Commercial Utilization of Minor Milk Components in the Health and Food Industries

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ABSTRACT

Whey has gained a great deal of respectability in the US during the past 5 to 10 yr as an ingredient in many food and dairy products. However, its value as a resource for many medically active components is not recognized in this country as it is in Japan and Europe. This paper reviews the minor components in whey and the potential for commercial application.

Individual whey components of significance include α-lactalbumin, β-lactoglobulin, bovine serum albumin, immunoglobulins, lactoferrin, and lactoperoxidase. Whey is also a good resource for lactose and lactose derivatives such as lactulose, lactitol, and oligosaccharides. Other minor milk components of biological significance include milk salts and components related to casein.

Many of these components exhibit biological activity that is valuable in nutraceuticals or antimicrobials. Commercial utilization in the US is compared with that of other countries.

(Key words: milk, milk components, health)

INTRODUCTION

This paper presents suggested areas of research to enhance the utilization in the US of the minor milk components that are recovered from whey, a by-product of cheese making.

Table 1 shows the most common terminology for the major components of milk. Each component has "milk" as the identifier, which ties the component to this naturally healthful product. Our discussion is about the minor rather than the major components, so the immediate question is a definition of "minor". Is minor <1, <.5, or <.1% on a total weight basis? Or some measure as a percentage of the solids? Or something else? No definition is imposed in this paper, which includes discussion of some derivatives of the major component, lactose (milk sugar), which was discussed by S. T. Yang in this symposium (9), but, generally speaking, the minor components have promise if the requisite research and development are carried out. Most major components are, in fact, made up of a series of minor components.

Milk Fat

Milk fat, which was discussed by K. E. Kaylegian in this symposium (5), comprises mono-, di-, and triglycerides, a series of fatty acids, cholesterol, milk fat globule membrane, and phospholipids. Milk fat globule membrane and phospholipids actually show up in whey and have interesting properties (e.g., emulsification and skin softening) that could be exploited in time. However, because this discussion deals with existing commercial utilization, milk fat globule membranes and phospholipids are simply noted as products that may be worth exploring more closely by the US research establishment. Phospholipids thus far have a mostly negative history with respect to highly functional whey protein concentrates and isolates because they interfere with foaming and gelation properties and their removal is preferred or even necessary.

Milk Proteins

The components that make up the milk proteins are of rapidly growing importance for nutritional as well as functional applications. They are listed in Figure 1.

Although some exciting work is being done on the medical uses of the individual casein

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TABLE 1. Milk components.

Component	(%)
Milk fat	≈3.5
Milk proteins	≈3.5
Milk sugar	≈5.0
Milk salts	<1.0
Subtotal	≈13.0
Water	≈87.0
Total	100.0

components and related compounds [(8); J.-L. Maubois, personal communication, 1994], and although commercial products are emerging, much more meaningful information will be able to be presented in a year or two. Thus, the casein portion of the milk proteins is not discussed.

Soluble milk proteins, or whey proteins, and the NPN remain in whey when milk is converted to cheese plus whey. The terminology "soluble milk proteins" has a more positive connotation for the consumer and thus is more desirable for use on labels. For example, the use of whey protein concentrates and isolates has been blocked from a number of upscale ice creams and other dairy products; manufacturers will not put whey on the label because it connotes something negative or puzzling. I have suggested to the pertinent trade association that "soluble milk protein" ought to be cleared as the official terminology, but the time and money to be spent in getting this done probably precludes any change away from use of the word "whey" related to these protein products.

Milk Sugar

Normally, lactose is thought of as being *the* milk sugar. There are, however, very small amounts of other carbohydrates or saccharides (especially oligosaccharides) present, and those minor components are included in the present discussion.

Milk Salts

Milk salts represent the unique combination of minerals found in milk. Sometimes significant amounts of sodium and chloride are found because some of the table salt used in salting certain types of cheese drains with the whey. The milk salts represent a disposal problem when left behind when products such as lactose are removed from whey.

Others

Other minor components of milk include citric acid, sialic acid, and, in whey, lactic acid. The most valuable of these are discussed.

DISCUSSION

Milk Proteins

The known commercial utilization of individual protein components from milk, but recovered from whey after cheese making, are summarized in Table 2. All current usage is outside the US, and, until the efficacy is proven in the US, usage in the US is not expected.

The production of lactoferrin in the milk of transgenic animals is being pursued because some people think that the colostrum from such animals will be a less expensive source of lactoferrin than whey. Lactoferrin is present in much higher concentrations in the new colostrum. The cost saving has yet to be proved, especially if the whey is sent for the manufacture of other profitable products after the lactoferrin is extracted.

Casein
- α-, β-, and κ-casein and casein-related compounds, including casomorphine compounds

Soluble Milk Proteins (Whey Proteins)
- α-Lactalbumin
- β-Lactoglobulin
- Bovine serum albumin
- Immunoglobulins
- Lactoferrin
- Lactoperoxidase

NPN
- Polypeptides and proteose-peptones
- Free amino acids
- Urea
- Glyco- and macropeptides

Figure 1. Minor protein components of milk.

TABLE 2. Commercial utilization of individual soluble milk proteins.

Component	Properties	Uses	Where used	
			US	Elsewhere
α-Lactalbumin (with bovine serum albumin and immunoglobulins)	Nutrition	Infant formula	No	Yes
Lactoferrin	Antibacterial	Infant formula	No	Yes
Lactoperoxidase	Anticaries	Toothpaste	No	Yes
Growth factor	Stimulates mammalian cell growth	Growth of human skin and lung cells	No	Yes

Proving the efficacy of lactoferrin might at first appear to be simple, because lactoferrin exists in human breast milk. However, extreme caution is exercised by the governmental agencies whose role it is to protect consumers from bogus medical claims; gaining acceptance of efficacy can be complex and slow.

The commercial sale of a protein growth factor for mammalian cells is signaled by two Australian research organizations with the cooperation of the producing dairy company and the distributor of the product (4).

Possible commercial uses of individual protein components are shown in Table 3. Some β-lactoglobulin is being used commercially in Japan, most likely for its gelling properties, but the purity involved and the exact end use have not yet been identified. A hindrance to the use of β-lactoglobulin in the US is its price. As those making whey protein concentrates and isolates have found, attractive functionality and nutritional properties must be accompanied by attractive prices or the uses languish. A price of $22/kg for β-lactoglobulin probably is too high. The prices of whey protein concentrates with 80 to 90% protein are dropping from $7 to 10/kg to $4.50 to 8.80, and the prices of whey protein isolates are dropping from $12 to 14/kg to $10 to 12.

One really exciting item to note in Table 3 is the potential anticancer property of some milk components. These properties have been arbitrarily assigned to the immunoglobulins, bovine serum albumin, or both, but one or both of them are responsible for the promising behavior being studied in Australia and Canada (1, 2, 3). The purity required to get the effect is not known publicly. Because the immunoglobulins and bovine serum albumin occur with α-lactalbumin in the main whey fractions now being produced in Australia and France, the α-fraction may be the practical product with anticancer properties. The role of the Dairy Research Laboratory, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, is of particular note because that laboratory has conducted the developmental work on recovering the protein growth factor mentioned.

The question of efficacy of the immunoglobulins and bovine serum albumin is similar for the other important property listed

TABLE 3. Possible commercial utilization of individual soluble milk and whey proteins.

Component	Properties	Uses
β-Lactoglobulin	Gelling	Restructured meats and fish.
	Solubility and nutrition	Clear sports and dietetic beverages.
Immunoglobulins and bovine serum albumin	Anticancer	Cancer prevention and treatment.
	Enhanced immunity	Diets for persons who are, HIV-positive, have AIDS, or otherwise compromised immune systems. Diets for athletes.

TABLE 4. Commercial utilization of selected lactose derivatives.

Component	Properties	Uses	Where used	
			US	Elsewhere
Lactulose	Bifidobacteria enhancement	Infant formula	No	Yes
	Laxative	Laxatives	No[1]	Yes
	Oxygen uptake, ammonia reduction in blood	Diet for athletes	No[1]	Yes
	Suppresses ammonia production in intestine	Drug against chronic portal systemic encephalopathy	No[1]	Yes
	Ammonia reduction in blood	Drug against hepatic encephalopathy	No[1]	Yes
Lactitol	Bifidobacteria enhancement	Infant formula	No	Yes
	Noncaloric sweetener	Chewing gum	No	Yes
Lactobionic acid	Bifidobacteria enhancement and other health-related uses	Various	No	Yes
Oligosaccharides	Bifidobacteria enhancement	Infant formula,	No	Yes
		baby foods,	No	Yes
		other foods (yogurt, etc.)	No	Yes

[1]Requires prescription.

in Table 3, enhanced immunity. This property could be especially exciting for persons who are HIV-positive (human immunodeficiency virus) or have AIDS (acquired immune deficiency syndrome) because of their need to stave off opportunistic diseases—something probably being researched in this country as well as in Canada and perhaps Europe.

Interestingly, there is an exception to all the highly scientific proof of efficacy that is needed badly for the nutritional and medical uses of the minor components of milk. Whey proteins are used in diets of body builders, weight lifters, and other high intensity athletes. For this population, various whey protein concentrates and isolates are viewed as not only being good for building tissue and muscle, but also being helpful in preventing colds and flu when extreme and frequent exercise lowers the normal level of defensive immunity (7). Of course, scientific proof would enlarge the health food market enormously, but even the pull of high energy diets alone could prove to be a very effective mover of whey proteins and derivatives such as hydrolysates (peptides and peptones). Even the individual proteins would be included if their prices were acceptable.

Milk Sugars

Natural oligosaccharides exist in milk in very minor concentrations. These oligosaccharides are not yet commercially available.

Sialic acid, a carbohydrate placed in the milk sugar category for convenience, is produced commercially in Japan and is used in infant formula because it is thought to improve growth of brain and other mammalian cells (T. Kimura, personal communication, 1994). As for nearly all of the minor components mentioned, its utilization has been initiated in Japan. Scientific proof of efficacy does not yet exist.

In a discussion of milk sugars, lactose cannot be ignored even though it is a major, not minor, component of milk. Lactose also is in large oversupply in the world, thanks primarily to the development of whey protein concentrates and to the reasonably steady growth of cheese consumption. In the US, I have estimated that approximately 410,000 tonnes/yr of lactose are generated when whey protein concentrates are made. Of this, perhaps 82,000 tonnes go to the manufacture of edible lactose, 55,000 tonnes are left in the lactose mother liquor (which is sold, given away, or wasted), and a maximum of 45,000 tonnes go to the manufacture of ethanol and other products, leaving at least 230,000 tonnes/yr of unused lactose in permeate per year.

The Japanese and Europeans have found interesting derivatives of lactose that are used for their health-related properties. The commercially available derivatives identified for this discussion are summarized in Table 4. Lactulose and lactitol were described at an

TABLE 5. Commercial utilization of milk salts.[1]

Component	Properties	Uses	Where used	
			US	Elsewhere
Mixture of milk salts recovered from whey UF permeate	Flavor	Table salt substitute	No	Yes
	Nutrition	Health drinks	No	Yes

[1]Salts from whole whey are available as a table salt substitute.

International Whey Conference in October 1986 in Chicago, but are not used much in this country (although lactulose may possibly now be in an infant formula). These derivatives seem to have a long voyage before they find acceptance, although the USDA is trying to commercialize a new continuous process for making lactulose (6) and is developing a process for lactobionic acid.

Japan clearly has a governmental system set up for approving products with health benefits that are not in the pharmaceutical category. The European Union is trying to come to terms with such products. The US is lagging in this regard. In Canada, lactulose is treated as a "behind the counter" drug. A prescription is not needed, but the customer must ask for the product by name and purpose; it is not sold "over the counter".

Milk Salts

What about the mix of minerals from milk that now wind up in such abundance in whey UF permeate? Much interest has been expressed in getting a return for them.

Table 5 indicates even more examples of commercial utilization of the minor components of milk that do not yet exist in the US. An exception is the company, previously noted for a table salt substitute recovered from whole whey (probably dried mother liquor from lactose manufacture), that may have switched to using permeate as the source, and, for a time, one US whey processor supplied mother liquor from permeate lactose manufacture to Japan for use in nutritional beverages. The countries most active in use of the milk salts appear to be Japan and Finland.

Production Amounts of Minor Components of Milk

To give further perspective on the status of the commercial utilization of the minor components in milk, Table 6 shows estimates of the current annual production of three of the milk and whey protein products. Production of whey protein concentrates and whey protein isolates is included for reference as to both their major or minor status and the maturity of the markets. None of the three individual protein products is manufactured yet in the US.

As much as 18,000 tonnes of the lactose derivatives lactulose, lactitol, lactobionic acid, lactose-derived oligosaccharides, and lactosucrose are now manufactured each year. As far as is known, none is produced in the US. This situation could change in the next few years if the efficacies were proven. The first move may be by the Dutch company, Purac, which has requested GRAS (generally recognized as safe) status for lactitol, but for use as a noncaloric sweetener and not as an enhancer of bifidobacteria.

The manufacture of milk salt products probably totals <230 tonnes/yr; there is little or no production in the US.

CONCLUSIONS

If the health-related benefits of the minor components of milk reviewed here are really as important as they are said to be, some evaluation of efficacy in this country is logically needed. The values of several of these compo-

TABLE 6. Estimated worldwide production of whey protein products.

Products	(tonnes/yr)
Whey protein concentrates (34 to 85% protein)	>140,000
Whey protein isolates	≈2,300
α-Lactalbumin (50 to 90% pure)	≈230
Lactoferrin	<11
Lactoperoxidase	≈2.3

- Determine extent of efficacy of whey proteins as anticancer agents and determine which are key and what purity is needed.
- Determine extent of efficacy of whey proteins as immune system enhancers and determine which are key and what purity is needed for preventing the common cold and flu and for patients with life-threatening diseases.
- Obtain agreement from US medical establishment on positive role of lactulose, lactitol, and lactobionic acid in enhancement of bifidobacteria in the gut.
- Determine role of series of oligosaccharides in health and nutrition (bifidobacteria enhancement and antibacteria).
- Determine role of sialic acid in cell growth, especially brain cells.

Figure 2. Areas suggested for research to define efficacy of minor milk/whey components and to enhance utilization.

nents are such that they could reward cooperative farmers with attractive dividend income that could become quite significant during times of low farm gate milk prices. Market estimates should be made that quantify the potential income of selected products to farmers so that the return on efficacy can be assessed.

A list of areas suggested for research related to efficacy is given in Figure 2. Some of this work might be done in collaboration with overseas laboratories already pursuing it because competitive issues for supply may not be a hindrance.

Obviously, the anticancer and immunity-enhancing properties are complex and very expensive to pursue. However, the potential payoffs for the dairy industry in terms of the reputation of milk are such that these topics should not be ignored.

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