Milk and dairy products as food materials

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Europe with a long and proud tradition of dairy farming is about 105% self-sufficient in dairy products. This paper has been developed to answer the questions: (1) Should Europe continue to consume a high level of dairy products? (2) Should Europe remain self-sufficient in dairy products? (3) If the answers to 1 and 2 are 'yes', is any change required in Europe's attitude towards the use of dairy products?

There are four principal reasons why any food commodity should be included in the diet: nutritive value, organoleptic attributes, local availability and cost compared with alternatives.

Nutritive value of Milk

Because milk is capable of sustaining growth on its own, it is often regarded as a complete food. While this is not strictly true it is the most nearly perfect natural food available; 'only the whole carcass of an animal, including bones and liver, could contribute as much as milk, taken as a single food' (Kon, 1972). The nutritive value of milk is well recognized and widely reported (Kon, 1972; Porter, 1975; Anon, 1971; Rusoff, 1970; Davis, 1974; Phillips & Briggs, 1975). The value of milk in relieving malnutrition, especially among the young, in developing countries is particularly noteworthy.

While milk and dairy products do supply energy (cheese yields as much energy as sugar on weight basis), their main nutritional benefit is as a source of protein, calcium phosphate and some vitamins. The percentage of total dietary protein supplied by milk and dairy products ranges from 2–5% in South-east Asia to 30–35% in Northwest Europe (Abbott, 1966). According to Yudkin (1976), liquid milk supplies 10% of the energy, 20% of the protein, 90% of the calcium, 45% of the riboflavin and 25% of the vitamin A of the average UK diet; cheese, cream, dried and concentrated milks make further significant contributions. The contribution of dairy products to the US diet is somewhat less (Rusoff, 1970). The value of milk as a source of dietary calcium is particularly striking (Phillips & Briggs, 1975).

Not all recent references to the nutritive value of milk and dairy products have been favourable. The most serious allegations have been made against high-fat dairy products as a possible risk factor in cardiovascular disease (CVD). However, major, non-dietary CVD risk factors are now acknowledged (Anon, 1976) and whole or skim milk is reported to be hypercholesterolaemic (Howard, 1977). Lactose intolerance is widespread throughout the world except among populations of Northern European descent and certain Nigerian tribes (Rosensweig, 1969), but

most individuals adjust to lactose in the diet if it is introduced gradually, probably due to changes in intestinal flora (Kretchmer, 1972; Reddy & Pershad, 1972) and many lactase-deficient patients can consume relatively large amounts of lactose without displaying symptoms of lactose intolerance (Reddy, 1973). The Protein Advisory Group of the UN consider that on the basis of present information it is inappropriate to discourage milk consumption by non-white populations. A small proportion of children are allergic to cows' milk, presumably to the protein fraction, resulting in such diseases as eczema, asthma, ulcers, hay fever, migraine and sinusitis which are frequently relieved by replacing cows' milk by goats' milk.

Organoleptic attributes and availability

The organoleptic attributes of food are very much a matter of personal preferences but in north-western Europe dairy products are at least generally acceptable and in many cases are highly valued dietary items, particularly liquid milk, fermented milks, cheeses and ice creams, Dairy products are readily available throughout north-western Europe which is generally well suited for dairying. Mediterranean countries are less well suited and supplement local production with imports from north-western Europe.

Cost

Of the various forms of animal agriculture, the dairy cow is the most efficient convertor of plant material into food (Hodgson, 1971). Its significance is all the greater because the cow does not require concentrate feed although dairying as practised in much of Europe and North America depends heavily on concentrates. Satisfactory milk yields may be obtained from cows fed only on grass (fresh or conserved) and cattle are capable of utilizing non-protein nitrogen (e.g. urea) for much of their nitrogen requirements. Thus dairy cows need not compete with man for cereal products and produce satisfactorily on land unsuitable, or only marginally so, for arable farming.

Protein is the limiting nutrient on a world scale and comparison is frequently made of the efficiency of animal and plant agricultural systems as means of supplying mankind with a diet adequate in protein. The soya bean far outpaces any alternative currently available as a means of producing protein (Pagington, 1975) and it might be concluded that soya beans offer the solution to the protein problem; however, the soya bean is a fastidious plant and produces good yields only in parts of the USA, Asia and South America. Thus if Europe wishes to have an independent food supply, the soya bean is not really relevant. Milk compares favourably as a means of protein production with crops grown in Europe on a large scale, e.g. wheat; this is particularly so when the yield of essential amino acids rather than crude protein is used as the criterion, e.g., dairy cows yielding 700 gal/acre at 3·5% protein produce 20 lb lysine and 7 lb methionine/acre while wheat at 2 tons/acre yields only 8 lb lysine and 7 lb methionine/acre.

Milk has a further major advantage over other food commodities, versatility and flexibility. Milk and dairy products are used as ingredients in a wide range of foods

with both functional and nutritional considerations in mind; no other food group possesses the same versatility.

Taking all these considerations into account, a good case can be made for expanding the European dairy industry which might occur by: (1) expanding markets for traditional dairy products, (2) developing new dairy or mainly dairy products, (3) expanding the use of milk and dairy products as ingredients for non-dairy foods.

Traditional Products

Results from IDF (1977*a*) show considerable regional differences in the *per capita* consumption of dairy products in Europe: liquid milk 53·6 to 242·8 kg; fermented milks 1·7 to 35·4 kg; cream 0·06 to 2·39 kg; butter 0·4 to 13·1 kg; cheese 2·8 to 15·4 kg. The average *per capita* consumption for Europe, calculated from the IDF results, is: liquid milk 92·6 kg; fermented milks 7·3 kg; cream 0·8 kg; butter 6·8 kg; cheese 9·7 kg. If consumption could be increased to the highest national average, the increase in total European consumption would range from 158% for cheese to 483% for fermented milks. These targets are high but may not be too unrealistic. Consumption in Finland is already close to the highest national average in all cases and with the exception of cheese, Ireland ranks high also; obviously these dairy products are not mutually exclusive. The ready availability of high quality products at competitive prices, supported by effective advertising, is a major controllable factor influencing consumption. Other factors like tradition and sociology may be rigid but by no means unalterable as evidenced by the remarkable increase in the popularity of yoghurt throughout Europe, even in countries with no tradition of such products, and by the rapid expansion of dairying in Spain.

New Dairy Products

The need to expand milk utilization through the development of new dairy products is well recognized. There is no shortage of ideas for new dairy products (Mann, 1971*a*, 1972, 1977; IDF, 1977*b*) but few of these have come to commercial fruition. Major new products include casein coprecipitates, undenatured whey protein, UHT products and milk-based desserts.

The development of casein precipitates, reviewed by Fox (1968), Muller (1971), Southward & Goldman (1975) and Richert (1975), occurred mainly in Australia during the 1960s. Advantages of coprecipitates compared with casein are higher yield, a more nutritious protein and a greater range of functional properties, but in spite of wide claims for applicability the product has had limited commercial success to date. Only a little of the 5×10^8 lb of whey protein available annually is recovered, as heat-denatured lactalbumin which is insoluble in water, has very limited functional properties and limited application. Recently developed methods for producing undenatured whey proteins include precipitation with various polyelectrolytes, gel filtration, ultrafiltration and reverse osmosis (Fox, 1978). The functional properties of undenatured whey protein are satisfactory, (McDonough, Hargrove, Mattingly, Posati & Alford, 1974; Delaney, 1976) and many food

applications have been suggested. The product is available only in limited amounts which appear to be finding application.

Lactose has many applications in the food industry but only 10% of the available whey is used for lactose production (Ash, 1976). The potential market for lactose *per se* appears to be limited by cost and functional characteristics but there is considerable interest in the production of glucose-galactose syrups by hydrolysis of lactose with β-galactosidase (Shukla, 1975) or by acid (Coughlin & Nickerson, 1974; Haggett, 1976; Vujicic, Lin & Nickerson, 1977; Lin & Nickerson, 1977; Short, 1977).

UHT-treated products have been the outstandingly successful new dairy product of recent times and UHT milk is rapidly replacing HTST milk in mainland Europe (Regez, 1977; Leonard, 1977). The UK and Ireland have shown little interest in changing to the UHT process, probably because of the availability of high-quality HTST products and daily door-to-door deliveries. The availability of UHT milk should increase consumption in southern Europe and perhaps in remote areas elsewhere, where good HTST milk has not been available heretofore. UHT processing also creates the possibility of large-scale movement of liquid milk within the traditional dairying areas of Europe, e.g. from the low-cost to high-cost regions. Markets for UHT milk are being developed by some European countries in Arab and African countries. Other UHT products, notably coffee cream, whipping cream, dairy-based desserts (custards, mousses), flavoured milks and fermented milks, have also been successful.

Modifications of existing dairy products have had considerable commercial success; in this case, a market has already been established and the introduction of an improved product facilitates marketing. Low or non-fat milk has been very successful in the USA and some European countries at the expense of whole milk. Modifications of skim milk powder (instantly soluble, heat classified, heat stable, fat filled, protein enriched, lactose enriched, demineralized, etc.) have also been successful.

Butter represents 35% of the 16m tons of milk fat produced world-wide annually (Hake, 1977) but because of poor spreadability, high cost and nutritional considerations butter consumption is declining. Apart from modifying the crystalline structure of milk fat, three other approaches are used to modify its melting characteristics: (1) fractional crystallization and separation (Fjaervoll, 1970; Norris, 1973; Sherbon, 1974; Wilson, 1975; Jebson, 1976); (2) feeding protected polyunsaturated lipids to cows, pioneered by Scott, Cook, Ferguson, McDonald, Buchanan & Loftus-Hills (1970), successfully modifies the physical properties of milk fat (Kieseker, 1975; Kieseker & Eustace, 1975) and increases its content of polyunsaturated fatty acids simultaneously but is expensive and the simplest, cheapest and commercially most successful approach is (3) blending of butter and vegetable oils. Bregott (80% fat–80% milk fat and 20% soya-bean oil), introduced in Sweden in 1969 has been very successful (25% of the Swedish market for dairy spreads; Zillen, 1977). Similar products have been test-marketed in Australia (Hehir, Fegan & Singh, 1975). Present legislation in most countries

forbids such products but it appears likely that in time they will become universally accepted.

Interest in low-fat dairy spreads dates from World War II but the first successful product, containing 25 or 40% fat and 18·2 or 16·8% skim milk powder, was produced on a laboratory scale by Bullock (1966), Bullock & Kenney (1969) and Bullock, Thomas & McKnight (1971). Latt & Lagom (39–41% fat composed of 60% butter oil and 40% soya-bean oil emulsified in concentrated buttermilk), launched in Sweden in 1974, enjoys 20% of the Swedish market for spreads (Zillen, 1977).

Simulated whipping creams, based on vegetable fats and caseinates, have made significant inroads into the market for traditional dairy whipping creams, because of lower cost, uniformity of whip, longer shelf life. Natural creams are subject to legal standards of identity which offer little scope for product improvement and standardization but the investigations of Min & Thomas (1977) into the physical properties of "synthetic" dairy whipped toppings are of interest.

Instant whole milk powder (lecithinated) is now commercially available. Although the product has some flavour defects it appears to have a viable future. Frozen yoghurt on a stick (lollipop) was recently introduced in the USA with considerable initial success. Other examples of new or modified dairy products include spray-dried butter and cream; flavoured butter and similar spreads; whey-based beverages; fruit-flavoured yoghurts; milk-based custards and desserts; modified cheese products. It should be apparent that there is scope for product innovation and modification within the traditional range of dairy products. However, the dairy industry will have to adopt a more flexible attitude towards the use of milk and be prepared to accept some non-traditional ideas such as the addition of non-milk constituents to milk and its products.

Milk and dairy products as ingredients in non-dairy foods

Milk and dairy products are traditional ingredients in home cooking. Liquid milk is used in a variety of bakery and confectionery products, custards, puddings and other desserts, as a whitener for tea and coffee and on ready-to-eat cereal products. The British Milk Marketing Board (personal communication) estimates that only 15% of 'liquid milk' sold in the UK is actually consumed as a beverage. Butter is widely used in bakery products, as a garnish for vegetables and is regarded as a superior cooking fat. It appears reasonable to assume that essentially all cream is consumed as a component of other foods: whipped toppings for desserts, dressings, fillings for bakery products and as a coffee whitener. The principal use of cheese in many countries is as a sandwich filler and as major ingredient or condiment in the preparation of cheesecake; pizza pie; lassagna; as flavouring for spaghetti, potatoes, soups, etc; sauces for fish, potatoes and vegetables. While the use of milk and dairy products in composite foods is obviously desirable from a nutritional viewpoint, functional characteristics, including flavour, are likely to be more significant.

With the development of industrial food processing and the widespread

acceptance of convenience foods, it became desirable to simulate home-produced foods in the factory. This has been done successfully in many cases and in addition to traditional outlets a range of new applications for milk products has been developed. Apart from nutritional considerations perhaps the most important attribute of milk as an industrial food ingredient is the ease with which it can be fractionated into its principal components by relatively simple, large-scale mechanised techniques. However, milk does suffer a major price disadvantage against alternatives; some of this is artificial, due to the pricing policy of certain trade blocks. A second disadvantage arises from the overly protective legislation pertaining to dairy products which frequently places the dairy industry at a disadvantage in competition with other food commodities.

Milk and dairy products are used in literally hundreds of composite foods (Fox, 1978); only the principal applications are summarized here.

Dehydrated Products

Production of dehydrated dairy products reached major proportions only after World War II (for production statistics see Hall & Hedrick, 1971 and Meat & Dairy Produce Bulletin, 1976). Almost all major dairy products are commercially available in dehydrated form, usually spray-dried, and most are now readily available with tailor-made characteristics.

According to Hall & Hedrick (1971), 70% of the whole milk powder (WMP) consumed in the USA is used in the confection industry with minor quantities used in bakery products and soups. Although statistics are lacking, it appears that most of the WMP produced in Europe is consumed in beverage form, much of it as baby food, or exported.

Skim milk powder (SMP) is used in large quantities by food processors in a range of applications although it is facing increasing competition from whey powder, soya protein and whey-soya blends, due mainly to price factors. According to Hall & Hedrick (1971) the principal uses of SMP in the USA are bakery, domestic applications and other dairy products which together represent 80% of total US consumption. Data from Wolnak (1974) show a similar pattern. Equally comprehensive data are not available for Europe but according to Wolnak (1974) only 10% of total SMP production in the EEC (1·688m tons in 1972) went to human consumption, the vast majority going to the manufacture of animal feed. It would seen desirable that better use should be made of SMP in human nutrition and for economic reasons it appears unlikely that Europe can continue to give SMP to livestock. Most bread will benefit nutritionally and functionally from the use of 4% SMP in the dry mix but considerably more may be used in some bakery products (Kinsella, 1971). In the USA most bread contains some SMP but very little is used by the European bakers. Skim milk powder is a good emulsifier for meat products (Pearson, Spooner, Hegarty & Bratzler, 1965) and also improves flavour and nutritive value; as a meat extender, SMP is facing stiff competition from soya products which probably now dominate that market. Other uses for

SMP include ice creams, soups, synthetic whipping and coffee creams, reconstituted liquid or concentrated milks and humanized baby formulations.

While most recent attention on the utilization of whey has focused on the production of undenatured whey proteins, there have been considerable developments in the use of whey powders (WP) in foods. Here also progress has been greater in the USA than in Europe. In 1973, 40% (300 000 tons) of available whey in the US was dried of which 50% was used in human foods (Wolnak, 1974), principally baked goods (100 000 tons), frozen dairy foods (90 000 tons) and processed cheese (50 000 tons). Total WP production the EEC in 1972 was 309 000 tons (projected to increase to 1m tons by 1980) but only 20 000–30 000 tons were used for human consumption (Wolnak, 1974).

Lactose

Among sugars, lactose has many atypical characteristics (Nickerson, 1974) some of which are problematic in food processing, others being advantageous. The amount of lactose potentially available from whey is about 5×10^9 lb but only 10% of this is actually manufactured (Ash, 1976). Probably the principal uses of refined lactose are in the pharmaceutical industry; food applications include: baby food; free flowing agent; agglomerating or instantizing agent; candy, fudges, caramels, bakery products, flavour enhancement, texture and colour improvement (Webb, 1966, 1970; Potter & Zaehringer, 1965; Hofstrand, Zaehringer & Hibbs, 1965; Guy, 1971; Reger, 1958; Welch, 1965; Ash, 1976; Yabumoto, Jennings & Pangborn, 1975; Nickerson & Dolby, 1971; Goller & Kube, 1974; Jelen & Breene, 1973; Tybor, Dill & Landmann, 1973). The advantages of lactose in many of these applications are low sweetness, hygroscopicity, reducing capacity and its ability to absorb trace amounts of flavours. Developments in the preparation of glucose-galactose syrups from lactose have been discussed.

Milk Proteins

Lactalbumin. Traditional lactalbumin is produced commercially only in The Netherlands and New Zealand. Because of its poor functional properties its use is limited to protein fortification of such foods as sausage, other comminuted meats, breakfast cereals, certain types of breads and confectionery and roller-dried baby foods (O'Sullivan & Delaney, 1972; Jelen, 1975; Robinson, Short & Marshall, 1976; Jelen & McIntyre, 1977).

Undenatured whey protein. Based on its high nutritive value and good functional properties, a wide range of applications have been suggested for undenatured whey protein: baby foods (humanized milk) (Forsum, 1974); dietetic and thereapeutic foods (Delaney, 1976); protein supplementation of a wide range of foods and drinks (Wingerd, 1971; Holsinger, Posati, De Vilbiss & Pallansch, 1973; Seibles, 1975; Schoppet, Sinnemon, Talley, Panzar & Aceto, 1976; McDonough, Alford & Womack, 1976); textured protein (Jaynes & Asan, 1976); soft cheeses; egg white substitute (de Boer, de Wit & Widdink, 1977).

Casein and caseinates. World production of casein is fairly static at about

120 000 tons per annum, half of which is produced by New Zealand. The principal importing countries are the USA (45 000 tons) and Japan (20 000 tons). The application of casein in foods has been increasing rapidly: 20% of output in 1967 (Fox, 1968), 35% in 1970 (Mann, 1971*b*), 50% in 1973 (Wolnak, 1974). Poarch (1967) estimated that at least 26 products on the US market contained caseinates; human consumption of casein has quadrupled since and probably many more products contain it. Many outlets for caseinates was described by Mann (1971*b*) but comminuted meats, dietary products, coffee whiteners, desserts and toppings are the principal products (Wolnak, 1974). The benefits of caseinates in these products are described by Pearson *et al.* (1965), Hermansson (1975), Hermansson & Akesson (1975*a*,*b*), Knightly (1968) and Miller (1968). There has been rapid expansion in the USA in the production of 'synthetic' cheeses based on casein. Substantial growth in the use of functional proteins in foods is predicted by Hammonds & Call (1970) and Wolnak (1974) but prospects for soya are considered more favourably than those for caseinates, mostly from cost considerations. Approximately 112 000 tons of functional protein were used in human food in Europe in 1973 of which casein and caseinates represent 17 000 tons, used principally in meat products (Wolnak, 1974).

Casein coprecipitates. Coprecipitates with a wide range of functional properties are available but in spite of high praise, these products have not become well established to date. Low calcium coprecipitates may be substituted for caseinates or skim milk powder in many applications, frequently with superior results. Among the numerous applications suggested are: protein enrichment of breakfast cereals; manufacture of carbohydrate-free infant food; Australian milk biscuit; bakery products; meat products; snack foods; egg substitute for bakery goods (Fox, 1978).

Butter

Butter is used industrially as an ingredient in a variety of foods but for cost reasons it is at a major disadvantage against alternative fats; accurate data on the utilization of butter in foods are difficult to obtain. Bakery products (Guy, 1970) and ice cream are probably the principal applications; others include candy (Webb, 1970), sauces for canned vegetables (Weckel & Huang, 1968) and flavoured butter products (Lang & Lang, 1970). Attempts to produce butter and butter products better suited for non-dairy applications include better fractionation (Jebson, 1974; Tucker 1974) and the manufacture of butter powders (Mann, 1968). Anhydrous butter oil may replace butter in certain applications and is widely used with skim milk powder in the manufacture of recombined milk products.

In summary, it is clear that dairy products are important ingredients in composite food products. It would appear that greater use could be made of SMP from both nutritional and functional viewpoints, especially in the bakery industry; it is difficult to justify the widespread use of this product as animal feed. The use of whey powder, which has a cost advantage over SMP and for which it can substitute in many cases, will probably increase. Judging by developments in the

USA and Japan there is scope for expanded use of caseinates in Europe although competition from soya products and SMP makes expansion difficult. The market for undenatured whey protein is largely untried but there appear to be at least limited possibilities. The outlook for lactose and lactose derivatives is probably brighter at present than for some time but prospects depend on the price of sucrose and perhaps more importantly on developments in the production of glucose-fructose syrups from starch. Except in abnormal circumstances the potential for milk fat as a food ingredient appears limited because of cost considerations although it may be a superior fat from the organoleptic viewpoint.

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