Lipophilic Microconstituents of Milk

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Abstract  Milk has long been recognized as a source of macro- and micro-nutrients, immunological components, and biologically active substances, which not only allow growth but also promote health in mammalian newborns. Many milk lipids, lipid-soluble substances, and their digested products are bioactive, including vitamins and vitamin-like substances. Vitamins A, E, D, and K and carotenoids are known as highly lipophilic food microconstituents (HLFMs), and all occur in milk. HLFMs also include phytosterols, which, although they are not vitamins, are nevertheless biologically active and present in milk. Fat-soluble micronutrients, including fat-soluble vitamins, are embedded in the milk fat fraction, and this has important implications for their bioaccessibility and bioavailability from milk. In fact, the fat component of milk is an effective delivery system for highly lipophilic microconstituents. The vitamin content of animal products can be enhanced by increasing the feed content of synthetic or natural vitamins or precursors. An advantage of augmenting milk microconstituents by animal nutrition rather than milk fortification is that it helps safeguard animal health, which is a primary factor in determining the quality, safety, and wholesomeness of animal-origin foods for human consumption. The milk fat delivery system offers numerous possibilities for exploitation by nutritionists. For example, the payload could consist of enhanced levels of several micro-nutrients, opening possibilities for synergic effects that are as yet incompletely understood.

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Z. Bősze (ed.), Bioactive Components of Milk.
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Introduction

In recent years consumers have begun to look at foods not just for basic nutritional requirements, but also for health benefits. As a result, the concepts of “functional foods” and “nutraceuticals” have been developed, which focus on foods or the bioactive components of foods that promote health and well-being.

Milk is a remarkable source of macro- and micronutrients, immunological components, and biologically active substances, which not only allow growth but also promote health in mammalian newborns. Many milk lipids, lipid-soluble substances, and their digested products are bioactive, including triacylglycerides, diacylglycerides, saturated and polyunsaturated fatty acids, phospholipids, vitamins, and vitamin-like substances. Vitamins A, E, D, and K and carotenoids are known as highly lipophilic food microconstituents (HLFM), meaning that their octanol–water partition coefficients \(\log p_c\) are greater than 8. HLFMs also include phytosterols (Borel, 2003), which, although they are not vitamins, are nevertheless biologically active. Small quantities of phytosterols are present in milk (Brewington et al., 1970; Goudjil et al., 2003). In what follows, we consider the roles of this broader category of milk microconstituents.

Milk as a Source of Highly Lipophilic Microconstituents

It has long been known that milk fat is a major source of lipid-soluble vitamins. The lipid-soluble vitamin composition of various milks and some dairy products is shown in Table 1. In bovine milk, the fat-soluble vitamin content is known to vary with breed, parity, physiological state (e.g., pregnancy, lactation), production level, and health status (Baldi, 2005; McDowell, 1989; Nozière et al., 2006a, b). Other factors, such as nutritional state and amount and type of forage, can affect the vitamin E and A (and \(\beta\)-carotene) content, while the vitamin D and K content of cow’s milk is influenced by the animal’s exposure to direct sunlight, the quantity of sun-cured forage in the diet, and the functional state of the rumen (McDowell, 1989, 2006).

The vitamin A (retinol) concentration of bovine milk ranges from 0.28 to 0.92 mg/L (Lindmark-Månsson & Åkesson, 2000). Vitamin A is mainly present in milk in esterified form. The mammary gland takes up retinol derived from the liver, esterifies it, and outputs it to milk (Tomlinson et al., 1974). Other sources of milk vitamin A are retinol esters derived from dietary \(\beta\)-carotene and dietary retinol.

Milk also contains carotenoids, mainly \(\beta\)-carotene (see below), which yield vitamin A by cleavage of the centrally located double bond. Because there are losses during \(\beta\)-carotene absorption and conversion, normally 6 \(\mu\)g of \(\beta\)-carotene are required to yield 1 \(\mu\)g of retinol equivalent. However, absorption of \(\beta\)-carotene from milk is particularly efficient; only 2 \(\mu\)g of \(\beta\)-carotene