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THE APPLICATION OF SOME FOOD INDUSTRY BY-PRODUCTS IN THE PRODUCTION OF EXTRUDED PRODUCTS

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Abstract

Various by-products of the food industry (fruit and vegetable pulp, oilseed cake, different bark and shells...) are generated in large quantities and represent a huge problem for manufacturers, because they have a significant effect on the environment due to slow biodegradation, water pollution, emissions of methane, and related environmental problems. On the other hand, these by-products, aside from the fact that they are a rich source of polyphenols, dietary fibre, β-glucans, antioxidants, and essential fatty acids, represent cheap and easily available raw materials which could be used for the production of various products consumed by many people (snacks, breakfast cereals, pasta, bread, biscuits...). One of the most important product groups are certainly extruded products, and their production mainly uses various types of grains, such as corn, wheat, rice and barley, which are rich in carbohydrates. Therefore, in recent years there is much more research on the topic of improving the nutritional value of this product group by using various food industry by-products.

1. INTRODUCTION

The food processing industry generates a huge quantity of by-products, including pomace, peel, husks, pods, stems, bran, washings, press cakes, etc., which have a lower production value and create considerable environmental pollution (Sharma et al., 2016). The use of these by-products has become a growing trend in the food industry in recent years, including the production of extruded products. One of the motives is to increase the nutritional value of new products, since the consumers are aware of the close relationship between nutrition and health, so the demand for food enriched with nutritionally valuable ingredients and functional food is becoming a growing trend. Another motive is certainly the utilization of these nutritionally valuable raw materials, thereby reducing overall waste (Jozinović et al., 2014; Yağcı and Göğüş, 2010).

2. THE UTILISATION OF FOOD INDUSTRY BY-PRODUCTS IN THE PRODUCTION OF EXTRUDED PRODUCTS

Extruded products include a large group of various types of finished products consumed by many people (snacks, breakfast cereals, pasta, confectionery, etc.), as well as modified flours and starches, which are widely used in the food industry as additives. Due to the fact that the extrusion process allows processing of various types of raw materials, numerous by-products, mainly of plant origin, have found their application in the production of various types of extruded products. This paper provides a brief overview of the most commonly used by-products in previous research, as well as some of the possibilities for their application established within the research project "Application of Food Industry By-products in the Development of Functional and Environmentally Friendly Extruded Food Products and Additives" (FUNEXFOOD) (HRZZ-1321).

2.1. By-products of fruit and vegetable processing

Apple pomace is a major by-product, comprised of the remains left after crushing and pressing apples during the production of juice, vinegar, or cider, and it contains about 30% of the whole fruits. It is a wet by-product, mostly used as animal feed or as fertilizer, also as a source of pectin, dietary fibres, and polyphenols (Jozinović et al., 2014). Along with citrus peel, it represents basic raw material for the production of pectin, but it is important to note that pectin from apples can't be used for the production of very light products, because its colour contains a slight brown hue (Schieber et al., 2001). Furthermore, it is a great source of dietary fibres (51.1% of total dietary fibres), 36.5% insoluble, and 14.6% soluble fibres in dry matter. Several studies about the application of apple pomace in the production of extruded products were carried out so far, such as corn extrudates (Karkle et al., 2012; Jozinović, 2015), extrudates based on whey proteins (Sun et al., 2015), and pregelatinized corn starch (Paraman et al., 2015).

Grape pomace is the main by-product of wine production, and it represents about 20% of processed raw materials. It is a good source of dietary fibres, mainly cellulose, and small proportions of pectin and hemicellulose. Furthermore, it has also been evaluated as a source of antioxidants because of its high polyphenol content (Jozinović et al., 2014). Grape pomace contains pulp, seeds, skins, and stems, and since it is a valuable raw material rich in phenolic compounds, ethanol, tartaric acid, citric acid, grape seed oil, dietary fibres, etc., it could be used as raw material for the isolation of those groups of compounds, with the potential application in functional food production (Teixeira et al., 2014). Therefore, dry pomace as grape

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flour has found its application in the production of extruded products based on barley (Altan et al., 2008b; 2009) and whey proteins (Sun et al., 2015), as well as in the production of noodles (Rosales Soto et al., 2012).

Citrus pomace is generated in large quantities as a by-product of processing this fruit during the production of juice, and it mainly consists of peel and seeds. Aside from their use in the production of pectin, citrus peel and seeds have significant antioxidant potential, so their application has recently been steadily increasing (Jozinović et al., 2014). Thus, orange peel modified by extrusion was used for the production of cookies based on wheat flour (Larrea et al., 2005). Furthermore, it was found that by extruding lemon pomace, insoluble fibres could be transformed into soluble fibres (García-Méndez et al., 2011), and the successful application of mango peel has been observed in the production of macaroni (Ajila et al., 2010).

Tomato pomace is generated in the amount of 3 – 7% during tomato processing in the production of juice, paste, puree, ketchup, sauce, and other products. It contains a large proportion of dietary fibres, which represents up to 50% d. m. of this by-product, but it is also a good source of high-quality ingredients, such as lycopene. The application of tomato pomace has been recorded in the production of extruded snack products based on corn, rice, and wheat (Dehghan-Shoar et al., 2010), extrudates based on barley (Altan et al., 2008a), and corn extrudates (Da Costa et al., 2010; Huang et al., 2009; Caltinoglu et al., 2014; Obradović et al., 2015).

Carrot pomace is a by-product obtained during carrot juice processing. Considering that a large portion of valuable components, such as carotenoids and dietary fibre, are retained in the pomace, this valuable by-product is a good source of α- and β-carotene. The total dietary fibre content of carrot pomace was found to be 63.6% d. m, with 50.1% d. m. being the insoluble fraction and 13.5% d. m. the soluble fraction. Considering that carrot pomace doesn't contain kernels and seeds, it has a wide application in numerous products such as bread, cakes, dressing, and functional drinks (Schieber et al., 2001), and furthermore, its application in the production of "ready-to-eat" expanded products has been recorded (Kumar et al., 2010), as well as in the production of other extruded products (Upadhyay et al., 2010; Obradović, 2014).

2.2. Oilseed cakes

Oilseed cakes are generated as a by-product in the production of oil. Considering that the annual amount of processing of various types of oilseeds in the EU reaches 30 to 35 million tons, these by-products are created in large amounts, but they are mainly used as animal feed. They represent a rich source of protein and dietary fibres, so their application in the production of various types of food products started in the recent years, mainly in bakery (bread, biscuits, tortillas) and protein supplements (Lai et al., 2017). Some of the most important applications in the production of new products are certainly related to the production of extruded products, so the application of hazelnut cake has been recorded in the production of snack products (Yağcı and Göğüş, 2008; 2010), the application of sesame oil cake (Nascimento et al., 2012) and olive paste in the production of corn extrudates (Bisharat et al., 2013), as well as the application of hemp powder in the production of rice extrudates (Norajit et al., 2011).

2.3. Hulls and bran

Hulls and bran represent the outer shells of different types of grains and oilseeds. They are a rich source of dietary fibres, preferably insoluble, and therefore, they have found application in the production of different extruded products. Thus, the applications of wheat bran (Onwulata et al., 2001), soybean hulls (Duarte et al., 2009), and corn fibres (Wang and Ryu, 2013a; 2013b) have been recorded in the production of corn extrudates.

2.4. Brewer's spent grain

Brewer's spent grain (BSG) is the major by-product of the brewing industry. Although it is a rich source of protein (about 20% d. m.), dietary fibres (17% cellulose, 28% non-cellulosic polysaccharides, chiefly arabinoxylans, and 28% lignin in dry matter), and ß-glucans, it is mostly used as animal feed (Jozinović et al., 2014). Mussatto et al. (2006) observed that this by-product could be used for enrichment in the production of flakes, whole-wheat bread, biscuits, aperitif snacks, and other products, but before its application it should be dried and ground. Its application has been recorded in the production of various types of extruded products, such as baked snacks (Ktenioudaki et al., 2013), corn extrudates (Makowska et al., 2013; Ainsworth et al., 2007; Jozinović, 2015), and "ready-to-eat" expanded products (Stojceska et al., 2008).

The main limitations of its implementation are the significant effects on colour and flavour when it is used in higher amounts.

2.5. Sugar beet pulp

Sugar beet pulp (SBP) represents a major solid by-product of the sugar beet used in the sugar refining industry. The content of this valuable by-product is 20-25% cellulose, 25-36% hemicellulose, 20-25% pectin, 10-15% protein, and 1-2% lignin in dry matter. Although it is high in pectin content, pectins from SBP have poor gelling properties due to their high degree of methylation and low molecular weight, so they are not extensively used in the food industry when compared to citrus and apple pectins (Jozinović et al., 2014). The application of this valuable by-product in the production of extruded products has been recorded for the development of corn extrudates (Lue et al., 1991; Jozinović, 2015), and moreover, it is used in the production of spaghetti (Özboy and Köksel, 2000).

Table 1. Some examples of the application of food industry by-products in the production of extruded products*

 Apple pomace	→	• corn extrudates • extrudates based on whey protein • extrudates based on pregelatinised corn starch
 Grape pomace	→	• extruded products based on barley • extrudates based on whey protein • noodles
 Citrus pomaces	→	• extruded orange peel in the production of cookies based on wheat flour • extrusion of lemon pomace with the aim of transforming insoluble fibres into soluble fibres • mango peel application in the producti-on of macaroni
 Tomato pomace	→	• snack products based on corn, rice and wheat • extrudates based on barley • corn extrudates
 Carrot pomace	→	• "ready-to-eat" expanded products • corn extrudates
 Oilseeds cakes	→	• snack products with hazelnut cake • corn extrudates with sesame oil cake, and olive paste • rice extrudates with hemp powder
 Hulls and bran	→	• corn extrudates with the addition of wheat bran, soybean hulls, and corn fibres
 Brewer's spent grain	→	• baked snacks • corn extrudates • "ready-to-eat" expanded products
 Sugar beet pulp	→	• corn extrudates • spaghetti

*photos in the table are the property of the authors

3. EXTRUDED PRODUCTS DEVELOPED AS PART OF THE PROJECT FUNEXFOOD

During the investigation for the project "Application of Food Industry By-products in the Development of Functional and Environmentally Friendly Extruded Food Products and Additives", 9 new expanded snack products have been developed so far, with acceptable sensory properties, enriched with three food industry by-products: corn snack products with 5, 10, and 15% of BSG, 5, 10 and 15% of SBP, and 5, 10 and 15% of apple pomace (**Figures 1 and 2**) (Jozinović, 2015). Furthermore, current research on the project is focused on the development of new extruded products based on corn grits, produced by extrusion with supercritical CO_2, enriched with defatted hazelnut cake, pumpkin seed cake, hemp cake, and defatted *Camelina sativa* cake. Moreover, 10 new modified wheat and barley flours were developed as part of the project so far, enriched with various by-products (SBP, BSG, and apple pomace), these flours will be used in further investigations on the project, in order to produce enriched breads and cookies.

Figure 1. Corn snack products developed as part of the project FUNEXFOOD (from left to right: Corn grits (without added by-products); Corn + 10% brewer's spent grain; Corn + 10% sugar beet pulp; Corn + 10% apple pomace

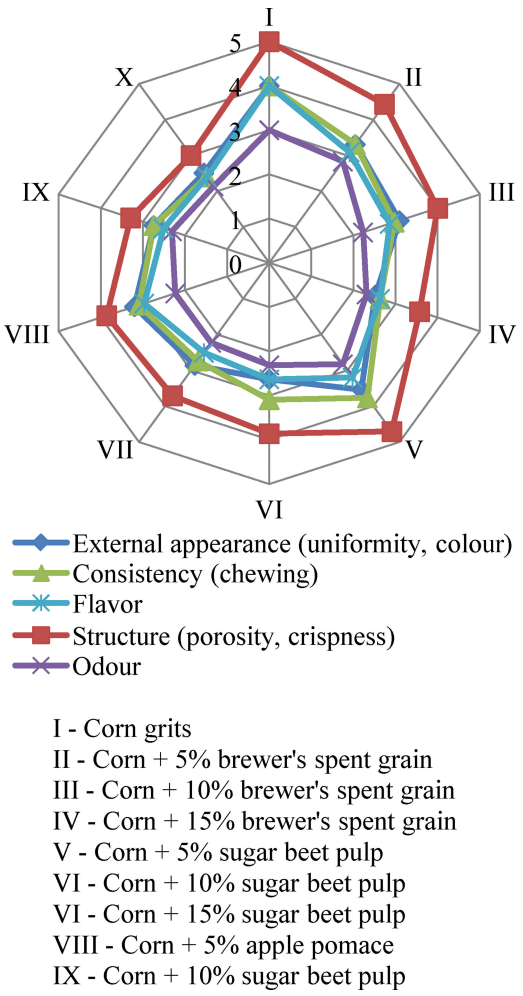

Figure 2. Sensory evaluation results of the corn snack products developed as part of the project FUNEXFOOD (HRZZ-1321) (Jozinović, 2015)

4. CONCLUSION

The trend of improving the nutritional value of various types of food products, including extruded products, is increasing as a result of increased consumer awareness about the importance of healthy diets and the increased demand for so-called functional products. On the other hand, the food industry is faced with the problem of generating large quantities of by-products, which are usually classified as waste, even though they are rich in nutritionally valuable components and can be used in the production of new products. This paper presents a part of the potential utilization of various by-products in the production of extruded products, along with examples provided by other researchers and the examples provided by the research team on the project FUNEXFOOD.

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