Shortening Formulation and Control

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ABSTRACT

Shortening provides a significant and increasing proportion of total fat in the diet. Functional and nutritional requirements have contributed significantly to the evolution of formulation and unit processing technology required to produce such products. Evolution of these changes and the effect on shortening requirements are reviewed. Basic structural considerations as well as practical processing characteristics are elucidated. Finally, the effect of such changes on the quality control of shortening manufacture is considered.

INTRODUCTION

In its narrowest context, a shortening may be defined as an edible fat used to shorten or tenderize baked products. Being insoluble in water, fat prevents the cohesion of gluten strands during mixing, thus literally shortening them and making the product tender. In its loosest sense, the term "shortening" is often used interchangeably with the term "fat." Thus, it is not uncommon to find reference to "icing shortening," "frying shortening," etc. For purpose of this discussion, the term "shortening" will be applied in the broader sense to fats used in bakery products where, in addition to shortening or tenderizing, such fats impart other important functional characteristics such as aeration to the finished product.

Historically, lard provided the earliest commercial source of shortening for the bakery industry. As a by-product of the meat industry, lard became available in significant quantities. However, since lard is a by-product, the extent to which it is produced is governed by the number and weight of hogs marketed. Consequently, the supply is not directly related to demand. More importantly, the consistency of lard at room temperature did provide the baker with a shortening that could be readily incorporated in bread, cakes, pastries, and other bakery products.

Although animal fat, and lard particularly, continues to provide a significant quantity of shortening to the bakery industry, a long term significant trend toward utilization of vegetable-derived shortening continues. This trend is driven by five important factors: vegetable oil availability, oil processing capability, bakery automation, nutritional needs, and technology. A brief review of these factors will provide a basis for understanding the increasingly complex nature of modern shortening formulation and processing.

Oil Availability

A brief examination of the domestic production and domestic use of animal fats vs. vegetable oils for the period 1960 to 1970 will serve to illustrate a widely acknowledged longer term trend; i.e., the production of vegetable oils is increasing significantly faster than the production of animal fats (Table I). The use of vegetable fats vs. animal fats for edible purposes shows a similar trend. Although cottonseed oil, peanut oil, sunflower oil, safflower oil, corn oil, sesame seed oil, and palm oil are acceptable oil sources, their use is dependent upon availability and cost. By far, the most significant source of vegetable oil used in the domestic shortening industry today is soybean oil.

TABLE I

Supply and Use of Food Fats and Oils
1960-1971 (Millions of Pounds) (1)

	Domestic production		Domestic use	
Year	Animal	Vegetable	Animal	Vegetable
1960	4,389	8,349	3,755	5,725
1965	3,583	12,062	3,399	7,671
1970	3,745	14,578	3,238	8,988

Oil Processing Capability

The increased availability of vegetable-derived edible oils at prices competitive to lard permitted processors to market compounded animal/vegetable shortenings prepared by the blending of hard animal tallows and soft or liquid vegetable oils. Such products, designed as substitutes for lard, and termed "Lard Compounds," were introduced to meet a market demand for plastic shortening which exceeded available supply for lard. However, it was not until catalytic hydrogenation was introduced in 1910 that the processing of vegetable-derived shortenings could proceed independent of the meat packing industry. This key unit process now permitted processors to vary the composition of inherently softer or liquid vegetable oils and to increase their oxidative stability. By selective choice of edible vegetable oil, controlled hydrogenation and appropriate blending of unhydrogenated, partially hydrogenated, and fully hydrogenated base stocks, processors could now provide a range of products varying in state from a liquid through a continuum of plasticity to a sharp melting solid. Other unit processes such as winterization, solvent fractionation, and interesterification have provided further flexibility in the production of unique and selective fat compositions for specialized bakery usage.

Bakery Automation

The growth of the bakery industry from a cottage industry to a highly specialized industry with inter and intra state distribution has been fed by competitive pressures to produce high demand products under conditions of lowest cost per unit. Such pressures provided an ideal climate for the development of highly automated blending, mixing, proofing, baking, cooling, and packaging processes. Automated systems require shortenings which are stable to bulk handling, provide specialized functionality, and impart extended shelf life to the finished product mandated by the distribution channels.

Nutritional Requirements

Fats and oils have long been recognized as important nutrients in both human and animal diets. They provide essential fatty acids, a concentrated source of energy, and serve as carriers of fat soluble vitamins and antioxidants. Although an appreciable portion of dietary carbohydrate and some protein can be converted metabolically to fat, certain essential fatty acids such as linoleic acid must be supplied in the diet.

Although no responsible individual would debate the need for adequate dietary nutrition, lack of definitive knowledge as to what constitutes appropriate diet for the maintenance of good health and reasonable freedom from diet-related disorders exists even at this time. Although a significant proportion of the scientific community supports the desirability of increasing the polyunsaturated fat content and reducing the dietary cholesterol level of the average American diet, the relationship between diet and arteriosclerotic disease remains controversial. The Senate Select Committee on Nutrition and Human Needs has recommended (2,3) in part that Americans reduce overall fat consumption from 40% to 30% of energy intake, reduce saturated fat consumption to account for about 10% of energy intake and balance with unsaturated and monounsaturated fats, which should account for about 10% of energy intake each, and reduce cholesterol consumption to about 300 mg per day.

Development of a National Nutrition Policy based on these recommendations is not without minority dissent and reflects the need for continued research on diet and nutrition. Nonetheless, developing nutritional trends have been an important factor in the trend toward increased utilization of vegetable-derived oils for edible uses.

Technology

Increasing vegetable oil supplies, broadened oil processing capability, bakery automation and nutritional requirements have provided the driving force to the increased utilization of vegetable-derived oils in edible products. Technological achievement in modification of the composition and properties of vegetable fats has provided the methodology required to convert crude vegetable oils into edible shortenings meeting functional and nutritional requirements for specialized bakery shortenings. Rather than attempt to define specific shortening formulations, which for the most part are considered proprietary to the manufacturer, I will instead discuss those more basic physical-chemical considerations which affect functional properties. For purpose of discussion, I have classified shortenings on the basis of their physical state, packaged form, and functional application (Table II).

Physical State – Packaged Form – Functional Application

Shortenings are offered in liquid, plastic, and fluid states. Liquid shortenings are denoted by the absence of solids at ambient temperatures. The composition of such oils are characterized by high levels of triunsaturated and diunsaturated monosaturated triglycerides. Small amounts of disaturated monounsaturated triglycerides are tolerated due to mutual solubility. Only traces of trisaturated glycerides are tolerated due to their intrinsically low solubility.

Liquid oils are often formulated from refined bleached vegetable oils which have been lightly hydrogenated under selective conditions to increase oxidative stability, and then winterized to remove insoluble trisaturated glycerides. Such oils typically exhibit A.O.M. stability in the range of 25 to 100 hr. At least one manufacturer offers a liquid oil derived by solvent fractionation of a partially hydrogenated oil blend which has an A.O.M. stability in excess of 250 hr.

Liquid shortenings are generally used in applications where low viscosity, lubricity, or heat exchange characteristics are desirable. Liquid shortenings are easily stored in bulk and are readily pumped or metered at normal ambient temperatures. Since liquid oils are poor aerators, their use in leavened bakery products is generally supplemented by the addition of stearine and emulsifier.

Plastic shortenings are characterized by the presence of an intermediate level of solids over a broad temperature range. The workability and creaming ability of a shortening at any given temperature is largely a function of the level and type of solid glycerides present at these temperatures. Oxidative stability is inversely proportional to the concentration of active methylene groups present.

Typical plastic shortenings range in solids content between 15% and 30% and exhibit a relatively flat SFI

TABLE II

Classification of Shortenings

Physical state	
	Liquid
	Fluid (suspended solids)
	Plastic
Packaged form	
	Bulk
	Sheeted
	Cubed
	Printed
Functional application	
	Bread and rolls
	Cake
	Pastry
	Icing
	Doughnut

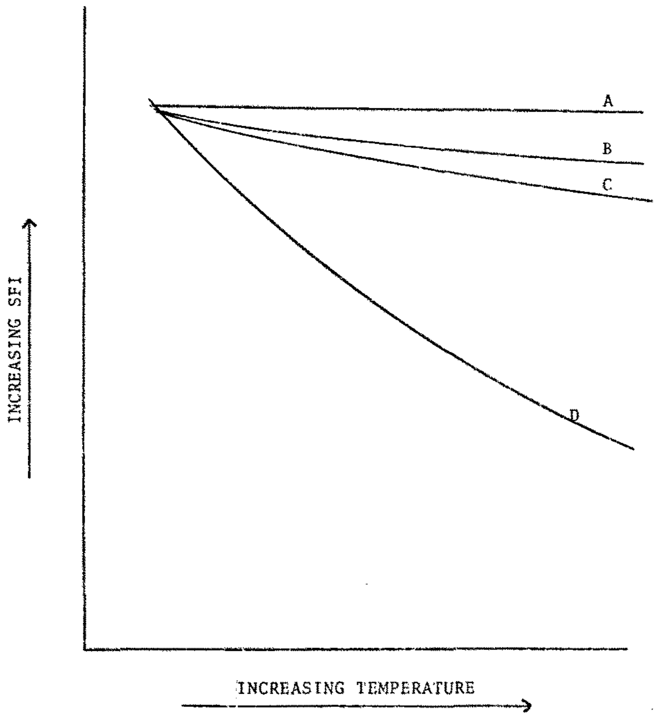

FIG. 1. The effect of formulation on solid fat index: (A) liquid oil plus hard fat; (B) partially hydrogenated fat plus stearine; (C) blend of two partially hydrogenated fats; (C) partially hydrogenated fat.

profile (Figure I) over a temperature range from 60 F to 90 F. Shortenings meeting these criteria, with acceptable oxidative stability, can be formulated in one of two ways: i.e., from a blend consisting of ca. 90% partially hydrogenated base oil (65-80 I.V.) and 10% hard oil (Figure 2 B) or from two partially hydrogenated base oils – one of which is harder than the other (Figure 1 C). The partially hydrogenated base oils may themselves be single oils or blends. Compositions consisting solely of partially hydrogenated oil, hydrogenated to a single iodine value (Figure 1 D), and blends of liquid oil and hard stock (Figure 1 A) are usually not employed due to the low oxidative stability of the former and the limited plastic range of the latter. The effect of unsaturation on oxidative stability is shown in Figure 2. The traditional approaches to formulation represent a compromise between the wide plastic range, but poor oxidative stability characteristic of liquid oil blended with hard stock and the narrow plastic range but excellent oxidative stability characteristic of partially hydrogenated oils.

It is most important that the solid glycerides of a plastic

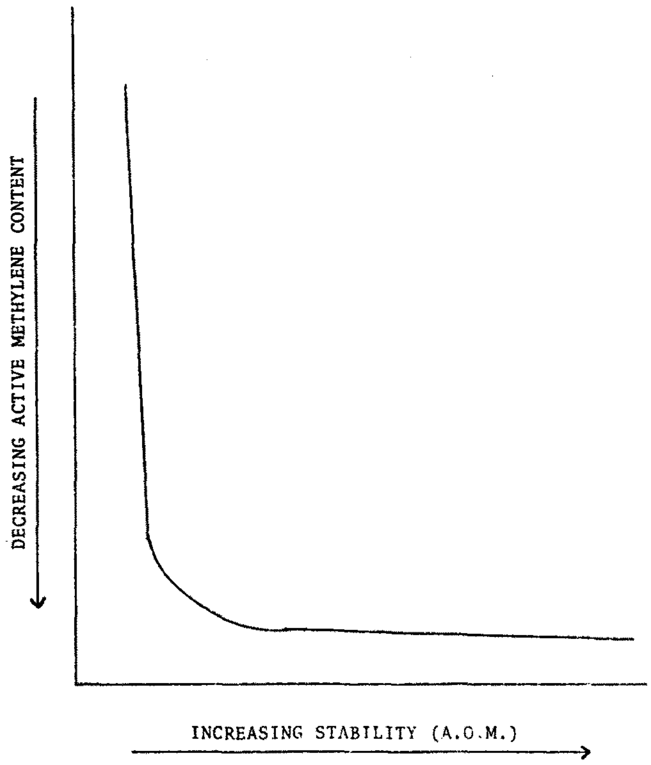

FIG. 2. The effect of unsaturation on oxidative stability.

TABLE III

Polymorphic Form of Hardstocks

Beta tending	Beta prime tending
Canbra	Butter oil
Cocoa butter	Cottonseed
Coconut	Modified lard
Corn	Palm
Lard	Rapeseed
Olive	Tallow
Palm kernel	
Safflower	
Soybean	

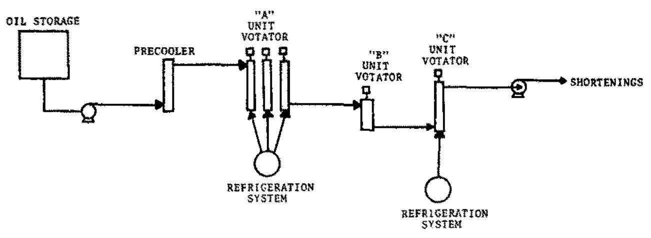

FIG. 3. Typical process for plasticizing fats.

shortening are comprised of the proper crystal habit and polymorphic form. When a fat containing solid glycerides is solidified, its crystalline habit and polymorphic form are determined by its triglyceride composition and the method of solidification. When the higher melting portion of the shortening is comprised of glycerides that are stable in the β' form, the entire fat will crystallize in a stable beta prime (β') form. Fats exhibiting a stable beta prime (β') polymorphic form tend to crystallize in small needles. Such shortenings appear smooth, provide good aeration, have excellent creaming properties, and make good cake and icing shortenings. Conversely, a shortening that crystallizes in a stable beta (β) polymorphic form tends to be grainy, produces large granular crystals, and is a poor aerator – but functions well in pie crust application. β' tending hard stocks includes hydrogenated tallow, cottonseed, and palm oils (Table III). β stable hard stocks include hydrogenated lard, soybean, peanut, safflower, and sunflower oils (Table III). The addition of a β' tending hard stock to a β' tending partially hydrogenated base oil may in some instances induce crystallization of the shortening blend into a stable β' form. However, lard, which contains a large quantity of β tending solid glycerides tends to retain its β form in the presence of all reasonable levels of β' tending hard stock.

While it is true that the ultimate polymorphic form of plastic shortenings is determined by triglyceride composition, the rate at which the most stable form is reached can be influenced by mechanical and thermal energy. Thus, it is customary to process plastic shortenings through various heat exchange working configurations to remove heat of crystallization and heat of transformation. Figure 3 illustrates a typical process for plasticizing shortenings. For slowly transforming formulations, conversion to a stable polymorphic form requires tempering. Stability is achieved by holding the processed shortening in the quiescent state at a temperature just below the melting point of the lowest melting polymorph. In practice, holding at ca. 85 F until a stable form is reached provides an acceptable compromise. Upon cooling to ambient temperature, such shortenings resist further change in form or habit unless heat abused. In addition to base oil and hard fat, many plastic shortenings contain one or more emulsifying agents added to provide specific functional characteristics advantageous to specialized uses. Emulsifiers are regulated by Federal Food and Drug regulations at levels consistent with efficacy in the end use application and human nutritional safety guidelines. Emulsified shortenings are widely employed to increase aeration, hold moisture, enhance tenderness, modify texture, retain softness, etc., and are a vital ingredient uniquely tailored to specialized bakery manufacture. A detailed discussion of this important segment of emulsifier technology is beyond the scope of this presentation.

It should be evident that the functional properties imparted to plastic shortening via formulation and processing can be destroyed or reduced by subjecting these products to elevated temperatures. Even limited exposure to high temperatures may cause sufficient melting to be detrimental.

Plastic shortenings are used in their semisolid state. They are usually packaged in cubes, prints, or sheets for ready end-use application. Bulk handling is reserved for applications such as frying where crystallographic properties are of minor importance. Because of their high oxidative stability, these shortenings are customarily transported and stored at temperatures ca. ten degrees Fahrenheit above their melting point.

Fluid (suspended solids) shortenings combine the highly functional characteristics exhibited by plastic shortenings with the bulk handling characteristics of liquid shortenings. Fluid shortenings are characterized by the presence of low levels of highly functional solids suspended in a liquid oil matrix. The choice of liquid oil is governed by the level of oxidative stability required. The choice of functional solids is dependent upon the specific end use application. Fluid shortenings currently find growing application in bread and cake shortenings. Characteristically, mono and diglycerides are employed as scrub softening or aerating agents. A varity of emulsifiers including ethoxylated monoglycerides and sodium stearoyl lactylate act as dough conditioning agents. Glyceryl Lacto Esters provide tenderizing and moisture retention properties to cake shortenings. Viscosity is often adjusted with hard stearines.

The type and level of solids are an important consideration in producing a stable fluid dispersion. In contrast to plastic shortenings, it is desirable to formulate Beta stable shortenings whose large crystals tend to form a dispersion favoring prolonged suspension. Aeration properties normally associated with Beta prime small crystals are achieved by the addition of appropriate emulsifier.

Equally important to fluid stability are processing conditions for fluid shortenings which are conducive to production of stable beta crystals in a concentration such that the viscosity is low enough to effect easy pumping, but high enough to prolong suspension. Many fluid shortening compositions and unit processing conditions for cake and bread shortenings are covered by patent (4-10) Several are cited for reference. Fluid shortenings are recent additions to shortening technology and are finding increasing acceptance in the bread, roll, and cake segments of the bakery industry. Enhanced functional properties achieved through the use of appropriate emulsifiers permit fluid shortenings to function as shortening sparing agents. Because of the highly functional characteristics and ease of handling, it is fully expected that specialized shortenings will be developed in time for end use applications other than cake, bread, and rolls.

Quality Control

The most critical areas of shortening control relate to those factors affecting oxidative stability, consistency and texture, color, emulsifier level, and functionality. Refractive index, iodine value, A.O.M., and peroxide value provide standardized methodology for those factors affecting oxidative stability. Solid fat index, wiley melting point, dropping point, penetration and viscosity are customarily used to measure factors affecting consistency and texture. Color is most frequently measured by the Lovibond procedure. Emulsifier level and functional tests are frequently based upon internal methodologies due to the highly specialized requirement for such tests.

Finally, assurance of product quality is based on an understanding of and adherence to the underlying principles of shortening formulation and processing technology. Such principles provide for an acceptable standard and limits which should not be exceeded by formulation, comingling, or unit process control. Management support to product quality and technical training of first line production management is key to any quality assurance program and essential to the production of quality shortenings.

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