certain characteristics, namely, density and physical dimension of the individual crystals, β crystals are the preferred form for both the hardfats and emulsifiers added to the base oil (Weiss, 1970a).

Fluid suspensions can be prepared in several ways. The method typically used for commercial production is to rapidly chill the mixture of liquid base stock and solid fat in a Votator A unit, hold the product in a tank for at least 16 hr while the mixture forms a soft solid, stir gently to fluidize the shortening, and then package it. Another method is to grind the hardfat or hard emulsifier into a fine powder, suspend the unmelted powder in the base oil, and homogenize the mixture in a pressure homogenizer, or a colloid mill, or by use of shear pumps (Weiss, 1970a).

Fluid emulsions are a hydrated form of fluid suspensions. As such, they contain a large amount of water, often 50%. Also, there are some differences in the types and amounts of emulsifiers used. One formulation for a fluid suspension and one for a fluid-emulsion shortening are given by Griffin and Lynch (1968).
Stability of these various shortenings depends upon their type. Liquid shortenings remain liquid at normal usage temperatures. If they should solidify, they are ready for use after remelting and mixing to resuspend any minor quantities of settled solid fats and silicones. Fluid suspensions, however, must be stored at the proper temperature. When stored below 65°F (18°C), they solidify and lose fluidity. Storage above 95°F (35°C) may result in partial or complete melting of the suspended solids and, upon recooling, they form large crystals that will not remain in suspension. If these solids are hardfats, their loss from the bulk of the shortening may be of little consequence. If they are emulsifiers, their settling out upsets the shortening formulation, with the upper layer becoming under-emulsified and the lower layer over-emulsified (Weiss, 1970b).

Several commercial bulk fluid shortening products are now being used in cake production. The fluid shortenings usually contain hard fat flakes or emulsifier combinations, or both, either dissolved, dispersed, or suspended in vegetable oils. Such shortenings perform well in specific types of cakes, but no one combination serves as an all-purpose shortening system. To provide a degree of flexibility, some bakers use a vegetable oil, usually soybean, and meter in the appropriate emulsifiers and the proper additives, as required, either into the oil or into the batter for the specific type cake being produced. Cakes produced by use of the soybean oil-emulsifier system have excellent crumb softness and moisture-retaining properties, both of which are desirable (Baldwin et al., 1972).

**DRY (SOLID) SHORTENINGS**

Such shortenings can be prepared in pelletized or powdered form in several ways. A conventional method is to spray and cool droplets of warm molten shortening in a stream of cold or refrigerated air and then collect the solidified, powdered shortening at the bottom of the spray tower. Although the process produces a desirable product, it is rather expensive. Another method is to solidify molten shortening as a continuous film on a chilled, metal, flaking roll, and then subject the flakes to further cooling so they can be ground into a powder without the formation of a gummy product. Campbell et al. (1970) patented a continuous process wherein the molten shortening is solidified as individual droplets on the chilled flaking roll; the resultant flakes, if they have been cooled sufficiently (e.g., 55°F or 13°C for a cottonseed hardfat of 10 IV), can then be ground immediately.
Davies and Worstall (1966) devised a continuous process for coating molten droplets of soft shortening with particles of hard fat as the shortening solidifies in a stream of cooled air. Kessinger (1968) prepared for use in dry baking mixes such as cake mixes, pie crust mixes, and biscuits a dry-to-the-touch, free-flowing, non-caking shortening composition containing up to 80% shortening. A specially prepared, gelatinized, powdered starch is used to absorb either a shortening, such as lard, or an edible vegetable oil.

USES OF SOYBEAN OIL FOOD PRODUCTS

INTRODUCTION

A number of the uses of soybean oil and soybean oil food products are quite apparent. Other uses have been mentioned in the discussions under shortenings, margarines, and salad/cooking oils. The discussion that follows will center largely on, but will not be limited to, the uses of shortenings.

TYPES OF SHORTENING

To orient the reader, it is desirable to look first at the various types of shortenings. The types given in Table 12 are taken from Baeuerlen et al.'s (1968) classification, with the selection being limited to those that include soybean oil. Possible uses for each type as suggested by Baeuerlen et al. (1968) and by Brody (1978) are included. Unless noted otherwise, the information given in the remainder of this chapter on the food uses of soybean oil food products is based on information provided by Brody (1978) in his report.

SHORTENING PERFORMANCE PROPERTIES

As indicated in Table 12, various types of shortening are available, each tailored to best meet overall the performance requirements for one or more uses. The descriptions given below relate to several properties of importance when the shortenings are used in baked goods. A brief description is also given of how the shortening manufacturer attains each desired property in his product.

Bland flavor or butter-like flavor and aroma. For most uses, a shortening with a bland or very mild flavor is desired. Sometimes a butter-like flavor and aroma is desired. The bland flavor is obtained by properly deodorizing the base stocks used in the shortening and reducing their free fatty acid content to 0.05 wt. % or less. The hardfats and the fats used to prepare the mono- and diglycerides must also be
The flavor and aroma of butter have not been duplicated exactly, but the butter-like flavors available commercially for addition to the shortening or margarine are quite acceptable for many uses.

Creaming property. Good creaming property in a shortening (or margarine) depends upon proper selection of the base stocks used in the shortening and upon the chilling and tempering conditions. Usually, either a single partially hardened (i.e., partially hydrogenated) vegetable oil, or a mixture of two such base stocks, is blended with 5 to 15% of a hardfat. As described earlier, this blend must be chilled quickly to obtain small crystals of fat and, after chilling and packaging, the shortening must be tempered to produce the numerous small crystals needed for good creaming properties. Some emulsifiers of a highly hydrophilic nature also have some creaming ability.

Soybean oil is excellent for the base stocks.

Emulsifying property. The shortenings used in loaf cakes, layer cakes, cream icings, and cream fillers for cookies and cup cakes must be dispersed uniformly and as small globules. Addition of the proper amount, normally 4 to 6%, of a mono- and diglyceride blend made from partially hydrogenated oils usually will result in the shortening having good emulsifying property.

Prepared mixes for layer cakes, fudge icings, and flat icings require a shortening with greater emulsifying power. This is obtained by adding, in small increments (usually 0.5%), emulsifiers of a more hydrophilic nature to the normal complement of mono- and diglycerides.

Soybean oil is excellent for the base stocks and also for the mono-and diglyceride mixture when it is prepared from a partially hydrogenated oil.

Long shelf life. Cookies distributed and marketed through grocery stores and supermarkets and prepared mixes for baked goods are expected to have a long shelf life. To a large extent, the resistance of the shortening to oxidative rancidity controls the shelf life of these products. Shortening with high oxidative resistance is made by using only base stocks that have been properly hydrogenated to reduce or eliminate their polyunsaturated fatty acid content. Soybean oil is excellent when so processed.

Plasticity. Good plasticity is required for shortenings used in roll-in doughs from which Danish pastries, puff pastries, and pie crusts are made. Excellent plasticity in the shortening is obtained by blending appropriate base stocks. In general, a large proportion of a very soft base stock blended with a very small proportion of hardfat, in the
TABLE 12
Types of Shortenings that Contain Soybean Oil and Some of Their Uses

<table>
<thead>
<tr>
<th>Group</th>
<th>Type and description</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Vegetable oils and salad oils</td>
<td>Salad oils</td>
</tr>
<tr>
<td></td>
<td>The unhydrogenated oils are bland or very mild in flavor and liquid at room temperature. Salad oils are additionally winterized, when necessary, to prevent the oil from solidifying or clouding at refrigerator temperatures.</td>
<td>Deep-fat frying when the turnover rate is sufficiently high and frying odor is not a factor. Wholesale bakery production of bread, buns, rolls, and cakes</td>
</tr>
<tr>
<td>II</td>
<td>Hydrogenated winterized oils</td>
<td>Salad oil</td>
</tr>
<tr>
<td></td>
<td>These oils are similar to those in Group I except for having been lightly hydrogenated and winterized. They possess greatly improved oxidative and flavor stability. Hydrogenated winterized soybean oil (HWSBO) is a prime example.</td>
<td>Deep-fat frying in restaurants and institutions when the turnover rate is moderate Preparation of some potato chips</td>
</tr>
<tr>
<td>III</td>
<td>Hydrogenated vegetable shortenings</td>
<td>Deep-fat frying of some foods in restaurants and institutions Preparation of some fried snack foods</td>
</tr>
<tr>
<td></td>
<td>(a) Oils specially hydrogenated to render them resistant to oxidative changes at frying temperatures and in packaged, fried foods. Such shortenings are fairly firm and brittle at room temperature. Most expensive of the plastic frying shortenings. Referred to as the &quot;heavy duty&quot; frying fats. Have narrow plastic range. Example: frying shortening, Table 4, Chapter 10.</td>
<td>Fried snack foods</td>
</tr>
<tr>
<td></td>
<td>(b) Oils slightly less hydrogenated than those in (a). These shortenings have a lower melting point but impart a better mouth feel, a very important factor in snack foods.</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>All-purpose vegetable shortenings</td>
<td>Bakery operations where an inventory of shortenings for special uses is not maintained.</td>
</tr>
<tr>
<td></td>
<td>Oils hydrogenated to a lesser degree than for Group III. Less stable at frying temperatures. Sufficient hardfat added to improve the shortening's plasticity and creaming properties. Example: general-purpose shortening nos. 1 and 2, Table 4, Chapter 10.</td>
<td></td>
</tr>
</tbody>
</table>

continued--
<table>
<thead>
<tr>
<th>Group</th>
<th>Type and description</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Blended vegetable shortenings</td>
<td>Much the same as Group IV</td>
</tr>
<tr>
<td></td>
<td>Blend consists of unhydrogenated vegetable oil(s) with a larger percentage of hardfat than used in the all-purpose shortenings. They possess good creaming power, are only slightly less resistant to oxidation, and are less costly than the all-purpose shortenings.</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Meat fat and vegetable oil blends</td>
<td>Generally the same as Group IV</td>
</tr>
<tr>
<td></td>
<td>A blend of lard and/or tallow and vegetable oils. Proportions vary from supplier to supplier with related effect on melting point and other properties. Some of these shortenings have excellent creaming properties, and their oxidative resistance may equal or exceed that of the all-purpose hydrogenated vegetable oil shortenings.</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>Hydrogenated meat fat-vegetable oil blends</td>
<td>Same as Group III</td>
</tr>
<tr>
<td></td>
<td>These are similar to those in Group VI but have been hydrogenated. They have good resistance to oxidation, are firmer in consistency than the all-purpose shortenings, and therefore do not cream as well when used in baking. Often less costly than Group III shortenings.</td>
<td></td>
</tr>
<tr>
<td>VIII</td>
<td>Hydrogenated, fractionated vegetable oils</td>
<td>Deep-fat frying when turnover rate is low</td>
</tr>
<tr>
<td></td>
<td>Although this group was not described by Baeuerlen et al. (1968), it comprises the liquid fraction obtained by selectively hydrogenating a vegetable oil, such as soybean for example, typically to 80-85 iodine value and then winterizing the hydrogenated oil to remove the solid (stearines) fraction. With proper additives, the product is a fluid shortening nearly comparable in oxidative stability to Group IIb shortenings.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Baeuerlen et al. (1968) and Brody (1978).

The hydrogenation conditions eliminate substantially all of the linolenic acid and reduce the linoleic acid content to under 15% as described by Simmons et al. (1968) in preparation of the above product.
proper amount to yield the desired plasticity, will result in
a shortening or margarine having excellent plasticity.
Consistency will vary from very soft to firm and waxy as
harder base stocks are used and more hardfat is added.

Soybean oil is excellent for the partially hydrogenated
base stocks but not as the sole hardfat. Soybean oil hardfat
crystallizes in the $\beta$ form and when used alone generally
causes the shortening to become brittle rather than plastic.
However, it can be used satisfactorily when blended with a
greater or equal amount of a $\beta'$ hardfat (Erickson, 1979).

Stiffness. The shortening used in creamed icings and in
the cream fillers found in cookies and cup cakes must impart
stiffness to the icing and filler for desired body and texture.
The shortening's ability to provide this stiffness is
related directly to the ratio of hard fats to soft fats in
the base stock. Generally speaking, a base stock that is
itself quite stiff will result in a cream filling or cream
icing that is stiff.

CONSUMER PRODUCTS

Household shortenings sold in the United States are used
primarily for frying and, to some extent, for general baking
and cooking. Those analyzed by Sheppard et al. (1978) con-
tained an 80:20 mixture of partially hydrogenated soybean and
cottonseed oils (also see Table 6). Shortenings now on the
supermarket shelves usually contain palm in place of cotton-
seed oil. Also, household shortenings almost always contain
sufficient emulsifier in the form of mono- and diglycerides
to give an $\alpha$ monoglyceride (the active form) content of about
3%, making them well suited for domestic baking (Schroeder,
1969).

BAKED GOODS

YEAST-RAISED BAKED GOODS

Large quantities of plastic and pourable shortenings,
many made from soybean oil, are used for bakery, shop, and
institutional production of yeast-raised goods. For these
products (which include bread, buns, rolls, sweet rolls,
yeast-raised doughnuts, and coffee cakes), the shortening
should be bland or mild flavored and provide the necessary
lubricity and tenderness. The means for producing a bland
shortening have been described earlier. Lubricity is im-
parted by the oil phase in the shortening. For this reason,
the plastic shortening should be soft rather than hard and
plastic rather than brittle. Tenderness of baked goods is
largely dependent upon the amount of fat present. The tenderness of bread increases with fat content up to a level of about 8%, based upon the flour weight (Brody, 1978).

Shortenings used in these baked goods normally contain emulsifying agents, often α-monomglycerides. The crumb tenderness of bread increases with increasing amounts of the monoglyceride up to 8%, based on the shortening weight, and extends the shelf life of wrapped goods by 20-33% (Brody, 1978).

The wholesale baking industry also uses large quantities of liquid or fluid shortenings, often prepared from soybean oil, or uses a liquid oil. These are used because of better control of product formulation in automated baking systems, reduction in shortening usage, and economy of bulk handling of an unheated liquid as compared with a semisolid shortening. Based on lard and the appropriate additives (i.e., crumb softners and dough conditioners), savings of 10, 19, 25, and 30% by use of a "complete fluid shortening" have been reported for the production of batch process sponge and dough bread, continuously mixed bread, hamburger and frankfurter buns, and yellow cakes, respectively (Petricca, 1976).

One fluid shortening for bread contains 89% liquid soybean oil, 8% hardfat (amount is critical and is adjusted to meet the conditions of the bakery), and 3% of a hard monoglyceride (90% concentration) (Baeuerlen, 1973). Baldwin et al. (1965) report satisfactory results were obtained in the laboratory production of continuous mix bread when lard was replaced by soybean oil plus cottonseed oil hardfat and hard monoglycerides.

Hartnett and Thalheimer (1979a) produced bread, by both the conventional and continuous-mix methods, that was of comparable or higher quality when soybean oil and a dough conditioner-softener (i.e., a mixture of polysorbate 60 and mono- and diglycerides) were used in place of lard alone or lard plus the conditioner-softener. They also obtained excellent results when soybean oil and the conditioner-softener replaced lard in sweet goods (Hartnett and Thalheimer, 1979b). Less oil than lard was needed for both the bread and the sweet goods.

As stated earlier under the section on preparation of shortenings, the shift away from plastic to pourable shortenings results, in part, from the development of satisfactory emulsifier systems that permit use of the liquid oil. The more unsaturated oils such as soybean are said to be more effective shortening agents in bread making than are the plastic shortenings (Landfried, 1977). Proper use of the appropriate emulsifier systems with the oil can give very satisfactory and economical results with both conventional
and continuous baking systems. Also, the use of fluid rather than plastic shortenings raises the linoleic acid content of the baked food product, a nutritional factor of interest to some people.

CHEMICALLY LEAVENED BAKED GOODS

Cakes. Chemically leavened baked goods include cakes, cookies, cake doughnuts, and Danish and puff pastries. Whereas the housewife normally obtains satisfactory results with household-type shortening, the wholesale baking industry generally uses a variety of specialized shortenings, each of which is formulated to best meet the needs for a particular type of baked goods and often to produce a better product. Because the small baker cannot afford to stock a large number of shortenings, he may use an all-purpose bakery shortening, or an unemulsified shortening plus an appropriate emulsifier system. Often a hydrated emulsifier is used, and it is added directly to the batter (Hartnett, 1977).

For loaf and layer cakes, the shortening must be formulated to have moderate to excellent creaming and emulsifying properties, that is, properties superior to those of butter or an unemulsified shortening.

Liquid oils often are used now by the wholesale bakery industry for cake production. One typical cake shortening contains 91% soybean oil, 8% propylene glycol monoester, and 1% monoglyceride (90% purity). Another cake shortening is based on 94% soybean oil, 5% lactylated mono- and diglycerides, and 1% of the high purity monoglycerides (Baeuerlen, 1973).

With the proper emulsifier system (i.e., mono- and diglycerides, polysorbate 60, and sodium stearoyl-2-lactate), Hartnett and Thalheimer (1979b) found soybean oil to be an effective alternate to plastic shortenings in cakes (white, yellow, and devil's food). Also, appreciably smaller amounts of the oil were needed. Soybean oil containing 8-14% of propylene glycol monoester (i.e., PGMS-Type 2180) also proved to be a very good shortening, is a clear liquid, and presents no separation, handling, or storage problems when reheated to 68-72°F (20-22°C) after storage at 30°F (-1°C).

Development of a fortified, baked, cake-like product containing liquid soybean oil and a creamed filling for the U.S. school feeding program was made possible by use of an emulsifier system. In this product, more than 5% of the total calories comes from linoleic acid. When served with 8 oz. of milk, the combination is stated to be the nutritional equivalent of a breakfast consisting of 4 oz. of orange juice, 2 slices of bacon, 1 egg, 1 pat of butter, and
1 slice of bread (Baldwin et al., 1972; Cotton et al., 1971).

Cookies. For cookies, the shortening may have a bland, a very mild, or a butter-like flavor and generally (but not always) should have a moderate creaming ability. The melting point requirement varies with the type of cookie. Extended shelf life is needed when the cookies are made for distribution and sale through grocery stores and supermarkets, as compared with those made and sold by the retail bakery.

The shortening's melting point increases as the hardness of the base stocks increases and with the amount of hard fat added. Sometimes the shortening formulator has a formidable task in satisfying the conflicting requirements of good creaming property, low melting point, and long shelf stability in the same shortening.

Cake doughnuts. Most cake doughnuts are made from a prepared mix to which only water need be added. A small quantity of fat is used in the mix, and even distribution of this fat is most readily accomplished by spraying the oil or molten fat as a fine mist onto the other premixed ingredients while they are being agitated. Some premix manufacturers use an oil containing up to 8% of a hard monoglyceride. In this case, the oil needs to be heated to dissolve the hard monoglyceride before spraying.

Cake doughnuts are fried in fat heated to 360-390°F (182-199°C), during which time they absorb about 10% fat. Because this fat is concentrated largely on the doughnut's surface, the fat must contain little or none of the polyunsaturated fatty acids to avoid later development of undesirable flavors. After the doughnut is removed from the frying vessel, the fat must solidify relatively slowly so the doughnut can be given a coating of "doughnut sugar" that will adhere well and remain white.

Proper hydrogenation will give a relatively flavor-stable base stock. Blending of the base stock with the proper amount of hard fat will produce a frying shortening with the proper solidification characteristics. Soybean oil is excellent for preparation of the base stock, for the hardfat when used within the limitations described under Shortenings--Introduction, and for the oil sprayed onto the mix ingredients.

Danish and puff pastries. These pastries have an unusually high proportion of fat, and the fat is interleavened in alternate layers throughout the dough. In many cases, interleavening the fat into the dough gives a baked product having a highly desirable flakiness that is obtainable in no other way. For Danish pastries, a variety of fat sources such as pure butter, soft margarine, and ordinary shortening are used. Most puff pastry, however, is made with a roll-in
fat that is very firm and very waxy. However, a softer fat source can be used if the dough and the equipment are kept cold by refrigeration; the resultant pastry has a less waxy feel when eaten.

Pie crusts. Lard has been and is today the favored shortening for pie crusts made commercially. The procedure used in making pie crusts has been developed in deference to the peculiar characteristics of lard. Use of the identical procedure with a vegetable oil shortening will result in failure. However, when the dough handling procedure is changed to mixing colder doughs and using them immediately, pie crusts of prime quality can be made with a properly formulated vegetable oil shortening. Part of the commercial pie industry in the U.S. is now using a shortening prepared from soybean oil, and the pies equal the best of those made with lard.

REFRIGERATED DOUGHS

A variety of products, some chemically leavened and some yeast leavened, are marketed as refrigerated doughs. The doughs are packaged as individual cuts in a tube. The dough pieces often are sprayed with soybean oil before packaging for easy separation later. Products available to the homemaker include hot baking powder biscuits, dinner rolls, sweet rolls, and Danish pastry. Small bakery shops now use refrigerated doughs in which the fat has already been rolled in and interleavened for Danish pastry and puff pastry. The saving in time has resulted in good acceptance of these products despite their cost.

The performance requirements for the shortenings and margarines used in refrigerated doughs are similar to those used in products that are not frozen.

PREPARED MIXES FOR BAKED GOODS

Prepared mixes are used in large quantities by the homemaker and to an increasing extent by bakers in hotels, institutions, restaurants, and retail bakeries. The principal requirement, in addition to traditional ones, is the ability to resist oxidative rancidity in the prepared mix at ambient temperature for periods of about one year. Soybean oil can be processed (i.e., hydrogenated) to give such resistance, and it serves as an excellent base oil for the shortening.

Fulfillment of this particular requirement is sufficient for most of the mixes, but sometimes additional properties are required, as in the two mixes discussed below.
Layer-type cake mixes require very fast creaming, greater emulsification, and resistance to loss of creaming property with aging of the mix. These properties are obtained by the use of completely different emulsifier systems. One consists of the following: propylene glycol monopalmitate and monostearate, monoglycerides, diglycerides, and lecithin.

For cream icing and cream filler mixes, the required faster creaming action is provided by the use of hydrophilic emulsifiers along with the normal complement of mono- and diglycerides.

SODA CRACKERS

For cracker dough, a bland or mild-flavored, good-stability shortening, which can be produced from processed soybean oil, is needed to ensure adequate shelf life. In addition, some crackers are coated with a thin layer of a "cracker spray oil." Because of the large exposed surface and long shelf life factor, this oil must have good stability. Slightly hardened coconut oil has good stability and fluidity and is generally used as the spray oil. A properly hydrogenated and fractionated soybean oil product high in oleic acid will also give satisfactory results.

ICINGS AND CREAM FILLERS

The icings applied in thin strips or thin smears primarily on yeast-raised sweet goods contain only 1-3% fat. This fat must be soft and plastic to make the icing flexible. In some instances, commercial butter-like flavors are added to the shortening for their aroma and taste.

The flat and fudge icings used for completely covering some cookies and cakes contain 12-18% fat. The shortening for such icings is sometimes required to contribute a butter-like flavor and/or to provide emulsification. From 4 to 6% of mono- and diglycerides made from plastic fats usually provide sufficient emulsification and, when necessary, about 0.5% of a highly hydrophilic emulsifier is also added to the shortening.

Cream icings that cover the outside of cakes, lie between layers, or are injected into small snack cakes contain 22-40% fat. For such icings and fillers, the shortening should have good emulsifying, creaming, and stiffening performance properties. The means for attaining these has been discussed earlier.

The cream fillers used in sandwich cookies must have a long shelf life and be reasonably stiff, yet have good eating properties. Shortenings with good oxidative rancidity,
reasonably low melting point, and adequate stiffness are needed. All three characteristics are obtainable by blending properly hydrogenated vegetable oil base stocks. Soybean oil is excellent for preparing such shortenings. As stated earlier, soybean hardfat can also be used in amounts up to 50% of the total hardfat content.

FROZEN FOODS

Frozen foods cover a variety of items sold in two major types of markets. One market is foods that the customer prepares or serves. The foods range from various vegetables to complete meals that need only be defrosted and heated, before they are ready to eat. The meals usually include a vegetable, mashed potatoes, and fried chicken or some other entree. Sometimes dessert is also included.

The institutional market, in which we shall include the fast-food restaurants, consumes large quantities of frozen foods such as partially fried potatoes, fried fish, meat, and vegetables. Some of these items need only be heated before serving.

With one exception, the performance properties required of the shortenings used in frozen foods are similar to those required for the same foods not frozen. The exception relates to fried foods that in the frozen state lack customer appeal because of their dull appearance. The appearance is improved when the partially hardened oil is fractionated to remove hard fats, which solidify and give the food a dull appearance and a dry feel.

Soybean oil is excellent for the various shortenings used.

FRIED FOODS

DEEP-FAT FRYING

Fats play a dual role in the preparation of fried foods. First, they aid in the transfer of heat to the food being fried. Second, some of the fat is absorbed by the food and thus contributes to both its nutritive value and to its flavor.

Most frying shortenings should have a bland or very mild flavor, a minimum smoke point of 400°F (204°C) when fresh, and adequate resistance to breakdown when in continuous use. The bland flavor is obtained by properly deodorizing the oil and reducing the free fatty acid content to 0.05 wt % or less. Reducing the free fatty acid content to this level also increases the smoke point to at least 400°F and often to
450°F (204 and 232°C). Proper hydrogenation to reduce or eliminate the polyunsaturated fatty acid content increases the shortening's resistance to breakdown at frying temperatures.

For potato chips and other fried snack items, surface appearance also is a factor. The surface will appear shiny and feel wet when the absorbed fat is liquid at room temperature. If the absorbed fat is solid at this temperature, the surface will be dull and feel dry.

Silicone compounds (e.g., polydimethyl siloxanes) serve as antifoam agents, raise the smoke point, and greatly increase the oxidative stability of an edible oil at the elevated temperatures used to prepare fried foods. These compounds are approved by the Food and Drug Administration at addition levels up to 10 ppm and are often added to frying shortenings (Freeman et al., 1973; Howard and Martin, 1968; Lorenz, 1978; Martin, 1953).

Frying and specialty shortenings, such as those shown in Table 4, Chapter 10, generally have a narrow plastic range and consist of partially hydrogenated vegetable oils with little or no added hardfat.

Soybean oil shortenings are being used in restaurants—including the fast-food type, institutions, and homes for deep-fat frying of chicken, meat, sea foods, and various vegetables. HWSBO is being used by some processors of potato chips. Some processors use slightly hydrogenated soybean oil to which 15-20% cottonseed oil is added, ostensibly for its flavor effect (Weiss, 1970b).

A variety of fats can be used for deep-fat frying. As indicated in Table 12, these range from unhydrogenated vegetable oils and meat fats to shortening compounds partially hydrogenated for high oxidative stability such as the heavy duty frying shortenings listed in Table 6. The preparation of non-greasy foods depends upon the heat balance of the frying system and the manner of using the shortening rather than type of shortening. Unhydrogenated soybean and other vegetable oils and deodorized, stabilized lard can serve as frying fats when the shortening turnover rate is high. When fried goods are served hot and consumed immediately after preparation, the frying fat need not have unusual stability (Weiss, 1970d).

Thompson et al. (1967) concluded that the frying life of deep-fat frying shortenings is not dependent upon the degree of fat unsaturation but upon how the fat is used. In a discussion of the chemistry and technology of frying fats, Roth and Rock (1972) mention four major factors that affect deterioration of the frying fat. These are: (1) the temperature history of the fat, (2) the degree of fat exposure
to the air, (3) the extent to which fat is contaminated with foreign material, i.e., "fall-off" particles from the food being fried and contaminants from or inadequate cleaning of the frying equipment, and (4) the rate at which fat absorbed by the fried food is replaced with fresh fat, a factor related to the turnover rate as defined below. All the above factors are influenced by the fryer design, various operating parameters, and the products fried.

Furthermore, fat in the food being fried, under either atmospheric or elevated pressure, often will migrate into and commingle with the frying fat. For example, after usage in a pressure cooker, a frying fat may, under equilibrium conditions, contain 30 to 40% chicken fat (Erickson, 1979). Such commingling naturally has some bearing on the useful life of the frying fat.

Turnover rate refers to the addition, usually daily, of fresh fat to the fry kettle to replace that absorbed by the food being fried and of any additional amount withdrawn to maintain the frying fat in a satisfactory condition. The quantity is expressed as a percent of the initial amount of fat in the fry kettle.

Because of the broad range of frying conditions and fats used, specific information on the optimum or minimum turnover rate is limited and general in nature. To prevent serious flavor or color defects from developing in the fried food, Weiss (1970b) suggests the daily addition of 15-25% of makeup fat, and Bassett (1979) suggests 25%. In citing these figures, neither made reference to any specific frying fat or particular conditions of use. If necessary, some fat should be withdrawn from the fryer and discarded when the daily turnover is low. The turnover rate probably is the most important factor for retaining the frying fat in satisfactory condition. It also strongly influences the type of shortening selected.

There is no general agreement on the physical or chemical criteria to be used to indicate when a frying fat should be discarded. Factors that have been considered include viscosity, foaming, color, visual smoke, flavor, odor, conjugation, free fatty acid content, iodine value, carbonyl content, oxidized fatty acid content, polymerized fat content, melting point, set point, and SFI. Commercial kits are available and can be used to monitor the increase in free fatty acid content. Fritsch et al. (1979) and Graziano (1979) reported on monitoring of the dielectric constant of several shortenings as a measure of their deterioration. The instrument appeared to be most effective on shortenings having some polyunsaturation.

Almost any test method can be employed, and the key to
its successful use is to correlate the method with the frying operation sufficiently well so that the test results serve as a reliable indicator of the frying fat's condition (Erickson, 1979).

The selection and control of frying fats, the practice of deep-fat frying, and the design, proper operation, and maintenance of the frying equipment have been discussed by various writers, including Baueerlen et al. (1968), Jacobson (1967), Perkins (1967), Robertson (1967), Rock and Roth (1964), Roth and Rock (1972), and Weiss (1970a and 1970b).

For detailed information on the chemistry and technology of frying fats, the reader is referred also to the writings of S. S. Chang, E. N. Frankel, F. A. Kummerow, E. G. Perkins, E. Selke, and their coworkers, as well as others. Many of their publications appear in the Journal of the American Oil Chemists' Society. Technical articles have also appeared in the English, French, German, and Japanese literature.

PAN OR GRILL FRYING

When foods are pan- or grill-fried in unhydrogenated soybean oil or any of the other common vegetable oils, such as corn, cottonseed, olive, palm, rapeseed, safflower, and sunflower, they have an oily surface and a good mouth feel. Based upon a consumer panel evaluation, Theunissen et al. (1977) observed no meaningful differences in the palatability of five foodstuffs panfried in any one of the five vegetable oils most frequently used in the Netherlands; namely, soybean, sunflower, safflower, corn, and "vegetable" (probably sunflower). Based upon their results, the authors advised using the least expensive oil for pan frying.

A method described by Madison and Shulman (1979), reportedly for improving the flavor of fried foods, i.e., chicken, involves the addition of a small amount (e.g., 500 ppm) of a polymeric triarylphosphine compound to polyunsaturated frying oils to prevent the build-up of hydroperoxides and their decomposition products in both the oil and the food. The food is said to have a flavor similar to that obtained by frying the food in an oxygen-free atmosphere, that is, under a nitrogen or carbon dioxide atmosphere.

Any unemulsified shortening can be used for pan frying. Some may contain lecithin as an antistick compound and buttery colors and flavors of the heat-stable variety (Weiss, 1970b).

PRESSURE FRYING

This method is frequently used to prepare fried chicken.
in many of the present-day, fast-food restaurants. Marinated pieces of chicken coated with breading or batter are quickly cooked in a sealed fryer filled with a shortening, often a soybean oil hydrogenated to 65-70 IV. The hot shortening rapidly vaporizes the moisture present to the point where the fryer operates under an elevated pressure; then the chicken can be completely cooked in 8-10 min. A high fat turnover rate is needed because chicken fat leaches into the shortening and raises its content of polyunsaturated fatty acids (Nelson, 1965; Weiss, 1970b). Contrary to what one might expect, the fat undergoes relatively little hydrolysis during such usage.

CANNED AND DEHYDRATED FOODS

Soybean oil is used in canned foods such as tomato soup and chicken soup with rice or noodles. Canned goods are expected to have long shelf stability at ambient temperatures. Good resistance to oxidative rancidity is not mandatory for the oils used in vacuum-packed canned goods where oxygen is largely absent. When the canned goods have a high moisture content, the conditions usually will promote fat hydrolysis. In such cases, the lauric-acid type oils normally should be avoided because products of the fat hydrolysis may impart a disagreeable soapy flavor to the canned goods.

Dried egg mixes prepared commercially and containing 15% of HWSBO, RBD corn oil or RBD cottonseed salad oil were equally acceptable initially and after accelerated storage tests when judged by a trained panel (Evans et al., 1974).

Soybean oil is excellent for use in canned goods and a number of dehydrated foods.

CONFECTIONERY COATINGS AND CANDIES

Soybean oil is being used for the commercial preparation of certain hard butters (Paulicka, 1976). Hard butters are specially prepared vegetable fats that can extend or sometimes replace cocoa butter in coatings used by the confectionery trade. Hard butters must have a narrow plastic range, be hard and brittle at and below room temperature, must melt completely or nearly so at body temperature, and be compatible to an adequate degree with cocoa butter. Gordon et al. (1979) have studied the phase behavior of binary mixtures of cocoa butter with three types of confectionery fats. By use of iso-solids phase diagrams, the authors provide an explanation for why practically all fats have a limited compatibility with cocoa butter in confectionery coatings. They also provide information on acceptable blend-
ing limits for the three types studied. Johnston (1972) has reviewed the basic requirements of fats for use in confectionery coatings.

Fractions obtained by interesterifying, hydrogenating, and winterizing or otherwise fractionating cottonseed, palm, and soybean oils and edible tallow have been proposed as replacements for cocoa butter. Such fractions serve as only partial replacements for the reasons given above. The trend now is to produce hard butters that can be used by themselves as the only fat in candy products. The products are more uniform and the special tempering conditions required for cocoa butter need not be used (Sheppard et al., 1978).

One hard butter is prepared by hydrogenating soybean oil "under optimum trans conditions to an IV of about 70." This hard butter can be used as an ingredient in confectionery coatings used for enrobing soft cake goods (Paulicka, 1976). The fatty acid composition of another hard butter prepared from hydrogenated soybean oil is given in Table 6.

Snyder (1979) prepared a substitute for cocoa butter and butter fat in confectionery products by hydrogenating a mixture of soybean oil and palm oil (80:20) with a catalyst mixture consisting of a conventional nickel catalyst and a sulfur-modified nickel catalyst.

Processed vegetable fats are also employed otherwise in candy manufacture. The largest quantities are used in fudges, caramels, and nougats and smaller quantities are required in other candies such as creams and jellies. Soybean oil is used to some extent, as well as others such as cottonseed and peanut and the lauric acid oils—coconut, palm, and babassu (Langwill, 1965).

**IMITATION DAIRY PRODUCTS**

Vegetable fats are used in imitation dairy products including margarine, mellorine (an ice cream substitute), filled and simulated milk, filled and simulated cheese, frozen and chilled desserts, coffee whiteners, whipped toppings, milk shakes, and eggnogs. The "filled" products consist in part of defatted milk in the form of skim milk or nonfat dry milk solids and an edible vegetable fat that replaces the butter-fat. "Imitation" or simulated products contain no milk as such but are made with sodium caseinate, which is a milk protein, or with sodium soy protein isolate. In filled milk, the fat component may be a liquid vegetable oil, a low-melting, lauric-type hard butter, or a partially hydrogenated domestic oil (Ryberg, 1968).

In addition to margarine, partially hydrogenated soybean oil is found in some whipped toppings, filled evaporated
milk, and imitation cheeses. Although the lauric-acid type fats are often used in a number of these products (e.g., toppings and coffee whiteners), selectively hardened soybean oil will serve satisfactorily (Brody, 1978).

Both Brody (1978) and Weiss (1970b) emphasize the need for careful and thorough deodorization of soybean oil or any other oil substituted for butterfat. An oil that seems bland when tasted as an oil may not be sufficiently so in a dairy product. Emulsification of the fat system exposes extremely large surface areas to the tongue and accentuates the presence of any flavor compounds (Weiss, 1970e).

The economics of replacing butterfat with an edible vegetable fat generally become favorable whenever the product's butterfat content is 10% or more (Brody, 1978).

Weiss (1970e) provides information on the formulation of several types of imitation dairy products.

OTHER USES

Soybean oil or tomato sauce is added to sardines sold in tinned containers (Pedersen, 1966).

An approximately 50:50 blend of soybean and rapeseed hardfats (IV of 12 or less) added to peanut butter at a level of 1-2% will promote rapid flavor release and thus give a high impact of peanut flavor when the peanut butter is eaten (Japikse, 1966).

A reading of product labels shows that soybean oil in unhydrogenated and partially hydrogenated states is being used in a number of products. A recent list includes the following: dehydrated soup mix, prepared pudding mix, prepared pancake and waffle mix, macaroni and cheese mix, prepared spaghetti sauce, mustard, dry breakfast cereal, frozen fried seafood, hamburger meat extender, pizza, and popcorn. This list is by no means complete, but it illustrates the fact that soybean oil is being used in a wide variety of products and that usage can be expected to increase both in volume and number of outlets.

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