Milk Fat Technologies and Markets: A Summary of the Wisconsin Milk Marketing Board 1988 Milk Fat Roundtable

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ABSTRACT

The Wisconsin dairy industry has initiated development of a coordinated research program to increase the marketability of milk fat. In September 1988, the Wisconsin Milk Marketing Board invited 15 researchers from industry and academia to a milk fat round table. This meeting had three goals: 1) to assess current technologies used to process milk fat; 2) to identify the technological needs for advanced milk fat manipulation; and 3) to determine the research priorities required to fulfill these needs. The round table identified research priorities for milk fat, calling for the development of research data in the following areas: milk fat ingredient functionality, milk fat fermentation, milk fat fractionation and cholesterol removal, milk fat health issues, control of milk fat composition, and economic data on milk fat derivatives.

INTRODUCTION

In late 1986, representatives of the dairy and related industries participated in The National Workshop on Research Opportunities for the Dairy Industry. The objective of this workshop was to identify those areas of research offering the greatest potential to improve the market for dairy products (1). The structure of small group meetings followed by an assembly of all participants encouraged active input during what is now referred to as the Berkeley Workshop. The Berkeley Workshop suggested the formation of a close alliance between nutrition research and product research. This alliance is most necessary in the milk fat arena. Given the position of several national health organizations, the US Surgeon General, and other government agencies, the message being sent to the American consumer is to reduce the percentage of calories from fat in the diet. Market projections indicate that the growth of milk SNF will continue to exceed the market growth for milk fat. Thus, new markets must be developed for this component of milk. The challenge to the dairy industry is to provide viable, competitive food products containing milk fat and to position them in a manner consistent with the nutrition education messages the consumer is receiving.

The results of the Berkeley Workshop have been used for planning purposes by several organizations including the six recently established Dairy Food Research Centers. That workshop also served as the starting point for a major project sponsored by the Wisconsin Milk Marketing Board (WMMB) and coor-
ordinated and administered by the National Dairy Council (NDC). This effort, known as the Bridge Project, was designed to link nutrition research formally with the various disciplines involved in the marketing of milk and dairy foods. After an independent task force of nutrition scientists identified dietary fat, cholesterol, and health as the most crucial nutrition issue facing the dairy industry, this issue became the focus of the Bridge Project.

The Bridge Project

The Bridge Project brought together an independent, multidisciplinary steering committee of experts to conduct a thorough examination of research information in the areas of public opinion, nutrition research and education, and dairy product development as related to the marketing of milk and other dairy products. The work of the steering committee and three expert panels enlisted to review relevant data resulted in a set of recommendations to the dairy industry for addressing the fat and cholesterol and health issue in a positive and proactive manner. The wealth of information resulting from the Bridge Project is available to the dairy industry as a data base to provide direction as it plans future promotion and product development efforts.

Milk Fat Round Table

As the Bridge Project neared completion, WMMB invited 15 researchers from industry and academia to participate in a round table discussion on milk fat technology. The participants' disciplines included lipid chemistry, engineering, economics, flavor chemistry, dairy science, dairy processing, microbiology, and nutrition. The Milk Fat Round Table established three goals: 1) to assess current technologies used to process milk fat; 2) to identify the technological needs for advanced milk fat manipulation; and 3) to determine the research priorities required to fulfill these needs.

Milk Fat Technology

Milk Fat Round Table participants identified chemical hydrolysis, interesterification, triglyceride and fatty acid distillation, crystallization, randomization, cis/trans-isomerization, hydrogenation, dehydrogenation, and polymerization as established technologies, many with full FDA approval. Several of these technologies are in use in the vegetable oil and margarine industry as well as in the European dairy industry where a surplus of milk fat has been an issue for several years.

Essentially, a triglyceride of nearly any composition can be fabricated using these technologies. Given the unique composition and board range of fatty acids in milk fat, the opportunities for exploitation are extensive. For example, triglycerides of milk fat can be hydrolyzed and reesterified chemically or biochemically such that specific fatty acids are placed in specific positions on the glycerol chain or on any other molecule with an esterifiable hydroxyl group. The functional requirements of the lipid component or product being formulated will influence the decision of which technology is most suitable for supplying the milk fat ingredient. If the objective is simply to provide a fat with a given fatty acid profile, with no regard to functionality or nutrition, a simple blend may be all that is required. However, if specific functional and nutritional properties are part of the objective, then the processing may require more sophistication.

Computer modeling to provide predictive functionality is developing, primarily in Europe, but has limited application. Ideally, a product developer could be given the physical, chemical, and nutritional specifications required of a fat for end product formulation. Through a cataloging process, the product developer could then describe the performance specifications of the fat and set about making it, based on least cost analysis. This ingredient could then be used in the end product formulation.

Conversely, the product developer could be given an analysis of a fat and predict where it could be modified or used directly for the best economic return. Today, the application of interesterification is in the vegetable oil
industry in a manner similar to that just
described. In some cases, the system enables
the processes to be introduced directly at pro-
duction levels, thus avoiding the problems
with scale-up.

This reesterification process need not be
limited to glyceride synthesis. Nearly any
compound with a free hydroxyl group can be
substituted for the glyceride. Innumerable
functional properties could be created under
this concept. Sucrose polyester is but one
well-known example. Many other products
could be made in food and nonfood areas.
Milk fat, as a source rich in certain fatty acids
found in only small amounts in vegetable oils,
possibly could find new markets via esterifi-
cation of this sort, but little basic research has
been conducted.

Milk Fat and Nutrition

Milk fat offers a variety of ingredient pos-
sibilities through chemical or biochemical
modification or fractionation of its compo-
nents, but its nutritional components should
not be overlooked. It is said that "consumer
perception is marketing reality". Today's con-
sumer is subjected to conflicting messages
that lay the guilt for many chronic afflictions
at the doorstep of dietary cholesterol and sat-
urated fat. These messages create the illusion
that milk fat contains nothing more than sat-
urated fat and cholesterol. These misconcep-
tions are the result of attempts to oversimplify
dietary fat messages to the consumer. During
the many years that have passed since these
messages were first issued, tremendous levels
of new nutritional research data have been
generated for the variety of components in
fat. This new research begins to clarify, qual-
itatively and quantitatively, the relationship
of certain fat components to certain diseases.

Fat should no longer be described simply
as saturated or polyunsaturated, but con-
sumer food product labels continue to make
this sole distinction. Fat can contain short,
medium, or long-chain, saturated, monoun-
saturated, omega-3 or omega-6 polyunsatu-
rated, trans-isomer fatty acids, and more.
Each of these classes of fatty acids elicits
unique physiological responses. Moreover,
these physiological responses are not com-
pletely understood and may vary from indi-
vidual to individual according to genetic
expression or phenotype.

Food labels currently are not allowed by
law to make distinctions except those that fall
within the narrow definition of saturated or
polyunsaturated fat. Milk fat, with its high
proportion of long-, medium-, and short-
chain saturated fatty acids, yields an unat-
tractively low ratio of polyunsaturates to satu-
rates, whereas a hydrogenated vegetable oil
possibly containing 50% trans isomers may
show a very favorable polyunsaturate:
saturate (P:S) ratio. These ratios cannot be
adequately described by today's labeling reg-
ulations. Furthermore, a high P:S ratio may
be perceived as desirable relative to coronary
heart disease but may not be so relative to
other serious chronic conditions such as dia-
etes, some cancers, and immune functions.
Again, the consumer is not receiving com-
plete information.

Similarly, the position of milk fat in the
total diet is generally falsely perceived by the
consumer. In the average US diet, milk fat
provides only 10 to 15% of the average dietary
fat and approximately 12% of the dietary cho-
lesterol. Research studies that employ milk
fat as the sole fat in an experimental diet and
go on to form conclusions on the effects of
milk fat in a traditional, multisource fat diet,
may be misleading and a disservice to the
industry and the consumer. Likewise, other
experiments have been conducted to study
the effect of saturated fat diets using only
tropical oils. The negative health findings of
these experiments were extended to milk fat
by inference rather than direct testing. In real-
ity, the fatty acid patterns of milk fat and
tropical oils are quite different. The consumer
should be given information regarding the
health implications of milk fat, in contrast to
"generic" saturated fat consumption in the
context of the total diet.

Great effort is underway to develop simple
messages that accurately portray the com-
plete lipid composition of foods. This effort
needs continued attention and support if it is
to be successful. Labeling laws, amended to
portray the fat composition of foods more
accurately, should be accompanied by bal-
anced health claims. If health benefits are to
be claimed, then the negative aspects of any particular ingredient must also be stated. Information of this sort will influence consumer purchasing behavior, and in turn, the formulation of products, as market-driven food manufacturers respond to consumer preferences for nutritious and healthy food choices.

At WMMB's Milk Fat Round Table, participants were asked: from a nutritional perspective, what kind of fat is the "ideal" fat that could serve as the target for milk fat modification? And as cost and functionality components are devised for an “ideal” designer fat, what are the nutritional goals that should be met? The general opinion from WMMB Round Table members for an ideal nutritional fat, based on current dietary recommendation, was: less than 10% polyunsaturated fatty acids, including the omega-3 and omega-6 and up to 8% saturated fatty acids, with the rest being monounsaturated fatty acids.

**Cholesterol Issue**

In spite of the observation that, within usual intakes, dietary cholesterol is poorly correlated with plasma cholesterol in many people, the typical consumer continues to equate the two. Thus, cholesterol-reduced products have found a market. One approach to a cholesterol-reduced product is via some form of fractionation. A solvent-based fractionation technology emerging in the fat and oils industry is supercritical fluid extraction. Carbon dioxide serves as the solvent, eliminating any concerns over residual contamination. Current WMMB research is directed toward cholesterol removal from milk fat. Included in this research will be economic projections of scaleup, capitalization, and operating costs. A milk fat so processed could yield a cholesterol-reduced milk fat fraction with applications in a great variety of foods. A small fraction that is very rich in cholesterol could find application in the cosmetic and pharmaceutical industries.

Other methods to reduce cholesterol in milk fat are being developed.

**Milk Fat Modification and Biochemical Technology**

Researchers and nutritionists at WMMB's Milk Fat Round Table discussed supercritical fluid extraction and progressed to a discussion of biochemical technology. The first technology described was enzymology. Enzymes offer tremendous variety and specificity and are inherently safe. The challenge in nearly every potential application is to identify and characterize the enzyme or enzyme systems and find a source of the enzyme for production quantities. Lacking an economical enzyme source, genetic information can be extracted, cloned, and recombined with the DNA of an organism that could produce production quantities of the enzyme, or the organism itself could serve as the fermenting organism.

Next, the reactor must be constructed. The reactor may take a variety of forms, such as immobilized cells or immobilized enzymes in continuous or batch systems. Also, two or more enzyme systems may be coupled. For example, specific hydrolysis may be coupled with a reesterification of the glycerol along with a flavor precursor or another molecule that adds a desired flavor to the fat. Other processes, such as biodehydrogenation, elongation, flavor production using methyl ketones or esters, ether linkages for pharmaceuticals, and cholesterol reduction, are being investigated now and should be exploited if feasible. Round table researchers noted that very little is known about lipid metabolism of starter cultures. This area has biotechnology potential for applied research, especially in the fermentation of creams, and should be explored.

Fractionation technologies, based on melting point, molecular weight, sensitivity to detergents, and solubility properties, have potential application for developing value-added products. Generally, the problem of residual solvent would dampen interest in solvent extraction. Nevertheless, solvent separation to yield a narrow milk fat fraction for experimental work is a useful tool. If a fraction is identified to be of special value for a particular application, other means of separation may be employed in the final production.
A relatively simple example of the fractionation of milk fat through crystallization is now being used in Europe. This process yields both butter oil, containing lower melting point triglycerides, and a hard fraction. It appears that the position of fatty acids on the triglyceride is more important than the overall fatty acid profile in determining melting points.) The soft fraction has export market potential in the Middle East, India, and Africa, while the hard fraction is used primarily by the baking industry.

It is conceivable that as certain components of milk fat distinguish themselves as more marketable than other components, cows could be genetically engineered to produce a milk relatively rich in the more marketable components at the expense of the less marketable components. The use of transgenic animals for this purpose is in its infancy but can be expected to make great strides as the chemists learn more about milk fat components.

**Market Specifications for Milk Fat Ingredients**

It is well-known that milk fat is not uniform from source to source. Feed, breed, environment, and other factors all influence the composition of milk fat. In some cases, specific novel applications for milk fat or milk fat fractions may require and build a demand for a standardized uniform base material. For example, the baking industry has definitive product specifications for an item such as a cookie. If the milk fat used in the manufacture of the cookie varies in its solid fat index, the resultant product may not consistently meet these set specifications, causing losses in production. In this example, the value of the milk fat could be increased by employing proper technology, such as randomization or fractionation, which would provide greater uniformity. The solution may be one of these process technologies or the solution may rest in controlled milk production, where feeding or environmental factors are manipulated. Potential dairy ingredient applications of these technologies are currently being explored, including: replacement of cocoa butter, improved compatibility with confections, tropical oil replacement (especially for flavor contributions), and polymerization to less digestible fats for reduced-calorie product formulations. These technologies could also yield isolation of specific fatty acids via hydrolysis and distillation, as well as products for pharmaceutical uses and development of natural flavorants.

It is technically feasible that milk fat could be "designed" for specific product uses if the selected technical skills identified were to be refined and directed to milk fat applications. The question remains: what are the target applications and the specific milk fat compositions desired? To answer this question, round table researchers recommended that the industry should catalog the physical, chemical, and functional properties of all permutations and combinations of triglycerides made from the fatty acids available in milk fat. At the same time, the special functional advantages of fatty acids from nondairy sources that may be combined with the functional advantages of milk fat could be cataloged. The dairy industry should direct substantial basic research toward this effort.

Developing milk fat products for the sophisticated and diversified food industry demands an ability to describe these products analytically. Analytical tools should be fast, inexpensive, and accurate. Milk fat ingredients have a greater potential for application if equipment costs and product development demands are minimal. Basic research, correlating triglyceride composition to product functionality, is needed before analytical tests can be useful. That is, if a test measures the composition, we must be able to translate that measurement to functional performance.

Analytical equipment and procedures could be developed by forming strategic alliances between dairy research, promotional organizations, and equipment manufacturers. Current experiences in the food packaging industry could serve as an initial model. Much of the basic technology exists, but this technology needs to be adapted to the dairy industry.

**Finding New Markets for Milk Fat**

Use of milk fat as an ingredient is often cost-driven. The greatest obstacle in creating
products that are price competitive is the artificial value placed on milk fat by the USDA. Until a new pricing system for milk is implemented, the marketability of milk fat derivatives will be held in check. Nevertheless, milk fat derivatives can provide a variety of improved functions, offsetting part of the raw material costs. Milk fat derivatives can provide texture in pastries, compatibility in confections, flavor in cheese powders or beverages, moisture barriers in refrigerated or frozen foods, and controlled flavor generation in dry baking mixes. Other functions that milk fat derivatives can provide include microbial inhibition in refrigerated foods, control over ice cream crystallization (allowing ice cream to become softer and colder), improved milk characteristics in microwavable foods, and stabilization of toppings.

The rapidly growing food service industry has special ingredient needs for clinical settings. Patients desire good flavor and texture but may need foods with modified saturated fat and cholesterol content. As America’s population ages during the next decades, dietary needs for the elderly must also be addressed. The elderly have a reduced energy requirement and possibly poor dentition and sensory capabilities. Spreadable foods are desirable as motor skills decline in older and handicapped individuals.

Milk fat derivatives offer functions for the pharmaceutical industry. These uses and products include encapsulation, potential antitumor agents such as ether derivatives of milk fat, cosmetics, dietary supplements, and structured lipids (interesterification to construct a specific triglyceride for clinical applications).

Round table participants noted that nondigestible fat substitutes are on the horizon. Undoubtedly, some milk fat will be displaced by these fat substitutes. However, new opportunities for milk fat fractions will arise. These new fat substitutes have associated side effects, flavor defects, and other limitations in their application. With no history of safety, quality, or functional performance to back these substitutes, adoption may be slow. Also, legal obstacles may delay their use. Researchers at the Round Table concurred that fat substitutes are not perfect ingredient substitutes. Their adoption may provide a market for milk fat-derived, value-added products used in combination with these fat substitutes. These applications may even extend into new markets.

Another important role for milk fat derivatives is cholesterol reduction. As mentioned earlier, “consumer perception is marketing reality”. Today’s consumer perceives that dietary cholesterol is harmful. Products bearing statements such as “no cholesterol” or “reduced cholesterol” have a marketing advantage. Round table members agreed that research to reduce cholesterol in milk fat is justified. Processes include supercritical fluid extraction, steam stripping, adsorption, enzymology, and fermentation. Economics will dictate which technology or combination of technologies will be employed for each application. The US population perceives a need to restrict consumption of some dairy products, despite the fact that many dairy foods fall into the low cholesterol classification proposed by the FDA. Consumer research shows that purchase decisions today are based first on cost, then taste, convenience, and nutrition. However, nutrition and attention to labeling are expected to become top purchasing issues as the population matures and as current dietary recommendations are adopted as part of a health-conscious lifestyle. Individuals are being encouraged to have their plasma lipid status assessed. Those identified as sensitive to dietary fat or cholesterol may prove to be a smaller group than is currently thought, but as group, they are highly motivated to seek foods that will meet their dietary needs.

CONCLUSION

Improving milk fat technologies to meet food industry ingredient needs and the needs of a changing consumer population will require coordinated research programs. Round table members suggested the following coordinated effort: commitment to the support of research (including personnel, facilities and equipment); advanced information exchange capabilities; a skilled technology transfer system; multidisciplinary approaches to the problems including economics, nutrition, food science, engineering, and dairy science;
and a concerted effort by academic resources across the country. The opportunities for milk fat are clear. The Bridge Project has assessed views from consumers and nutritionists and described current nutrition axioms. Round table participants have defined applications and markets for milk fat components employing a variety of technologies. The next step is to coordinate research to explore these technologies and to offer a new generation of milk fat products to the food processing industry and ultimately the consumer.

Summary of Research Priorities for Milk Fat

Suggested research priorities are:
1) to develop a catalog that relates triglyceride composition and physical properties to functionality; 2) to conduct basic research to relate functionality to traditional dairy applications such as cheese and frozen desserts, as well as nondairy applications, including confections, baked goods, fat substitutes, fresh refrigerated and frozen foods, convenience foods and special food service diets; 3) to develop a basic understanding of milk fat fermentation by starter cultures. Follow this with selection, recombinant DNA, or other approaches to improve the application of cultures to milk fat utilization.
4) to continue to develop technology for removal of cholesterol from milk fat; 5) to elucidate further the relationship between milk fat and health;
6) to conduct basic research on the means to modify milk fat composition by way of genetic engineering of the bovine mammary gland; and
7) to develop economic data that accurately reflect the true value of milk fat derivatives.

REFERENCES