1 **Byproducts as a Source of Novel Ingredients in Dairy Foods**

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28 **Keywords**

29 byproducts, dairy products, functional foods, sustainability, health

30 **Synopsis**

31 The food industry generates a large amount of food wastes and byproducts along the
32 food chain. These fractions are excellent sources of bioactive compounds and nutrients
33 with a high potential for valorization as novel food ingredients. In this chapter, the
34 applications of byproducts in the development of sustainable and novel dairy foods
35 were revised.

36 **Abstract**

37 Food losses represent a waste of resources used in production, in addition to the loss of
38 the economic value of the food produced. The valorization of food wastes and
39 byproducts has become a major subject of research to improve the sustainability of the
40 food chain. Food byproducts are excellent sources of bioactive compounds and
41 nutrients with a high potential for application as novel food ingredients. In this chapter
42 we revised the latest data on food loss generation, the group of byproducts mostly used
43 as food ingredients in dairy product development, and their function in the dairy matrix.
44 We also address the challenges associated with the sensory properties of the products
45 developed including ingredients obtained from byproducts, and consumers attitude
46 towards these new sustainable and novel dairy foods.

47 **Introduction**

48 The large amounts of byproducts generated in the food industry, together with the need
49 of innovation in the dairy sector, has led food researchers to look for new alternatives
50 to valorize these food side streams and develop novel dairy foods.

51 The potential of the valorization of these agro-industrial food wastes and byproducts is
52 currently supported by the extensive information available on their content of healthy
53 promoting phytochemicals (Teixeira et al., 2014). This has led to the rise in popularity of
54 various health promoting functional foods, including a wide range of products within the
55 dairy sector. Yogurts are particularly trendy among functional foods because they are
56 one of the most preferred foods by consumers as carriers for bioactive ingredients (Ares,
57 Giménez and Deliza, 2010).

58 The development of novel food and/or functional food products is increasingly
59 challenging, as it has to fulfill the consumer's expectations for products that are
60 simultaneously palatable and healthy (Granato et al., 2010a). Compared to conventional
61 foods, the development of functional components and technological solutions can be
62 demanding and expensive, and it needs of a tight strategy between research and
63 business. All this, in a context where functional food markets are continuously changing
64 (Menrad, 2003; Urala and Lähteenmäki, 2007).

65 In this era where people are shifting from synthetic to natural and newer ways of healthy
66 living, using new sources of bioactive compounds, as food byproducts, are being
67 explored (Sharma et al., 2015). Sustainability presents both a challenge and opportunity
68 to the dairy sector. An opportunity, because the possibility of utilization of food
69 processing byproducts for bioactive compound and nutrient extraction has created

enormous scope for waste reduction and indirect income generation (Espírito Santo et al., 2012a). However, the challenge is to render the concept of sustainable functional foods into a marketable product that can be accepted by consumers. Granato et al., (2010b) described that the acceptance to a specific functional ingredient or a functional food is linked to the consumer's knowledge of the health effects of specific ingredients. Therefore, more efforts need to be done to influence consumer demand patterns and make sustainability, together with health, one of the main drivers in food consumption.

Byproducts Used as Novel Ingredients in Dairy Foods.

Food waste was defined by FAO in 1981 as the wholesome edible material intended for human consumption, arising at any point in the food chain system that is instead discarded, lost, degraded or consumed by pests.

The latest Food Balance Sheets (FAO, 2017) indicated that fruits and vegetables presented the highest values of food waste along the food chain compared to the rest of the commodity groups: cereals, roots and tubers, oilseeds and pulses, meat, fish and seafood, and dairy products. In industrialized regions, losses were generated throughout the food chain, especially due to post-harvest fruit and vegetable grading caused by quality standards set by retailers, but also at the consumer level, with 15-30% of the purchases being discarded (FAO, 2011).

Considering the number of studies published from 2000 to 2017, 86.2% of them used byproducts from plant materials for the development of innovative health promoting dairy products (Figure 1). Plant byproducts include a wide range of food matrixes which are sources of functional ingredients like antioxidants and dietary fibers (Galanakis,

2011). Hence, they enable wide range of potential functions and technological uses. In the development of novel dairy foods, 60.4% of the studies used byproducts from fruit (48.3%) or vegetables (12.1%), followed by the application of winery byproducts (19%).

<Figure 1 near here>

Byproducts from meat, fish and seafood contain high amounts of protein, which may be less necessary in dairy foods as they already contain this compound in their matrix. However, when protein has been needed, it has been mostly obtained from cheese whey, which is a saccharide and protein rich dairy waste generated during cheese production (Pasotti et al., 2017).

Applications as Ingredients in Dairy Foods

During the last years there have been different approaches in the applications of food byproducts in dairy foods. Most studies have focused on using plant byproducts for the extraction of functional ingredients such as polyphenols, dietary fiber and others.

Polyphenols

Polyphenols are secondary metabolites that are synthesized during normal plant development and in response to stress conditions (Naczk and Shahidi, 2004). Plant phenolics include phenolic acid and its derivatives, flavonoids, lignans and stilbenes (Costa et al., 2017). Although phenolic compounds are not considered nutrients, several biological and pharmacological activities have been attributed to dietary polyphenols, including antioxidant, anti-allergic, anti-inflammatory, anti-viral, anti-microbial and anti-carcinogenic effects (Bahadoran, Mirmiran and Azizi, 2013). These properties play a relevant role in the prevention of several major chronic diseases associated with

oxidative stress, such as cardiovascular diseases, cancers, type II diabetes, neurodegenerative diseases or osteoporosis (Scalbert et al., 2005). In this sense, the health-protecting capacity of plant phenolics has become of great interest for researchers, the food industry and consumers.

Although phenolic compounds are ubiquitous in plants, they are not uniformly distributed at the tissue, cellular and subcellular levels (Naczki and Shahidi, 2004). Peels, husks, hulls, pods and bran are major processing byproducts of the fruit, vegetable and cereal industry that are considered sources of polyphenols.

Product development using byproducts as a source of polyphenols has mostly been carried out in yogurt and fermented milks (Table 1). Namely, winemaking byproducts have been used as the main source of polyphenols, including different flours and extracts from grape pomace and other selective fractions, such as grape skins and seeds. This could be justified both by the fact that black grapes stand among the richest dietary sources of polyphenols (Dimitrios, 2006; Pérez-Jiménez et al., 2010) and by the high amount of grape losses generated during processing and conversion into wine, storage and transportation, which reached 3637 thousand tons in 2013 (FAO, 2017).

<Table 1 near here>

Addition of polyphenols in dairy foods other than yogurt and fermented milks has received less attention. Wine pomace byproducts have been the major source of polyphenols in the development of cheese (Shan et al., 2011; Felix da Silva et al., 2015; Marchiani et al., 2015). On the other hand, lycopene from tomato peels was used to improve oxidative stability during storage of ice-cream and butter (Kaur et al., 2011; Rizk, El-Kady and El-Bialy, 2014; Abid et al., 2017).

Frumento et al. (2013), Tseng and Zhao (2013) and Marchiani *et al.* (2016) used doses ranging from 1% to 6% of wine pomace flours in fermented milk and yogurt development. However, more recent studies have switched towards using extracts from wine pomace, as lower amounts of the concentrated extracts were needed to achieve significant polyphenol levels (Ersöz et al., 2011; Chouchouli et al., 2013; Aliakbarian et al., 2015; dos Santos et al., 2017). Other byproducts from fruits, nuts, vegetables and cereals were also used as sources of polyphenols for the development of fermented milk and yogurt. Byproducts included pomegranate seeds and peels, almond peels, hazelnut skins, olive pomace and rice bran (Ersöz et al., 2011; El-Said et al., 2014; Bertolino et al., 2015; Ozcan et al., 2016; Demirci et al., 2017; Vital et al., 2017).

In foods, polyphenols may contribute to the bitterness, astringency, color, flavor and odor of the products (Shahidi and Naczki, 2006). Polyphenols are associated with the precipitation of salivary glycoproteins and mucopolysaccharides onto the tongue, resulting in roughness and dryness on the palate (Haslam and Lilley, 1988). Therefore, it is necessary to achieve a compromise between functional properties and sensory acceptance. Marchiani et al. (2016) reported a significant decrease in the overall acceptance of yogurts with 6% added polyphenols from grape skin flours. Similarly, Tseng and Zhao (2013) reported significantly lower overall acceptance scores in yogurts with 1% and 2% grape pomace powders. Moreover, yogurts with 2% grape pomace powders were significantly less accepted in terms of yogurt texture and consistency than those with 1% of grape pomace powders. The inverse relation between polyphenol dosage and consumer acceptance in dairy products has been widely described (Tseng and Zhao, 2013; Bertolino et al., 2015; Marchiani et al., 2015; Karnopp et al., 2017). In this sense, several researchers have opted to include other ingredients that could mask

the negative sensory effects of polyphenols. In yogurt and fermented milk fortification with wine pomace byproducts, the best acceptance scores were obtained when adding the polyphenols in combination with sucrose (5%), oligofructose (0.5% to 0.667%) or grape juice (0.167% to 0.5% and 15%) (dos Santos et al., 2017; Karnopp et al., 2017).

Dietary fibers

Plant derived byproducts, such as seed, skins, pods, peels, pomace, hulls, husks, cores, stores, etc., are known sources of bioactive compounds and nutrients including dietary fiber (McKee and Latner, 2000; Sharma et al., 2015), whose caloric value has been estimated at 2kcal per g (FDA, 2018). The European Food Safety Authority, (2010) defined dietary fiber as non-digestible carbohydrates, including non-starch polysaccharides, resistant starch and oligosaccharides, and lignin. A terminology often encountered is the classification of dietary fiber into “soluble” and “insoluble” (Álvarez and González, 2006). Therefore, the physicochemical properties of the different dietary fibers can be determinant when selecting their applications.

The European Food Safety Authority confirmed that there is evidence of health benefits associated with consumption of diets rich in fiber-containing foods at dietary intakes greater than 25 g per day. Health benefits have been related to reduced risk of coronary heart disease, intestinal disorders, type 2 diabetes and improved weight maintenance (Peters et al., 2003; Pereira et al., 2004; Lindström et al., 2006).

Product innovations have been focused on increasing the fiber content of dairy foods to facilitate consumers achieving the daily recommended intake of dietary fiber. Also, as a marketing strategy with the final aim of adding a nutritional claim in the food package. The European Parliament and Council, (2006) (Regulation No. 1924/2006) stated that

the nutritional claim “source of fiber” or “high in fiber” may only be made when the product contains at least 3% or 6% dietary fiber, respectively. Bearing this in mind, several researchers have used dietary fiber concentrations ranging from 2.5% to 10% to evaluate its feasibility as an ingredient in dairy products (Table 2). This is because an increase in concentrations of dietary fiber in foods can lead to changes in the resultant nutritional, textural, rheological, and sensory properties of the developed products (Guillon and Champ, 2000).

<Table 2 near here>

Product development using byproducts as a source of dietary fiber has mostly been carried out in yogurt and fermented milks. As observed in Table 2, available studies have used a wide variety of plant origin sources derived from fruit and vegetable industry byproducts. Water soluble soybean polysaccharides from okara, which is the byproduct of tofu, soymilk and soybean protein isolate, were used in the development of ice-cream, pudding and a milk-based beverage (Chen et al., 2010). From the initial concentration ranges tested of fiber addition (3% to 10% in the milk beverage, 4% to 8% in pudding, and 1% to 4% in ice-cream), optimal sensory acceptance was achieved at 4% fiber addition in the milk beverages and pudding, and at 2% fiber addition in ice-cream. This was due to texture modifications in the dairy matrixes, as consumers considered fiber fortified dairy foods too thick when evaluated using Just About Right (JAR) scales. In fermented milks and yogurts, fiber from apple pomace (3% to 10%), date byproducts (1.5% to 4.5%) and hazelnut skins (3% to 6%) were used in the development of dietary fiber enriched foods (Hashim, Khalil and Afifi, 2009; Bertolino et al., 2015; Issar, Sharma and Gupta, 2016). In these cases, optimal sensory acceptance of the products was

207 obtained at 3% fiber addition from hazelnut skins and dates, and 5% fiber addition from
208 apple pomace.

209 Addition of byproducts containing dietary fibers has also been applied in dairy foods
210 with technological purposes, such as fat replacers, probiotic carriers or texture agents.
211 Dietary fiber from orange byproducts was used to develop lemon ice-cream with a fat
212 content reduction of 50% (Crizel et al., 2014), and as fat replacers in low-fat yogurt (Yi
213 et al., 2014). The authors showed that reducing particle size of the orange dietary fibers
214 by micronization increased their water and oil holding capacities, which are also
215 important functional properties in relation with the facilitation of digestion and
216 absorption of nutrients in the body.

217 Apple, banana and passion fruit byproduct fibers were used to preserve viability of
218 *Lactobacillus acidophilus* and *Bifidobacterium animalis* subsp. *lactis* strains in yogurt
219 during the shelf life of the products (Espírito Santo et al., 2012a). Namely, apple and
220 banana byproduct fibers helped preserve probiotic viability up to 4 weeks of cold
221 storage. In addition to the probiotic viability evaluation, the authors observed that the
222 probiotic strains were able to modify the fatty acid composition of milk during its
223 fermentation to obtain yogurt. In the presence of the probiotic strains studied, the
224 addition of banana fiber significantly increased α -linoleic acid content, whereas passion
225 fruit fiber promoted the increase of conjugated linoleic acids in probiotic yogurts. As a
226 result, the fatty acid profile of yogurts was improved due to a synergistic effect between
227 the type of fiber used and its fermentation by the probiotic strain. The application of
228 dietary fiber from fruit byproducts was shown to be a more cost-effective and
229 sustainable option than the addition of conjugated linoleic acids precursors and

commercial soluble fiber that are normally used to improve the fatty acid profile of yogurts (Espírito Santo et al., 2012a).

Texture and rheological parameters of yogurts were analyzed when adding 1% of pineapple peel powders (Sah et al., 2016). Yogurt firmness and storage modulus decreased, and the syneresis level was similar to prebiotic-inulin yogurts. The color and textural properties of butter fortified with fibers from vegetal and fruit wastes (stone pear, celery roots and leaves, spinach, orange albedo) was evaluated by Göksel Saraç and Dogan, (2016). The type and dose (from 3% to 5%) of dietary fiber used changed the hardness and the spreadability rate, color and sensory acceptance of the butters. Results showed that butter produced with stone pear dietary fiber (3%) was the most preferred. The influence of different doses (0.6% to 1%) and particle sizes (0.471-0.701 mm and 0.701-0.991 mm) of orange byproduct fibers did not affect composition, syneresis, color or sensory acceptance of fiber added yogurts (García-Pérez et al., 2005).

These previous examples indicate that it is possible to obtain dairy foods that are “source of fiber” and “high in dietary fiber” without compromising their sensory acceptability. Future research should evaluate the satiating effect and gastrointestinal tolerance of a regular portion of the dairy products developed. As carbohydrates from dietary fiber are non-digestible, they reach the large intestine, where they can be fermented by colonic microbiota to different extents, depending on the degree of polymerization, solubility and structure of the carbohydrates (Nyman, 2002). Therefore, consumption of high content dietary fiber products may cause potential secondary effects from carbohydrate fermentation including bloating, distension, flatulence, loose stools and increased stool frequency (Grabitske and Slavin, 2009).

Other ingredients

Other innovations in dairy product development include the addition of ingredients from animal origin byproducts: omega-3 fatty acids and proteins.

Fish oil can be extracted from fish wastes, and it is an excellent source of many unsaturated fatty acids, including long chain n-3 cis-5,8,11,15,17- eicosapentaenoic acid (EPA) and cis-4,7,10,13,16,19-docosahexaenoic acid (DHA) (Jayathilakan et al., 2012). However, its application in food formulations is limited because of its easy oxidation and strong odor (Zhong et al., 2018). Yogurts containing n-3 that had sensory attributes similar to plain yogurt were obtained encapsulating fish oil in nano-liposomes (Ghorbanzade et al., 2017), and adding a fish oil/ γ -oryzanol nanoemulsion in yogurt (Zhong et al., 2018).

Whey proteins obtained from cheese processing have been widely used as fat replacers in dairy foods. Problems associated with using whey proteins and sodium caseinate as fat replacers in yogurt included powdery taste, excessive acid development from lactose fermentation, higher syneresis, excessive firmness and grainy texture (Sandoval-Castilla et al., 2004). Recent studies have focused on improving texture in low fat yogurts and low fat probiotic yogurts with added whey-buttermilk protein aggregates, whey protein concentrate and heat-treated whey protein concentrates (Akalın et al., 2012; Saffon et al., 2013; Zhang et al., 2015).

Concluding remarks

The large number of applications described in this chapter shows the high potential of valorizing food byproducts for the development of novel dairy foods. This approach not

only takes a step forward to waste reduction in the food chain, but also offers new ways to diversify the production of dairy foods, launching the possibility of creating a market niche based on functional and sustainable novel dairy foods. As many food byproducts are sources of natural bioactive compounds and nutrients, their application could reduce the use of synthetic ingredients without compromising the stability of the final product, while fulfilling the current consumer demand towards using natural ingredients. Dairy products with improved nutritional and health promoting properties, as well as optimal sensory acceptance, can be achieved employing extracts from food byproducts as novel food ingredients.

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