Nutrition Research Reviews, page 1 of 19 doi:10.1017/S0954422417000191

In vitro and *in vivo* antioxidant potential of milks, yoghurts, fermented milks and cheeses: a narrative review of evidence

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Abstract

The antioxidant potential (AP) is an important nutritional property of foods, as increased oxidative stress is involved in most diet-related chronic diseases. In dairy products, the protein fraction contains antioxidant activity, especially casein. Other antioxidants include: antioxidant enzymes; lactoferrin; conjugated linoleic acid; coenzyme Q_{10}; vitamins C, E, A and D_3; equol; uric acid; carotenoids; and mineral activators of antioxidant enzymes. The AP of dairy products has been extensively studied *in vitro*, with few studies in animals and human subjects. Available *in vivo* studies greatly differ in their design and objectives. Overall, on a 100 g fresh weight-basis, AP of dairy products is close to that of grain-based foods and vegetable or fruit juices. Among dairy products, cheeses present the highest AP due to their higher protein content. AP of milk increases during digestion by up to 2·5 times because of released antioxidant peptides. AP of casein is linked to specific amino acids, whereas β-lactoglobulin thiol groups play a major role in the AP of whey. Thermal treatments such as ultra-high temperature processing have no clear effect on the AP of milk. Raw fat-rich milks have higher AP than less fat-rich milk, because of lipophilic antioxidants. Probiotic yoghurts and fermented milks have higher AP than conventional yoghurt and milk because proteolysis by probiotics releases antioxidant peptides. Among the probiotics, *Lactobacillus casei/acidophilus* leads to the highest AP. The data are insufficient for cheese, but fermentation-based changes appear to make a positive impact on AP. In conclusion, AP might participate in the reported dairy product-protective effects against some chronic diseases.

Key words: **Dairy products: Antioxidant potential: *In vitro* antioxidant activity: *In vivo* antioxidant activity: Processing**

Introduction

The antioxidant activity of foods is important for both their shelf life and protection from oxidative damage in the human body. Increased oxidative stress is involved in the onset of most age/diet-related chronic diseases[1,2]. Therefore, antioxidant activity has been considered an essential nutritional property[3]. Its expression within the human body depends on the structure of the food matrix and density of food antioxidants, which both depend on the processing conditions, ultimately having an impact on the antioxidant bioavailability. Many *in vitro* assays have been proposed to estimate the antioxidant capacity of food. However, each method is based on different oxidoreduction reactions, yielding heterogeneous antioxidant potentials, as observed with the method used for milk[4].

Overall, the antioxidant potential has been more widely studied in plant-based foods than in animal-based foods[5,6]. Probably the main reason for this is the lower average antioxidant potential of animal-based foods as compared with plant-based foods, i.e. on average 64-fold less[6]. Thus, although being an important part of various diets worldwide, the antioxidant potential of dairy products has rarely been systematically measured[6,7]. The most comprehensive study is that by Carlsen *et al.*[6] who measured antioxidant potential of eighty-six dairy products among more than 3100 foods, beverages, spices, herbs and supplements used worldwide. In addition, in epidemiological studies, the antioxidant potential of dairy products has not been investigated as the primary explanation for some of their protective effects, for example, against weight gain, type 2 diabetes, some CVD and some cancers[8].

Dairy products contain antioxidant compounds in varying proportions depending on the matrix type (i.e. milks, yoghurts, fermented milks and cheeses) and processing (i.e. mechanical, thermal and fermentative). These compounds include both lipophilic and hydrophilic antioxidants: proteins (especially casein), peptides, antioxidant enzymes (i.e. superoxide dismutase (SOD), catalase and glutathione peroxidase), conjugated linoleic acid (CLA), coenzyme Q_{10}, lactoferrin, vitamins (C, E, A and D_3), carotenoids, some minerals and some trace elements[7,9] (Fig. 1). According to Grażyna *et al.*[7], the antioxidants in milk act in synergy by forming an antioxidant network, imparting high antioxidant potential to milk and effectively protecting milk fat against oxidation. In addition, although this is not a direct focus of the present review, the

Abbreviations: ABTS, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); ATCC, American Type Culture Collection; CLA, conjugated linoleic acid; CUPRAC, cupric-reducing antioxidant capacity; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric-reducing ability of plasma; ORAC, oxygen radical absorbance capacity; SOD, superoxide dismutase; TBARS, thiobarbituric acid-reactive substances; TE, Trolox equivalents; UHT, ultra-high temperature.

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