Importance of Glyceride Structure to Product Formulation

A.E. THOMAS III, Durkee Foods, Division of SCM Corporation, Dwight P. Joyce Research Center, Strongsville, OH 44136

ABSTRACT

Triglyceride composition is an important consideration in the development of fat systems for food products. Depending on the approach to formulation, physicochemical properties may be equally important. Analytical methodologies exist to determine composition and properties. Two systematic routes to the formulation of functional fats are possible–replication of triglyceride composition and approximation of physicochemical properties. Approaches to formulation of fat systems which are based on replication of triglyceride composition have achieved only limited success to date. Limiting factors include lack of commercial technology for converting readily available triglyceride structures to more valuable isomers, and limited availability at high cost of alternative fat sources containing the desired triglycerides. Approaches to formulation of fat systems which are based on fat systems whose physicochemical properties meet the desired functional attributes of the end use system irrespective of their triglyceride compositions are widely employed in the development of formulated foods. Such products are not expected to achieve functional identity to existing counterparts. Nevertheless, key attributes can be successfully approximated with this approach.

INTRODUCTION

Fats and oils, along with proteins, carbohydrates and flavorants are important components of most foods. Each contributes in some measure to the characteristics of foods and food ingredients. Such characteristics may be functional, organoleptic or nutritional, e.g., fats may permit incorporation of air into a cake batter, provide texture and taste to a candy bar or supply appropriate balance of dietary fatty acids. Fats and oils have long been recognized as required nutrients in human and animal diets. They provide, in addition to essential fatty acids, a concentrated source of energy; they also transport fat-soluble vitamins. Although an appreciable portion of dietary carbohydrate and some protein can be converted metabolically to fat, certain fatty acids such as linoleic acid are essential and must be supplied by the diet. These factors frequently are overlooked in countries where average caloric intake exceeds caloric requirements.

TRIGLYCERIDE COMPOSITION

Nearly all foods and many food ingredients contain fat, which is present principally in the form of triglycerides, and to a lesser extent, in the form of other molecular species, e.g., partial glycerides, fatty acids and sterols. The level of fat ranges from a fractional percentage, as in skim milk, to a value approaching 100% as in salad oil.

The glyceride structure and composition of fats present in such foods also differ widely. Differences in triglyceride structure and composition can be seen using a combination of analytical methods. For example, using fats from several foods or ingredients and employing programmed temperature gas chromatographic techniques, the distribution of triglycerides differing in molecular size by as little as one methylene group can be readily determined (Fig. 1).

The numbers above each peak represent the number of carbon atoms in the combined fatty acid groups present in triglycerides under the peak. The area under the peak approximates the quantity of triglyceride present and includes geometric and positional isomers not only of triglycerides but also of the fatty acids comprising the triglycerides.

Further insight into the molecular composition of fats can be obtained from the fatty acid composition. In Table I, the major fatty acids which differ by two or more methylene groups and by the number of double bonds are expressed in terms of weight percent (wt %) composition.

These kinds of data can be further refined with existing methodology to differentiate positional and geometric isomers of both fatty acids and triglycerides.

It is reasonable to assume that the physicochemical properties of such fats differ markedly and that the functional characteristics of foods and food ingredients which contain even modest levels of fat are, in part, imparted by the properties of such fats. Winterized cottonseed oil which is high in triunsaturated triglycerides contains little or no solids over the temperature range shown in Table II whereas cocoa butter, being high in disaturated-monounsaturated triglyceride and containing its saturates in the 1,3-position, has a high percentage of solids at 92 F and below, but none at 100 F. Butter oil, which contains a large number of triglycerides of varying molecular weight, exhibits a broad

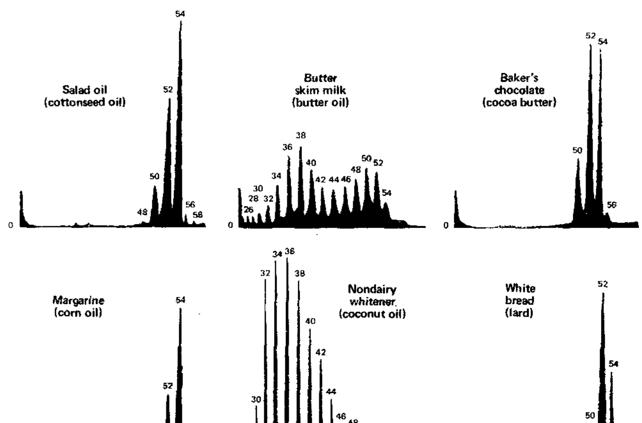


FIG. 1. Triglyceride distribution.

TABLE I

Fatty Acid Composition (wt %)

Food	Fat (%)	4:0	6:0	8:0	10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3	Other
Salad oil	Winterized cottonseed (100)						11	22	3	18	55		1
Margarine	Corn oil + hard stock (80)							11	7	33	47	1	1
Butter	Butter oil (80)	4	2	1	2	3	12	26	13	28	3		6
Chocolate	Cocoa butter (57)							26	35	35	3		1
Coffee whitener	Hydro-coconut (35)			8	6	49	18	8	10	1			
White bread	Lard (4)						2	25	12	45	10		6
Skim milk	Butter oil (1)	4	2	1	2	3	12	26	13	28	3		6

TABLE II

Fat	Predominant triglyceride	Solid fat index (F)					Fat type
		50	70	80	92	100	
Winterized cottonseed oil	Triunsaturated	0	0	0	0	0	Liquid
Cocoa butter	Monounsaturate disaturated	82	78	66	4	0	Hard butter
Butter fat	Mixed	33	14	10	3	1	Plastic

solid fat index (SFI) profile. These compositions and properties are typical of liquid oils, hard butters and plastic fats, respectively. Differences in physicochemical properties such as those illustrated by SFI account for the large range of functional, organoleptic and nutritional properties of foods and food ingredients which contain even modest levels of fat.

The relationship between triglyceride composition and end use characteristics is obvious if one considers key physicochemical properties as the connecting links. It should follow, then, that fats with similar key physicochemical properties, even while differing widely in triglyceride composition, will provide an approximation of the desired functional properties in the end use system.

Thus, the formulation of fat systems for foods and food ingredients may be accomplished in two ways: first, by replication of triglyceride composition of the desired fat system and second, by approximation of the physicochemical properties desired. Before discussing these two methods of formulating functional fat systems in detail, consider the sources of dietary fat.

SOURCES OF DIETARY FAT

Dietary fats are categorized as "visible" or "invisible." Visible fats are defined as those which have been isolated from animal or marine tissue, oilseeds, nuts or other vegetable sources, and are used to produce, e.g., shortenings, margarines and salad oils. Such fats are used "as is" (e.g., table margarine) or are formulated into a complex food (e.g., shortening as an ingredient in a cake mix). Invisible fats are defined as those which have not been isolated from their original source and are, therefore, consumed as part of the tissue in the diet. Invisible fats are contributed principally by meat, fish, poultry and dairy products consumed as such. Visible fats are unique dietary sources, in that subsequently applied processing techniques may be used to modify the composition to meet desired physicochemical properties and functional requirement of the end use system. This is in contrast to invisible fats, in which modification is essentially limited to genetic development of new strains.

Soybean oil continues to lead in world production of vegetable fats and oils with a 1979/80 crop year production of 14.8 million metric tons. Therefore, this oil continues to exert a major influence on the formulation of fat systems for food and food ingredients.

Consider now an in-depth look at the two methods of formulating functional fat systems and the utilization of soybean oil in such formulations.

REPLICATION OF TRIGLYCERIDE COMPOSITION

This approach to formulation requires qualitative and quantitative knowledge of the triglyceride composition and of individual molecular structures comprising the fat system of interest. This approach further assumes that triglyceride sources with the appropriate molecular structures are available or can be synthesized from available intermediates and that the desired triglycerides can be isolated in sufficient purity to permit blending with other triglycerides in order to replicate the desired composition at a competitive cost.

Although the characterization of triglyceride composition is possible, complete characterization is tedious and requires a well equipped laboratory. Of greater significance is the limited availability, often at very high cost, of alternative fat sources containing the desired triglyceride structures. Of equal importance is the lack of commercial technology for converting readily available triglycerides such as 1,2-dioleostearin (SOO) and 1,2-dioleopalmitin (POO) present in soybean oil to more valuable 2-oleodistearin (SOS) and 2-oleopalmitostearin (POS) without extensive formation of geometric and positional triglyceride isomers. Included here are recent attempts to produce such fats from readily available intermediates using directed synthesis.

Finally, because alternative source fats contain other triglyceride structures which are unwanted, the desired triglycerides must be separated from the mixture. In the process, one or more by-products may be created.

Approaches to formulation of fat systems based on replication of triglyceride compositions have achieved some commercial success, principally limited in scope and application to cocoa butter equivalents.

Extensive utilization of this approach to formulation with a readily available, low-cost commodity oil such as soybean oil requires the development of economic commercial processes for upgrading triglyceride structures to more valuable isomers.

APPROXIMATION OF PHYSICOCHEMICAL PROPERTIES

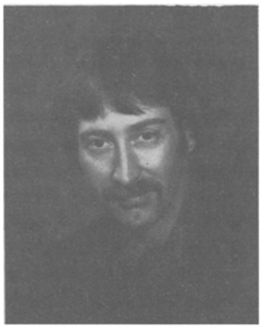
The quickest approach to the formulation of fat systems requires identification of the key functional attributes the fat system is expected to provide to the end use system, and the use of historical knowledge to identify those physicochemical properties which are likely to produce the intended functionality; e.g., the primary functional attribute of coffee cream is to whiten coffee. Secondary attributes may include consideration of flavor, appearance, stability and nutrition. If one wished to produce a coffee whitener derived from vegetable oil, historical data would acknowledge that the physicochemical properties of hydrogenated coconut oil meets fully the primary functional attribute. Secondary requirements are met at least in part. Indeed, coffee whiteners formulated from hydrogeanted coconut oil have been successfully manufactured and marketed for years. Although the triglyceride compositions of butterfat and hydrogenated coconut oil resemble each other little, both fat systems have key physicochemical properties conducive to meeting the primary and, in part, the secondary functional characteristics.

It is important to recognize and to identify key primary and secondary functional attributes and to disregard physicochemical differences which are unimportant to the end use system, when employing this approach to the formulation of fat systems. The utility of this technique is further enhanced when employed to develop new fat systems based on commodity oils such as soybean oil. Using this system, at least one manufacturer has developed a fluidized coffee whitener from soybean oil in which the primary functional attribute (whitening) exceeds that of either butter fat or hydrogenated coconut oil; at the same time, secondary characteristics are equivalent to the desired functional attributes.

A wide range of products has been commercially produced from soybean oil. Key to the efficient utilization of this approach to formulation of new fat systems is the use of experimental design for the systematic evaluation of physicochemical properties as modified fat systems in meeting key primary and secondary attributes. Although triglyceride composition is important to both approaches in product formulation, physicochemical evaluation offers more than one potential solution to the equation. Until a broader range of source-oil triglycerides becomes economically available or until processing technology is developed which will permit modification of triglycerides in existing commodity oils to more valuable triglyceride structures, approximation of physicochemical properties will be the preferred route to formulation of fat systems.

FUTURE

Efforts to broaden the scope and application of formulations based on replication of composition will be increased. Both new processing technology and new source oils will contribute to this increase. However, application will continue to be economical only for scarce, highly functional triglycerides. In the foreseeable future, fat systems based on low-cost commodity oils formulated to meet functional characteristics, rather than compositional criteria, will dominate.



Effects of Processing on Quality of Soybean Oil

R.T. SLEETER, Archer Daniels Midland Co., 4666 Faries Parkway, Decatur, IL 62526

ABSTRACT

The fate of major and minor components of soybean oil is examined at each stage of processing. Relationships are then drawn upon the effect on the quality of finished oil. General topics covered are (a) triglycerides and polyunsaturated fatty acids, (b) free fatty acids, (c) mono- and diglycerides, (d) phospholipids, (e) minor constituents, such as tocopherols, color bodies, and metal ions, (f) rearrangement and decomposition products, (g) foreign or toxic compounds not native to soya and (h) other additives, such as refining aids.

INTRODUCTION

Soybean oil processing technology dates to the 1930s for food use in the United States. Yet, it seems that we learn more precisely how processing affects the oil as each year passes. Basic processing techniques have not changed much. Crude oil is degummed, refined, bleached and deodorized. Each year, minor modifications in techniques are introduced. For example, deodorizers are now built with a heat exchange tray so that the heat from the deodorized oil may be used to heat incoming, nondeodorized oil. This saves energy and is less abusive to the oil.

This paper was written to pull together and summarize various aspects of refining techniques on quality of the resultant oil. For the sake of clarity, each refining term will be defined. Crude soybean oil is generally hexane-extracted, desolventized and filtered. Degumming removes phosphatides. This step is performed by adding water to warm crude oil followed by centrifugation to remove the gummy, hydrated phosphatides. Refining lowers free fatty acid content. Degummed or crude oil is heated and sodium hydroxide solution is added. The mixture is centrifuged to