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REVIEW ARTICLE

Antioxidant properties of dairy products fortified with natural additives: A review

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Abstract Antioxidant is a molecule that inhibits the oxidation of other molecules caused by free radicals. Antioxidant activity of a dairy food is important both for the shelf life of the product as well as for protection from oxidative damage in the human body. The objective of this work was to demonstrate the effects of natural antioxidants (plant-based sources) against synthetic antioxidants in dairy food.

1. Introduction

Natural products and health foods have to be given a lot of interests for enhancing overall well-being, in the prevention of diseases and also in the incorporation of health-promoting substances into the diet as natural food additives. Newly, the valorization of underutilized foods has more priority because of their antioxidant potential (Marles and Farnsworth, 1994; Prasad et al., 2012).

Consumers have more concerns and recommendations to use natural antioxidants from food sources rather than synthetic antioxidants which have been restricted because of their toxic and carcinogenic effects (Zambonin et al., 2012; Abdel-Hameed et al., 2014). Many epidemiological studies reported that the frequent consumption of high natural antioxidant containing foods could lower the incidences of particular types of cancers, hypertension, diabetes, and cardiovascular diseases, especially, in developing countries where most people have limited resources and access to modern treatments (Marles and Farnsworth, 1994). Dairy products are one of the most interesting and promising foods with regard to their potential antioxidant activity, due to their wide diversity of antioxidant molecules such as milk caseins and whey proteins (Pihlanto, 2006; Suetsuna et al., 2000). Furthermore, milk contains a variety of antioxidant molecule traces i.e. low molecular weight thiols (Niero et al., 2014, 2015), ascorbate (Nielsen et al., 2001), tocopherol, retinol and carotenoids (Jensen and Nielsen, 1996; Nozière et al., 2006).

Medicinal plants rich in natural antioxidants and phenolics are progressively applied in dairy foods manufacturing to improve nutritional and therapeutic properties (Shori and Baba, 2011a,b; Karaaslan et al., 2011; Martins et al., 2014; Bertolino et al., 2015). Natural plant-based antioxidants can be used to control the excess formation of free radicals and increase the antioxidant capability as well as replace synthetic antioxidants with side effects like liver damage and carcinogenesis (Meenakshi et al., 2009). Therefore, this mini-review focused on antioxidant activity of dairy products in which synthetic and natural antioxidants were incorporated.

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2. Antioxidant activity (AA) in dairy foods

Niero et al. (2016) reported that a high total antioxidant activity was found for partially skimmed milk (29.31–44.72 μmol l^{-1} TE, 22.65–41.43 μmol l^{-1} TE) in contrast to whole milk (24.15–43.05 μmol l^{-1} TE, 19.44–39.80 μmol l^{-1} TE) both for UHT and pasteurized samples (Table 1). As a consequence of the skimming process, partially skimmed milk was deprived of diverse lipophilic antioxidants (e.g. retinol, tocopherol and carotenoids), milk soluble fraction, however, contained other powerful antioxidant compounds (e.g. ascorbate, thiols, whet proteins) (Niero et al., 2016; Walstra et al., 2005). In another study, Santos et al. (2013) stated that the addition of grape residue silage in the diet cows in order to transfer its phenolic compounds to the milk exhibited antioxidant activity of 44.6 mg GAE l^{-1}. The addition of grape residue was thought to decrease the oxidation of milk fat which was enriched in unsaturated fatty acids due to dietary soybean oil supplementation. In fact, the transfer of some phenolic compounds to milk of dairy cows is low. For instance, ferulic acid has a recovery rate of 0.02 g 100 g^{-1} of the administered dosage (Soberon et al., 2012). Transferring high concentrations of phenolics to milk is not preferred to inhibit lipid oxidation (Sies and Stahl, 1995) as the suitable proportion between concentrations of antioxidant compounds and those of unsaturated fatty acids may be important (Granelli et al., 1998).

Antioxidant activity in dairy products supplemented with various plants is summarized in Table 1.

Shori (2013) studied the impact of soybean supplementation to improve the antioxidant and the viability of lactic acid bacteria in cow- and camel-milk yogurts during refrigerated storage. They observed that the antioxidant activity of *Glycine max* L. (soybean) supplemented camel milk yogurt had the highest antioxidant activity on day 7 of storage (67.59 ± 1.4%) and reduced to 61.56 ± 1.4% on day 21 of storage ($p > 0.05$) (Table 1). The antioxidant activity of soybean-cow milk yogurt showed significant reduction during 21 days of refrigerated storage to 35.29 ± 1.0%, while it was 58% on 7 days. The addition of soybean into yogurts prepared from either cow or camel milk enhances the viability of lactic acid bacteria and antioxidant activity during refrigerated storage. The antioxidant properties of soybean associated to isoflavones and polyphenolic compounds (Sroska and Cisowski, 2003; Kim et al., 2006; Slavin et al., 2009), as well as, milk protein proteolysis (Lourens-Hattingh and Viljoen, 2001) and organic acids production (Correia et al., 2005).

The antioxidant activities in fresh camel milk yogurt (15.4 ± 1.3%) were lower than cow milk yogurt (26.4 ± 0.7%). A yogurt formation with the addition of *Allium sativum* significantly increased the antioxidant activities in both cow milk yogurt (37.9 ± 0.8%) and camel milk yogurt (26.1 ± 0.8%) (Shori and Baba, 2011b). *Allium sativum* extracts were stated to have the ability to scavenge different radicals (Bhagyalakshmi et al., 2005; Pedraza-Chaverri et al., 2006) via sulfur, phenolic, flavonoid, and terpenoid compounds present in the mature garlic bulbs (Miller et al., 2000; Nuutila et al., 2003; Bozin et al., 2008). The presence of *Allium sativum* during milk fermentation affected antioxidant activities. The antioxidant activities of cow milk yogurt decreased to 26–28% whereas camel milk yogurt increased to 49–65% during 7–21 days of storage (Shori and Baba, 2011b). Caleja et al. (2016) reported that yogurts with the addition of *Foeniculum vulgare* Mill. (fennel) and *Matricaria recutita L.* (chamomile) decoctions had higher antioxidant activity than the synthetic additive (potassium sorbate). Chamomile showed the highest antioxidant activity, while fennel and the synthetic additives showed a very similar antioxidant activity in yogurt (Table 1). After seven days of storage, the potassium sorbate (E202) lost considerable antioxidant capacity as well as the natural product. The use of aqueous extracts produced from plants enhanced the antioxidant activity of yogurts (Table 1), and showed higher capacity than the synthetic additives (E202).

O'Sullivan et al. (2014) investigated the effect of addition of two common brown algae, namely *Ascophyllum nodosum* (AN) (100% water and 80% ethanol extracts) and *Fucus vesiculosus* (FV) (60% ethanol extract), on antioxidant potential of yogurt at concentrations of 0.25 and 0.5%. The highest antioxidant activities were detected in AN100 (0.5%) with 32% and FV60e (0.5%) with 47%. The DPPH radical scavenging action of all yogurts was comparable over the 28 day storage period. All algal extract-enriched yogurt samples had significantly higher DPPH radical scavenging activities compared to the corresponding control (plain-yogurt) indicating that the algal extracts were stable within yogurt.

El-Said et al. (2014) determined the antioxidant activities [radical scavenging activity (RSA %), ABTS radical scavenging, total phenolic content (TPC) and total flavonoids content (TFC)] of stirred-type yogurt fortified with 5%, 10%, 15%, 20%, 25%, 30% and 35% of the PPE, before and after inoculation with the traditional yoghurt starter. The antioxidant activities (ABTS radical scavenging) of control before and after addition of yogurt starter were 3.18 ± 0.03% and 1.91 ± 0.01% respectively. In addition, the antioxidant activities of yogurt with 35% of PPE before and after adding yogurt starter were 14.01 ± 2.07% and 12.22 ± 1.89% respectively. DPPH radical scavenging of control before adding yogurt starter was 19.12 ± 1.56%, and 17.91 ± 1.54% after addition of yogurt starter. This study indicated that, milk fermentation with PPE reduced significantly the antioxidant activity of yogurt.

Yogurt with the addition of *Azadirachta indica* showed higher antioxidant effect compared to plain yogurt (53.1 ± 5.0% and 35.9 ± 5.2%, respectively) after 28 days of storage (Shori and Baba, 2011a). *Azadirachta indica* have antioxidant properties due to the presence of high concentration of vitamin C and riboflavin (Sithisarn et al., 2005; Madhi et al., 2003; Atangwho et al., 2009). In addition, fermentation and post-acidification products produced during storage such as organic acid derivative and milk protein proteolysis could be possible sources of DPPH inhibitors. (Lourens-Hattingh and Viljoen, 2001; Correia et al., 2004). In the presence of *Azadirachta indica* yogurt showed higher antioxidant activity and this is beneficial in two respects: firstly, reducing lipid oxidation process in yogurt which might be responsible for unwanted chemical compounds and formation of off-flavors (Berset et al., 1994), and secondly, increasing dietary antioxidants which prevent the progressive impairment of pancreatic beta-cell function due to oxidative stress (Liu et al., 2005).

Marinho et al. (2015) compared the antioxidant activity of cheese samples coated and uncoated with the rosemary leaves. Activation energy (Ea) values indicated that the cheeses coated