Food industry by-products as raw materials in functional food production

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review

Summary

Western civilization problems nowadays are overweight, obesity, diabetes, cardiovascular diseases, cancer and different disorders closely linked to unbalanced diet. Since it is extremely difficult to influence nutritional preferences of consumers, food industry is now increasingly developing new products, such as bread, pasta, snack products and other highly consumed products by all groups of consumers enriched with ingredients that are lacking in every day nutrition (fiber, polyphenols, antioxidants, vitamins, ß-glucan…) and functional products which have scientifically proven beneficial effect on human health. Food industry by-products, such as apple pomace, by-products from sugar industry and brewers spent grains are rich source of polyphenols, fiber and ß-glucan. Grape pomace is rich in polyphenols, tomato pomace in lycopene and carrot pomace in β-carotene. These are just some examples of by-products with great potential of application in enriched and functional food production. In addition to natural substances which are produced in this manner, problem of large quantities of waste disposal is also resolved.

Keywords: food industry by-products, functional food, fiber, ß-glucan, antioxidants

Introduction

The modern problems of Western civilization are overweight, obesity, diabetes, cardiovascular diseases and various disorders that are closely related to improper diet. As it is difficult to affect eating habits of consumers, today's food industry develops new products consumed by the wide population, enriched with ingredients that are poorly represented in the daily diet (fiber, antioxidants, polyphenols, vitamins, ß-glucan, minerals,...) and functional products, which are scientifically proven to have a beneficial effect on health. Modern trend is a demand and production of food products with the specific taste and health benefits. All of these requirements of consumers pose a major challenge for food technologists and all those involved in the food production chain.

By-products of plant food processing represent a major disposal problem for the industry concerned, but they are also promising sources of compounds which may be used because of their favourable technological or nutritional properties (Schieber et al., 2001b). At present up to one third of fruit and vegetables in the form of peels, pips, kernels and skins can be discarded during preparation and processing, therefore creating a 'waste', while also decreasing the maximum nutritional potential of the fruit or vegetable (O'Shea et al., 2012).

This review illustrates nutritional value of some food industry by-products and their application in production of various type of new products.

Table 1. The content of various compounds in the fruit and vegetable by-products

Compound	Content [% w/w, db]	Source	References
Pectin	13 – 39	Apple pomace	Renard et al. (1996)
	15 – 30	Sugar beet pulp	Yapo et al. (2007)
Total dietary fibre • **Insoluble** • **Soluble**	51.1 • 36.5 • 14.6	Apple pomace	Sudha et al. (2007)
	57 • 47.6 • 9.41	Orange peel	Chau and Huang (2003)
	63.6 • 50.1 • 13.5	Carrot pomace	Chau et al. (2004)
Protein	27.5	Kernels of peach	Rahma (1988)
	20 – 25	Bitter apricot seeds	Tunçel et al. (1998)
	16.1	Cauliflower	Stojceska et al. (2008a)
	20	Brewer's spent grain	Mussatto et al. (2006)

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Fruit by-products

Because of its high quantity in fruit processing industry and their nutritive value (dietary fibers, polyphenols, pectins,...) in this chapter are presented some of the most investigated fruit industry by-products.

Apple

The major product from apple processing is apple juice. The entire fruit is usually pressed in a cold press to extract the juice from the fruit. This can result in much waste, which is termed apple pomace (O'Shea et al., 2012). Apple pomace, inexpensive and primary by-product of apple juice and cider production is used as a source of pectin (Hwang et al., 1998), as animal feed (Sandhu and Joshi, 1997), as dietary fibres (Leontowicz et al., 2001) or as a source of phenolic compounds (Schieber et al., 2004).

Since apple pomace is rich in pectins, between 13 and 39 % of pectins (Renard et al., 1996), Royer et al. (2006) showed that it is possible to obtain jellies with apple pomace without incorporating gel additive. Production of pectin is considered the most reasonable way of utilizing apple pomace both from an economical and from an ecological point of view (Endreß, 2000, Fox et al., 1991). In comparison to citrus pectins, apple pectins are characterized by superior gelling properties. However, the slightly brown hue of apple pectins caused by enzymatic browning may lead to limitations with respect to their use in very light-coloured foods (Schieber et al., 2001b).

Gorinstein et al. (2001b) investigated the dietary fibre levels of a whole apple, its pulp and its peel. Interestingly, they found that the majority of the total fibre was located in the peel of the apple (0.91 % fresh weight [FW]). The percentage of insoluble (0.46 % FW) to soluble fibre (0.43 % FW) was found to be well balanced in terms of receiving a health benefit. Dried apple pomace is considered as a potential food ingredient, having dietary fibre content of about 36.8 %, and has been used in apple pie filling and in oatmeal cookies (Carson et al., 1994).

Apple pomace has been shown to be a good source of polyphenols which are predominantly localized in the peels and are extracted into the juice to a minor extent. Major compounds isolated and identified include catechins, hydroxycinnamates, phloretin glycosides, quercetin glycosides, procyanidins, chlorogenic and caffeic acid, and phloridzin (Foo and Lu, 1999, Lommen et al., 2000, Lu and Foo, 1997, 1998, Schieber et al., 2001a, Garcia et al., 2009, Schieber et al., 2003).

Masoodi et al. (2002) studied cake making from apple pomace wheat flour blends at 5, 10 and 15 %, so as to enrich the cake with fibre content. Sudha et al. (2007) also investigated the addition of apple pomace in wheat flour at 5, 10 and 15 % levels and studied rheological characteristics and cake making. These authors concluded that the cakes prepared with apple pomace had pleasant fruity flavour, and had higher dietary fiber and phenol contents.

Recently, apple pomace is tried to be incorporated into other products, such as "snacks", which are highly consumed products by all groups of consumers (Karkle et al., 2012).

Grape

Grape (*Vitis* sp., Vitaceae) is one of the world's largest fruit crop with more than 60 million tons produced annually. About 80 % of the total crop is used in wine making and pomace represents approximately 20 % of the weight of grapes processed. From these data it can be calculated that grape pomace amounts to more than 9 million tons per year (Schieber et al., 2001b). Viniculture is an important agricultural activity in a lot of countries in southern Europe like in Spain, Italy and France and produces huge amounts of grape marc. This by-product consists mainly of skins and in certain case of seeds and some stalks. After extraction in the distilleries of wide range of products (ethanol, grape seed oil, anthocyanins and tartrate), the remaining pomace is currently not upgraded but used for composting or discarded in open areas potentially causing environmental problems. Considering the growing demand for green materials and components, agricultural by-products like pomace have an obvious potential as a renewable starting material (Rondeau et al., 2013). It is also used in the production of citric acid, methanol, ethanol and xanthan gum as a result of fermentation. The nutritional and compositional characteristics of grape pomace are known to vary, depending on the grape cultivar, growth climates and processing conditions (Deng et al., 2011).

Grape pomace has been shown to be a rich source of dietary fibre; its components mainly comprise of cellulose, small proportions of pectins and hemi-celluloses (Kammerer et al., 2005, González-Centeno et al., 2010).

Furthermore, grape pomace has also been evaluated as a source of antioxidants because of its high contents of polyphenols (Negro et al., 2003). Anthocyanins, catechins, flavonol glycosides, phenolic acids and alcohols and stilbenes are the principal phenolic constituents of grape pomace (Schieber et al., 2001b). Ruberto et al. (2007) carried out a study on the polyphenol content of Sicilian red grape pomace. The authors found that anthocyanins, flavonols and the phenolic acid, gallic acid, were the main polyphenols present.

In recent years grape pomace was used for production of different types of products. Altan et al. (2009) investigated the functional properties and *in vitro* starch digestibility of barley-based extrudates from fruit and vegetable by-products (tomato and grape pomace), and concluded that increasing level of both tomato and grape pomace led to reduction in starch digestibility.

Graphical optimization studies resulted in 155-160 °C, 4.47-6.57 % pomace level and 150-187 rpm screw speed as optimum variables to produce acceptable extrudates and the results suggest that grape pomace can be extruded with barley flour into an acceptable snack food (Altan et al., 2008b).

Peach and apricot

Peaches and apricots contain significant quantities of phenolics and carotenoids, components with various health benefits (Campbell and Padilla-Zakour, 2013).

Peach has been widely used around the world in the form of peach slices in syrup or just eaten as a dessert. The remnants from peach processing usually include the kernel and the peel. Over the years, these remnants have been used for their pectin as a thickener in jams; nowadays they are used commercially as a general thickener in foods (O'Shea et al., 2012). Págan and Ibarz (1999) described the recovery of pectin from fresh peach pomace**.** It is concluded that peach pectin is highly methoxylated and has favourable gelling properties (Págan et al., 1999). Kurz et al. (2008) characterized the cell wall polysaccharides of peaches and concluded that the main polysaccharides found were in the form of pectin.

Kernels of peach fruits contain 54.5 % and 27.5 % oil and protein, respectively, but ash and total carbohydrates were quite low (Rahma, 1988). Because of this high content of oil, Sánchez-Vicente et al. (2009) used peach seed as raw material for supercritical fluid extraction of oil. Furthermore, peach seeds may be used for the production of persipan (Schieber et al., 2001b).

Apricot is one of the most delicious and commercially traded fruits in the world. The plant is rich in mono- and polysaccharides, polyphenols, fatty acids and sterol derivatives, carotenoids, cyanogenic glucosides, and volatile components due to its appealing smell (Erdogan-Orhan and Kartal, 2011).

More than 650 metric tonnes of bitter apricot seeds are produced in Turkey per year as a by-product from the fruit canning industry (Tunçel, 1995). They are used as a substitute for bitter almonds to produce persipan for the bakery industry. The oil (53 % in the seed) is used, in e.g. cosmetics, as a cheaper substitute for bitter almond oil. The seeds can also be of interest as a food or feed ingredient because of their high crude protein content (20-25 % w/w, dry weight basis). The main problem is that bitter seeds contain approximately 50-l50 μmol/g (dry weight basis) of potentially toxic cyanogenic glycosides, mainly amygdalin and prunasin (Tunçel et al., 1998). Because of that, before using, seeds must be debittered by hydrolysis of amygdalin (Schieber et al., 2001b), and there are various researches about this (Tunçel et al., 1990, 1995, 1998, Nout et al., 1995).

Lemon and orange

Approximately 50 % of the original whole fruit mass, after citrus processing for juice, consist of the peel, membranes and seeds. Citrus residues consist mainly of insoluble fiber (celluloses) and a small proportion of soluble fiber (hemicelluloses and pectin). For this reason, citrus residues could be considered as a potential high fiber ingredient that is used for food industry (García-Méndez et al., 2011). Residues of citrus juice production are a source of dried pulp and molasses, fiber-pectin, cold-pressed oils, essences, D-limonene, juice pulps and pulp wash, ethanol, seed oil, pectin, limonoids and flavonoids (Schieber et al., 2001b).

Comparison of some biochemical characteristics of different citrus fruits investigated Gorinstein et al. (2001a). These authors concluded that lemons possess the highest antioxidant potential among the studied citrus fruits and are preferable for dietary prevention of cardiovascular and other diseases. The peels of all citrus fruits are rich in dietary fibres and phenolic compounds and suitable for industrial processing. García-Méndez et al., (2011) found that extrusion is a process that has the capability to transform insoluble fiber to soluble fiber in lemon residues. The highest content of soluble fiber was 50 %, when operating conditions were high in temperature (100 °C), low in moisture content (40 %) and low in screw speed (10 rpm).

85 % of oranges are processed into some form of orange juice, leaving behind tonnes of by-product after production. As a result of the functional and nutritional characteristics of orange peel, it may be

considered to be a viable ingredient for a wide variety of products such as meat pastes, baked goods and yoghourt (O'Shea et al., 2012). Chau and Huang (2003) found that the orange peel contain 57 % DW total dietary fibre; of this 47.6 % DW was the insoluble fraction and 9.41 % DW was the soluble fraction.

Larrea et al. (2005) investigated the effects of some operational extrusion parameters on selected functional properties of orange pulp and its use in the preparation of biscuit-type cookies. They concluded that biscuits of good technological quality and with a good level of acceptance were obtained by means of replacing up to 15 g/100 g of the wheat flour with extruded orange pulp.

Vegetable by-products

As a rich source of lycopene (tomato), β-carotene (carrot) and dietary fiber (cauliflower), and because of their high quantity in vegetable processing industry in this chapter are presented these three nutritive valuable vegetable industry by-products.

Tomato

Tomato (*Lycopersicon esculentum*) is one of the most popular vegetables and an integral part of human diet worldwide. Significant amounts are consumed in the form of processed products such as juice, paste, puree, ketchup, sauce and salsa (Altan et al., 2008a). During tomato processing a by-product, known as tomato pomace, is generated. This by-product represents, at most, 4 % of the fruit weight, and mainly consists of fibre; it can represent up to 50 % of the by-product on a dry weight basis (Del Valle et al., 2006). Furthermore, this by-product can still contain many nutrients and phytochemicals (O'Shea et al., 2012). The skin, important component of pomace, is source of lycopene. Lycopene is an excellent natural food color and also serves as a functional ingredient with important health benefits beyond basic nutrition (Kaur et al., 2005). It has been associated with various health benefit claims including immune system modulation, as a free radical scavenger and as having anticarcinogen properties (Dehghan-Shoar et al., 2010).

Nowadays, there are many researches about using tomato pomace as a novel ingredient in different types of food products. Dehghan-Shoar et al. (2010) investigated the addition of tomato derivatives to traditional starchy extruded snacks to improve their nutritional properties. These authors concluded that lycopene retention was higher in products containing tomato skin powder and significantly lower when wheat flour was used to make the snacks. Increases in the processing temperature improved the physicochemical characteristics of the snacks but had no significant effect on lycopene retention ($P > 0.05$) and texture of the product. Calvo et al. (2008) incorporated tomato powder (from tomato peel) into fermented sausages. Besides, tomato peel was successfully added to hamburgers to improve their nutritional content via the presence of lycopene (García et al., 2009). Tomato pomace can be extruded with barley flour into an acceptable and nutritional snack. Extrudates with 2 % and 10 % tomato pomace levels extruded at 160 °C and 200 rpm had higher preference levels for parameters of color, texture, taste and overall acceptability (Altan et al., 2008a).

Carrot

The carrot (*Daucus carota*) is a root vegetable, usually orange, purple, red, white or yellow in color, with a crisp texture when fresh. It is a rich source of β-carotene and contains other vitamins, like thiamine, riboflavin, vitamin B-complex and minerals. Carrot pomace is a by-product obtained during carrot juice processing. The juice yield in carrots is only 60-70 %, and even up to 80 % of carotene may be lost with left over carrot pomace (Kumar et al., 2010). The total dietary fibre content of the carrot pomace was found to be 63.6 % DM, with 50.1 % DM being the insoluble fraction and 13.5 % DM the soluble fraction (Chau et al., 2004).

Because pomace received from carrots doesn't contain kernels and seeds, it can easily be added to a product without introducing negative functional or flavour issues while still retaining a lot of its phytochemicals (Chantaro et al., 2008). Various attempts were made at utilizing carrot pomace in food such as bread, cakes, dressing and for the production of functional drinks (Schieber et al., 2001b). Upadhyay et al. (2010) investigated the optimization of carrot pomace powder (CPP) incorporation on extruded product quality. The study demonstrated that an acceptable extruded product can be prepared by CPP incorporation, and optimum incorporation level of CPP was found to be 5 %. Kumar et al. (2010) found that carrot pomace could be incorporated into ready-to-eat expanded products up to the level of 8.25 %.

Cauliflower

Cauliflower has a very high waste index and is an excellent source of protein (16.1 %), cellulose (16 %) and hemicellulose (8 %). It is considered as a rich source of dietary fibre and it possesses both antioxidant and anticarcinogenic properties. Encouraging characteristics such as its pale colour, bland taste and high nutritional content make it an attractive novel ingredient (Stojceska et al., 2008a). Llorach et al. (2003) analysed the antioxidant capacity of cauliflower by-products and found that flavonoids and hydroxycinnamic acids were the main phenolics present. Similar to some of the fruit and vegetables, cauliflower by-products (such as the stem) have been shown to contain a significant amount of phytochemicals (O'Shea et al., 2012), and can be good novel ingredient for production of various food products. Stojceska et al., (2008a) used cauliflower by-products in production of cereal based ready-to-eat expanded snack and found that increasing the cauliflower to levels of 5-20 % increased dietary fibre in the finished product by over 100 %, increased protein content and water absorption index. Sensory test panel indicated that cauliflower could be incorporated into ready-to-eat expanded products up to the level of 10 %.

Sugar beet by-products

A third of the world production of sugar comes from sugar beet (*Beta vulgaris*). One ton of sugar beet (sucrose content 16 %) provides a dried weight of around 130 kg of sugar and 50 kg of a by-product, sugar beet pulp (SBP) (Rouilly et al., 2006). Molasses represents the runoff syrup from the final stage of crystallization. It mainly consists of fermentable carbohydrates (sucrose, glucose, fructose), and of nonsugar compounds which were not precipitated during juice purification. Molasses is used as feed and as a source of carbon in fermentation processes, e.g. for the production of alcohol, citric acid, L-lysine and L-glutamic acid (Schieber et al., 2001b).

Sugar beet pulp (SBP), a major by-product of the sugar refining industry, is a potential feedstock for biofuels. It contains 20-25 % cellulose, 25-36 % hemicellulose, 20-25 % pectin, 10-15 % protein, and 1-2 % lignin content on a dry weight basis (Zheng et al., 2013). Due to highly digestible fiber it is valued as an excellent food complement for animal feed and energy source. Raw pulp has been proposed as cultivation substrate, as well, for divalent cations complexation, as source of polyols for the production of urethanes and polyurethanes, as source of fiber in biodegradable composites or for paper manufacture (Rouilly et al., 2009). Addition of sugar beet fiber to semolina increased dietary fiber content but adversely affected colour and cooking loss of spaghetti (Özboy and Köksel, 2000). Owing to its high pectin content (15-30 %) on dry weight basis, and its availability in large quantities, sugar beet pulp (SBP) is another source, after apple pomace and citrus peels, for commercial pectin production (Yapo et al., 2007). Because of that, there are many researches about extraction of pectin from SBP (Li et al., 2012, Yapo et al., 2007, Lv et al., 2013, Ma et al., 2013). Pectins from SBP have poor gelling properties compared to citrus and apple pectins due to their high degree of methylation and low molecular weight and they are not extensively used in traditional applications in the food industry (Mata et al., 2009). In many parts of the world, utilization of SBP is an economically marginal part of beet sugar processing due to the low feed value and high drying cost. In certain areas, dehydrating and pelletizing SBP contribute 30-40 % of the overall energy cost of sugar beet processing. Therefore, the beet sugar industry seeks to add value to SBP via a process that does not require drying. In light of this, converting SBP into fuel ethanol through biological pathways, including hydrolysis and fermentation, is an attractive option (Zheng et al., 2012).

Brewer's spent grain

Brewer's spent grain (BSG) is the major by-product of the brewing industry. BSG is a lignocellulosic material containing about 17 % cellulose, 28 % non-cellulosic polysaccharides, chiefly arabinoxylans, and 28 % lignin. BSG is available in large quantities throughout the year, but its main application has been limited to animal feeding. Nevertheless, due to its high content of protein and fibre (around 20 and 70 % dry basis, respectively), it can also serve as an attractive adjunct in human nutrition (Mussatto et al., 2006). According to these authors, BSG is good for the manufacture of flakes, whole-wheat bread, biscuits and aperitif snacks, but it must be first converted to flour. Nevertheless, there are some limitations in the use of the flour as a protein additive or as a partial replacement for presently used flours, due to its colour and flavour. However, ß-glucan from BSG has a significant positive impact on health and because of that BSG is excellent raw material for the production of functional products.

Recent researches show that BSG contains a significant content of polyphenols (Moreira et al., 2013, Meneses et al., 2013, McCarthy et al., 2012). Stojceska and Ainsworth (2008) added BSG in wheat flour in bread production. Increasing the level of dietary fibre increased dough development time, dough stability and crumb firmness but decreased the degree of softening and loaf volume. Ktenioudaki et al. (2013) investigated sensory properties and aromatic composition of baked snacks containing brewer's spent grain. They found that addition of BSG altered the odour profile of the snacks, however sensory results indicated that BSG-containing snacks at a level of 10 % were highly acceptable and highlighted the possibility of using BSG as a baking ingredient in the formulation of enhanced fibre baked snacks. Stojceska et al. (2008b) incorporated BSG into ready-to-eat expanded products and concluded that addition of BSG significantly increased protein content, phytic acid and bulk density. Furthermore, Ainsworth et al. (2007) found that addition of BSG in maize extrudates has no significant effect on the total antioxidant capacity (TAC) and total phenolic compounds (TPC) values, but increase phitic acid (PA), protein in vitro digestibility (PIVD) and resistant starch (RS) values.

Conclusions

The food processing industry produces large quantities of waste products. These by-products are sources of components of high nutritive value, and can be used as raw materials for other purposes. Furthermore, they are inexpensive and available in large quantities. This paper clearly demonstrates the high nutritional value that many by-products possess, and their application in production of various new products.

Acknowledgements

This work has been fully supported by Croatian Science Foundation under the project 1321.

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