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Diet and the Context of Fruit Industry

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Abstract: Poland is a big world producer of fruits and fruit products. The fruit industry leaves in large scale during fruit processing production waste called fruit pomace. Generally, the fruit pomace is thrown away on the prisms and calling production residues. Fruit pomace after processing still holds high amount of valuable compounds beneficial for human health, like dietary fibre, pectin and minerals. It also contains the broad spectrum of polyphenols which have high antioxidant activity. Therefore, it has big potential for being reutilized into pro-health edible products, not only for animal feed or pectin production as it mostly happens today. Many of the pomace components may be also successfully used in non-food industries like fuel industry; or be bio-transformed in the other way. For that reason, the use of fruit pomace as a raw material should be extended to production of more effective products to ensure sustainable development. Due to the problem of production residues disposal, it is advisable to present the possibility of further utilization of fruit waste and the consequent.

Keywords: *fruit pomace, waste utilization, fruits*

JEL codes: *I, L, O, Q*

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1. Introduction

The amount of world's total fruit production in the year 2013 was 790 million tons, with noticeable growth trend. Poland is a significant fruit producer on a global scale (Table 1.); among the European Union countries, Poland is ranked higher than Greece and Germany (Agencja Rynku Rolnego, 2014). Poland is one of the five top producers of apples in the world, the largest producer of chokeberries; ranks second place in current production and first in the European Union of sour cherries. In large scale in the fruit industry (mostly during juice production) from 25 to 35 percent

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of mass is being lost as the by-products (Rembowski, 1998). The production waste from the fruit industry can be categorized into two types: first, named the belt rejection of fruits thrown away during the sorting on the belt (spoiled, bruised), and the second called fruit pomace - generated during production of juice concentrate (in Poland mainly from apples), juice-drink and nectar.

Only the second type of fruit industry waste could be processed in food products in case of compliance with the technological sequence. Fresh fruit pomace has ~~a~~ high water content, what causes increased risk of developing undesirable microorganisms. Therefore, fruit pomace should be immediately dried after extraction (Kruczek, et. al., 2016). Dried pomace can be stored at room temperature for a long time, which would maintain continuity of production after season, particularly in Poland where season lasts only a few months. Unfortunately fruit pomace is usually thrown away which causes increasing the production waste amount, or is used as raw material in feed production. However, fruit pomace as a part of fruit is a rich source of many valuable for human health compounds, like: minerals, carbohydrate, pectin, antioxidants and crude fibre, so it has big potential for being converted into edible products and non-food products. It is important to identify the different ways of reuse for fruit pomace to preserve sustainable development of fruit industry. Due to the problem of waste disposal, it is advisable to present the possibility of further utilization of the waste of fruit production and the consequent barking for both man and the environment.

Table 1. Fruit harvest in Poland in years 2009-2013 (thousand tonnes)

	2009	**2010**	**2011**	**2012**	**2013**
Apples	2.626	1.878	2.493	2.877	3.085
Pears	83	47	63	65	76
Sour cheries	189	147	175	175	188
Plums	121	84	92	103	102
Sweet cherries	51	40	38	41	48
Peaches	19	9	9	9	10
Strawberries	198	153	166	150	193
Currants	196	196	170	195	199
Chokeberries	37	53	48	51	58
Highbush blueberries	11	9	9	11	13
Fruits in total	**3.646**	**2.744**	**3.415**	**3.843**	**4.129**

Source: Agricultural Market Agency (Agencja Rynku Rolnego, 2015)

2. Dietary fibre

According to American Association of Cereal Chemists (2000) definition, dietary fibre is composed of edible part of plants or carbohydrates which could not be digested and absorbed in the human small intestine, but could be completely or partially fermented in the large-intestine. The dietary fibre plays important role for human health, it prevents and treats obesity, atherosclerosis, large intestine cancer or diabetes (Jenkins, et al., 2004). Dietary fibre consists of two components: soluble (mostly pectin) and insoluble fibre (mostly hemicellulose, cellulose and lignin). When the fibre ratio is close to 1:2 it indicates that the fibre is appropriate for use as a food component (Figuerola, et al., 2005). As today, dietary intake of fibre in Western countries is about 50 percent too low. Therefore, it is recommended to increase amount of dietary fibre in food products. Fruit pomace is a rich source of dietary fibre which has better quality and better components ratio than the cereal one (Table 2.). Soluble fibre from fruit can lower the levels of total cholesterol. Dietary fibre from apple retains up 1.5 g fat/g fibre. Furthermore, fruit pomace has the ability to bind heavy metal compounds- pectin and hemicellulose have the strongest capacity of metal-ion binding. Lignin has poor properties, except lignin from apple and rosehip pomace which have ~~a~~ great capacity of binding cadmium ions. Borycka and Zuchowski (1998) have found that the blackcurrant pomace have the best relative cadmium-binding capacity (Borycka & Żuchowski, 1998). The polyphenol components from chokeberry pomace significantly increase binding of most popular heavy metal ions (Nawirska, 2005). Dietary fibre plays also important role as technological addition to food processing. The fibre from apple pomace can be used in the formulation of foods, modifying texture and enhancing the stability of the food products, resulting from water and fat absorption properties of dietary fibre (Thebaudin, et al., 1997).

Table 2. Dietary fibre composition in selected fruits pomace and cereal brans (g/100g dry matter)

	Total dietary fibre	Insoluble dietary fibre	Soluble dietary fibre
Apple	60	46	14
Pear	36	22	14
Orange	38	24	14
Peach	36	26	10
Wheat bran	44	41	3
Oat bran	24	20	4

Source: (Grigelmo-Miguel & Martin-Belloso, 1999)

3. Antioxidants

Fruits are one of the main dietary sources of antioxidants in the human diet. Antioxidants protect human body from many diseases. Oxidative stress caused by reactive types of oxygen and nitrogen can damage many biological macrostructures like proteins, lipids, enzymes, carbohydrates and DNA, what leads to damage of the biological membranes, mutations and transformation, and finally cancer. Studies have shown that antioxidants can decrease free radicals in the human body through scavenging activity, supporting the anti-oxidative enzymes, and catching catalysts ions of free-radical reactions (Lobo, et al., 2010). Polyphenols are a large group of antioxidants commonly present in fruit pomace (Brenes, et al., 2016; Struck, et al., 2016, Persic, et al., 2017).

In apple pomace the mostly present are: flavonoids, flavonols, hydroxycinnamates and dihydrochalcones (Kołodziejczyk, et al., 2007). In meat industry addition of apple pomace extract not only decreases the need of addition of synthetic antioxidants, but also increases nutritional volume of final product (Peiretti & Gal, 2015).

Grape pomace contains large amount of phenolic acids, phenolic alcohol, flavan-3-ols and flavonoids and the most famous antioxidant: resveratrol (Lu & Foo, 1999). Resveratrol is one of the most pro-health antioxidants in grape pomace. Numerous beneficial effects of that compound have been shown, including inhibition of low density lipoprotein, cardio protection, hindering of platelet aggregation, or anti-inflammatory effects. For industry of supplements and pharmacy resveratrol is made mostly from grounded grape pomace (Das, et al., 2010). Grape pomace is a valuable raw-material in bakery industry, where it can increase the content of dietary fibre and antioxidants in cakes, muffins and cookies (Maner, et al., 2015)

The blackcurrant pomace contains mostly anthocyanins and flavonoids. The supplementation of rabbits with blackcurrant extract has favourably affected the serum lipids and the antioxidant status of the body, and can be useful in treatment of obesity (Jurgoński, et al., 2014).

4. Fruit pomace seeds

Fruit seeds are rich in proteins, carbohydrates, minerals and lipids, what make them useful as valuable pro-health raw material. Fruits seed oils mostly consist of unsaturated fats, but could also contain tocopherols, hydrocarbons and sterols.

Apple pomace contains about 7% of seeds. The apple seeds consist in 15% of lipids; where the main component (about 50%) is unsaturated fat: linoleic acid (Kołodziejczyk, et al., 2007). The in vitro studies have shown that oil extracted from apple pomace has antimicrobial, antioxidant and anti-proliferative activities; what indicates potential applications in the food industry (Foschki, et al., 2015).

Grape seeds have the highest concentration of polyphenols (70% of grape pomace are polyphenols). The in vivo studies have shown that grape seed oil has property to reduce the low-density lipoprotein level, to prevent hypertension and heart attacks. This oil could also be a nutritional diet supplement for children and elderly (Agostini, et al., 2012).

Anti-oxidant and anti-inflammatory effect of kiwi fruit seeds has been proved as well; therefore they can be used as a source of many biological active compounds (Deng, et al., 2016).

5. Fuel purposes

Apart from the fact that fruits are a reach source of many nutrients and dietary fibre they can also be a good material for the production of fuels. The production waste from juice extraction hold large volumes of water, fermentable sugars (monosaccharides) and lignocellulosic materials, which together make them cheap materials for fuel purposes. They are two main biological processes which could be applied to fruit pomace for energy recovery: biogas production through anaerobic digestion, or bioethanol production. The availability of easily assimilated sugars and very fragmented structure make fresh pomace a great source for both of those processes.

Chatanta et al. have shown that solid state fermentation process for bioethanol production from apple pomace is very efficient (Chatanta, et al., 2007). They used consortia of micro-cultures consisting of Saccharomyces cerevisiae, Aspergillus foetidus and Fusarium oxysporum to obtain 19.09% of ethanol from apple pomace, using 98% of available sugars (monosaccharides), but without utilization of lignocellulosic materials (Chatanta, et al., 2007) Most of available types of yeast do not have enzymes allowing for hydrolysis, which could be used as a carbon source from lignocellulosic materials present in fruit pomace. Further researchers could solve the problem by using specially selected microorganisms i.e.: *Pichia stipitis*, *Hansenula* (*Ogataea*) *polymorpha*, which could carry out fermentation on arabinose and xylose with use of specially designed *S. cerevisiae* in order to increase the alcohol yield (Sybirny, et al., 2007). Interesting samples of using fruit by-products were shown by other authors (Mendes, et al., 2013). Grape pomace obtained from white wine production was subjected to a two-step fermentation: the first step consisted of extraction of fermenting sugars in boiling water, cooling and addition of *S. cerevisiae* to carry out ethanol fermentation, the second step involved extraction of pro-health oleanolic acid with non-polar solvent hexane. The skins remaining after extraction were used as the main component of low density insulation boards (Mendes, et al., 2013).

As mentioned above, the amount of methane in biogas depends on the level of easily digestible sugars. Biogas from grape pomace can contain even more than 82% methane, which shows that this raw material is excellent for biogas production (El Achkar, et al., 2016). The apple pomace, as well as a grape pomace, has a high yield of biogas production.

The possibility of biogas production from a mixture of fresh apple pulp with *Reynoutria x biochemica* biomass was tested. As a result, biogas of a 57-62% methane content was obtained (Kupryś-Caruk et al., 2014). In another experimental study, four substrates, including apples, with a liquid level of 90% were examined. The fermentation process lasted through 30 days. Approximately 90 Ndm^3 * kg $s.m.^{-1}$ of biogas with the composition of 62% methane and about 30% carbon dioxide were obtained from apples (Sikora & Mruk 2016). From Olech et al. (2016) research shows, that apple pulp and corn silage are good substrates for biogas production. In the fraction where the ratio of corn silage and apple pomace was 25: 75%, methane yield was 57%. Apple pomace can also be used as a substrate for the production of bio-hydrogen (Pachapur et al. 2015). Hydrogen fuel has significant energy efficiency, over 2.7 times higher that of hydrocarbon fuels (Chandrasekhar et al., 2015, Bockris, 2002, Christopher & Dimitrios, 2012). To summarize, the possibility of using apple waste as a carbon source has been proved (Lu et al. 2016).

6. Production of enzymes

High moisture and large quantity of easily digestible compounds of pomace expand their possibility to be re-used in production of enzymes. Solid state fermentation is one of the biotechnological processes, which is very often used in reutilization of fruit pomace. This kind of fermentation involves solids without (or almost) water. The substrate however must contain enough moisture to ensure appropriate conditions for growth of microorganisms. The solid state fermentation produces enzymes with higher titters than in submerged fermentation. Cellulases are important and relatively expensive enzymes with high application in paper, textile and food industries. In recent years, much work has been carried out to find cheap ways to receive those enzymes. The Sun et al. (2010) group presented the potential of apple pomace to be used as a raw material for the production of cellulose by *Trichoderma sp.* GIM.30010. They have found that moisture content is the critical factor for celluloses production and cell growth under solid state fermentation. Xylanase and pectinase production by *Aspergillus awamori* on grape pomace in solid state fermentation was carried out by Botella et al. group (2007). The enzymes are often used commercially in the pulp production, paper, food and animal feed industries. Solid grape pomace could be used as an alternative for hydrolytic enzyme production. Moreover, moisture was the critical factor for enzymes production, and extra carbon sources were necessary (Botella, et al., 2007).

7. Conclusion

Fruit pomace does not have any significant application yet. Low level of protein or other nutrients, anti-nutritional factors like phenolic components (which inhibit ruminal symbionts) limit the use of fruit pomace as animal food (especially for ruminants). Furthermore, phenolic compounds in pomace could inhibit the germination properties in fertilizers. But still, large-scale annual produce of pomace in fruit industry is a huge problem for the producers. Different varieties and high amounts of producing fruit pomace suggest that single way of use is insufficient. Given this situation it is highly recommended to look for different processes that allow controlling elimination of the production waste and the full use of the potential of the pomace.

Fruit pomace could be considered as a great example of by-products that can be successfully reused to benefit people and the environment.

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Marek KRUCZEK, Dorota GUMUL, Barbara DRYGAŚ, Elżbieta OLECH, Paweł DRYGAŚ, Anna ARECZUK and Halina GAMBUŚ

Zrównoważony rozwój przemysłu owocowego

Streszczenie

Polska jest znaczącym producentem owoców i produktów owocowych na świecie. Przemysł owocowy wytwarza na szeroką skalę podczas przetwarzania owoców pozostałości poprodukcyjne zwane wytłokami owocowymi. Generalnie wytłoki te są składowane na pryzmach i nazywane odpadem poprodukcyjnym. Wytłoki owocowe po procesie przetwarzania nadal cechują się wysoką zawartością składników prozdrowotnych, takich jak: błonnik pokarmowy, pektyna oraz składniki mineralne. Zawierają również duże ilości polifenoli charakteryzujących się wysoką aktywnością przeciwoksydacyjną. Dlatego też mają one wysoki potencjał do reutylizacji w prozdrowotne produkty spożywcze, nie tylko na pasze dla zwierząt czy do produkcji pektyn jak to miało miejsce na chwilę obecną. Wiele z składników wytłoków może być również z powodzeniem wykorzystywana w przemyśle niespożywczym, takim jak przemysł paliwowym lub ulegać innego rodzaju biotransofrmacjom. Z tego tez powodu wykorzystanie wytłoków owocowych jako surowca w innych procesach powinno być rozszerzone o otrzymywanie bardziej efektywnych produktów zgodnie z zasadami zrównoważonego rozwoju. Ze względu na problem utylizacji pozostałości poprodukcyjnych wskazane jest przedstawienie możliwości dalszego wykorzystania odpadów owocowych i wynikających z nich konsekwencji.

Słowa kluczowe*: wytłoki owocowe, utylizacja odpadów, owoce*