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Investigation of extruded cereals enriched with plant by-products and their use in fermented beverage production

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Abstract. The aim of the study was to analyse the quality of extruded cereals enriched with plant by-products and to obtain fermented drinks from production rejects. Extrusion was performed with co-rotating twin-screw extruder (compression ratio 8:1) at MILZU Ltd. from rye and oat flour (80:20, control samples) with addition of apple (ABF), carrot (CBF) and pumpkin (PBF) by-product flour in various amounts (10%, 15% and 20%). Naturally fermented kvass production process was used for non-alcoholic fermented beverage production. Total dietary fibre (TDF), textural properties and sensory features of extruded products after addition of by-products (BP) were determined. Dry matter, active acidity and sensory properties were analysed in fermented beverages. The obtained results showed a 12-55% increase in TDF of extruded cereals (11.8 g 100 g^{-1}) after addition of plant by-products. All extruded samples with BP showed lower hardness levels than control (35.55 ± 2.95 N); samples with PBF were the least hard ($P < 0.05$). Samples with the lowest bulk density were obtained by the addition of 10% and 15% PBF, and 15% CBF, whereas addition of apple by-product flour in all tested concentrations gave the samples a higher bulk density compared to control. Highest taste and aftertaste scores using 5-point hedonic scale were given to samples with addition of 15% and 20% ABF, which also showed high consumer acceptance. With regards to fermented drinks, the highest dry matter content was found in PBF and ABF drink, 8.1 ± 0.1 and 7.0 ± 0.1, respectively. Sensory evaluation of fermented beverages showed that the intensity of flavour, acidity and aroma was most pronounced in sample with ABF, whereas colour was most pronounced in sample with PBF. In order to reduce production costs, it is possible to use production rejects of extruded cereals enriched with plant by-products to obtain new products.

Key words: by–products, extrusion, dietary fibre, fermented beverage, sensory properties.

INTRODUCTION

Fruits and vegetables have the highest wastage rates of any food (Vaqué, 2015). Apple, carrot and pumpkin processing industry produces such by-products as pomace, peel, and seeds. They are used, possibly as animal feed, for biogas production, or not used at all and utilized. About 100 million tons of food are destroyed in the European Union annually (Vaqué, 2015). Disposal of food is not only an ethical or economic issue, but it also has important consequences for the exhaustion of natural resources. By-products of vegetable and fruit production still contain such biologically valuable substances as dietary fibre, vitamins, carotenes, antioxidants, organic acids that play an important role in human health (Gupta et al., 2015; Sharma et al., 2016; Lucera et al., 2018). Nowadays, the interest in products that are not only healthy, sensory acceptable and price-responsive to a wide range of consumers, but also contain nutrients that can provide the consumer the required daily intake is increasing.

Several researchers have used such fruit and vegetable by-products as apples, pears, oranges, peaches, black currants, cherries, artichokes, asparagus, carrot, legumes and tomatoes (Černiauskiene et al., 2014; Zargar et al., 2014) as dietary supplements in functional foods to contribute to optimal health (Arscott & Tanumihardjo, 2010; Karthika et al., 2016; Sharma et al., 2016).

By-products of apple (*Malus domestico*), carrot (*Daucus carota*) and pumpkin (*Cucurbita pepo*) processing are peel, pomace and seeds that contain a significant amount of fibre, vitamins, enzymes, sugars (Wolfe et al., 2003) which can be used for functional foods and beverages (Henríquez et al., 2013). One of such products is extruded cereals.

Extruded products are relatively new in the grocery segment, but can compete with other snack products. High-temperature, short-time extrusion technology (HTST) has become popular in preparing snacks and breakfast cereals using starchy base products (Nikmaram et al., 2017). Extrusion could be a viable and new method of adding fruit and vegetable by-products to convert them into innovative and functional foods in order to offer a healthy range of products for consumers.

However, similar to by-products which are considered a food waste, such production rejects as deformed product pieces are made during extrusion cooking, which do not have a demand in market. According to production data of Milzu Ltd., production rejects composed 1,500 kg monthly in 2018, which accounts to 10% of total production. At the moment, production rejects are donated as feed for forest animals.

In order to promote non-waste technology and reduce production costs, several possibilities to utilise production rejects could be considered, e.g., alternative to breadcrumbs for oven baked or fried products, compressed crispbreads, crackers or cookies, or fermented beverage production in order to transform this type of food waste into value products. Naturally fermented beverages are considered healthier alternatives to water compared to soft drinks (Wilburn & Ryan, 2016), therefore, given that consumers often prefer soft beverages to water, testing of alternative raw materials for fermentation is necessary.

The aim of the study was to analyse the quality of extruded cereals enriched with plant by-products and to obtain a fermented beverage from production rejects.

MATERIALS AND METHODS

The study was carried out at the scientific laboratories of the Faculty of Food Technology, Latvia University of Life Sciences and Technologies and production facility of Milzu Ltd.

Production of extruded cereals enriched with plant by-products

Control samples were prepared from rye and oat flour (80:20) and 17% water. Enriched experimental samples were prepared by replacing 10%, 15% and 20% of the dry ingredients with apple (ABF), carrot (CBF) and pumpkin (PBF) by-product flour (Table 1).

Table 1. Composition of experimental samples.

Sample	Composition
Control crispbread	80% - rye, 20% - oats
A10	90% - control crispbread, 10% - apple by-product flour (ABF)
A15	85% - control crispbread, 15% - apple by-product flour (ABF)
A20	80% - control crispbread, 20% - apple by-product flour (ABF)
C10	90% - control crispbread, 10% - carrot by-product flour (CBF)
C15	85% - control crispbread, 15% - carrot by-product flour (CBF)
C20	80% - control crispbread, 20% - carrot by-product flour (CBF)
P10	90% - control crispbread, 10% - pumpkin by-product flour (PBF)
P15	85% - control crispbread, 15% - pumpkin by-product flour (PBF)
P20	80% - control crispbread, 20% - pumpkin by-product flour (PBF)

Extruded cereals (crispbreads) were prepared using a co-rotating twin-screw extruder SLG65 – III (Datong Machinery, China) (compression ratio 8:1) at Milzu Ltd. The main drive of extruder was provided with a 7.5 HP motor (400 V, 3 HP, 50 cycles). Temperatures for extrusion zones were 125 °C /135 °C /145 °C according to developed process at Milzu Ltd.

Quality analysis of extruded cereals enriched with plant by-products

The content of total dietary fibre was assessed according to AOAC 985.29 using FOSS Fibertec™ 1023 Dietary Fibre analyser and Megazyme enzymes.

Textural properties and hardness of extruded cereal samples were determined instrumentally using TA.XTplus Texture Analyser (Stable Micro Systems, UK), data processing was completed with Texture Exponent 32. Samples were compressed with a 35 mm compression plate with test speed 2 mm s^{-1}, compressive force was measured.

Bulk density of the extrudates was calculated according to the equation (Varsha & Mohan, 2016):

$$Bulk\ density = \frac{Weight\ of\ the\ smaple, g}{Volume\ of\ the\ sample, mL}$$

5-point hedonic scale (ISO 4121:2003) and ranking test (ISO 8587:2006) were applied to determine sensory features of products. Overall liking (hedonic scale) was used to define acceptance by trained panellists. Extruded cereals enriched with plant by-products were evaluated by 35 trained panellists (20% men and 80% women), average age 32 years. Samples with different by-product flour addition were assessed on separate days. Such sensory parameters as taste, aftertaste, colour intensity, volume and crispness were determined. The product was considered acceptable if the it scored 3 or more points on the scale by 50% of evaluators. Ranking test (1 – most appealing, 4 – least appealing) was used to define consumer acceptance during the international food exhibition RigaFood in 2017; a total of 200 consumers participated (40% men and 60% women, average age 28 years).

Production of non-alcoholic fermented beverages from extruded cereals enriched with plant by-products

Naturally fermented kvass production process (Lidums et al., 2014) was modified to produce fermented beverages from extrudates. The following materials were used: extruded cereal production rejects with 15% apple, carrot and pumpkin addition, baker's yeast *Saccharomyces cerevisiae* (JSC Rigas Raugs), lactic acid bacteria *Leuconostoc mesentericus* (Chr. Hansen Ltd), beet sugar (Dansukker Ltd) and dark malt extract (Coopers Ltd).

One litre beverage mash was produced by soaking 200 g of extruded cereal rejects and 2 g dark malt in 2 litres of hot water (78 ± 2 °C) for 3 hours. Then the suspension was filtered (300 µm) and liquid fraction was cooled. 1 g baker's yeast, 2 units of lactic acid starter and 10 g of sugar were added to 1 litre extruded cereal mash, fermentation time – 9 hours at 27 ± 1 °C. Then fermented beverages were cooled to 3 ± 1 °C, filtered (5 µm) to remove yeasts and the remaining sugar (20 g) was added. Fermented beverages were matured in 0.5 litre PET bottles for 12 hours at 6 ± 1 °C.

Quality analysis of fermented beverages from extruded cereals enriched with plant by-products

Active acidity (pH) was assessed according to AACC 02-31 method, dry matter (ISO 6496) was determined using hand-held refractometer HR32B (Schmidt + Haensch, Germany).

Sensory evaluation of fermented drinks was carried out by 25 trained panellists (40% men and 60% women, average age 37 years). Four samples of fermented drinks were served to each panellist in a randomised sequence. Line scale (ISO 4121:2003) was used to evaluate such parameters as the intensity of aroma, acidity, colour and flavour of fermented drinks.

Data processing

Microsoft Excel v16.0 for Windows was used to process the obtained data; mean ± standard deviation was calculated. Cross-comparison of data was performed using ANOVA, Tukey's test and correlation analysis. Friedmann test is used to evaluate the results of ranking test. For the interpretation of the results it is assumed that α=0.05 with 95% confidence.

RESULTS AND DISCUSSION

Dietary fibre in extruded cereals enriched with plant by-products

The addition of plant by-products influenced the amount of TDF in samples (Fig. 1). TDF content in control sample was 11.8 g 100 g^{-1}, partial replacement of rye-oat base with by-product flour (BPF) increased total dietary fibre content in all samples. In samples with the highest proportion of BPF (20%) total dietary fibre content increase was 18.29 g 100 g^{-1} for apple, 14.82 g 100 g^{-1} for carrot and 15.49 g 100 g^{-1} for pumpkin by-product flour. A total of 12–55% increase in TDF of extruded cereals with BPF was observed, depending on the replacement of BPF in base recipe. The most noticeable increase in TDF was obtained when using apple by-product flour, especially at 20%. A similar trend has been observed by several researchers (Karthika et al., 2016; Sharma et al., 2016, Lucera et al., 2018).

Incorporation of fibre-rich ingredients influences physical properties of the extrudates such as oil and water binding ability, gel formation, texture and crispness (Elleuch et al., 2011). The quality of snacks depends upon the solubility of fibres (Henríquez et al., 2010). Soluble fibre enhances bubble formation and the crispness of extrudate (Varsha & Mohan, 2016).

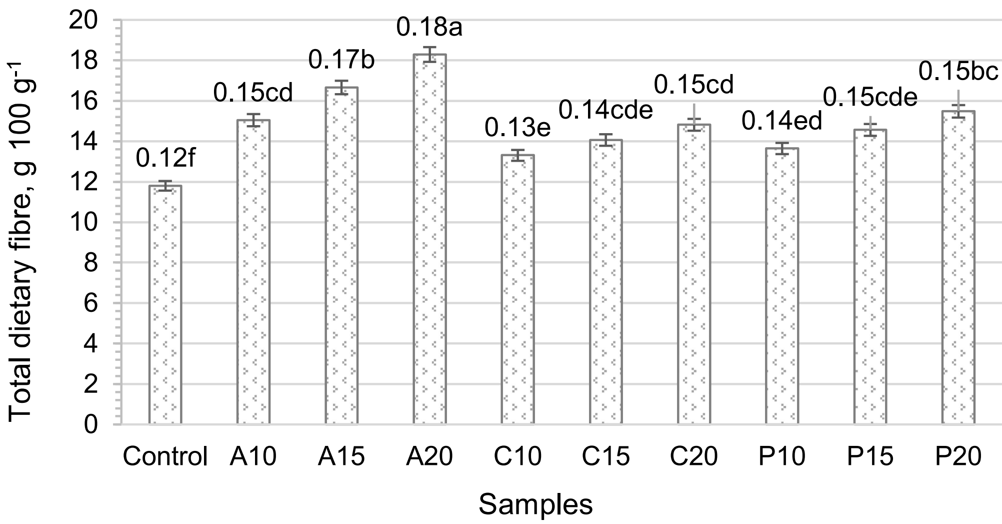

Figure 1. Content of dietary fibre in extruded samples. Values sharing the same letters are not significantly different ($P > 0.05$). Sample abbreviations are summarised in Table 1.

Bulk density and hardness of extruded cereals enriched with plant by-products

Textural properties of extruded products are perceived by the final consumer as prime criteria of acceptance.

Hardness (Table 2) of extruded products is the surface property, which is essential to obtain the shape, and it is expressed as the maximum force applied by teeth to compress the food (Varsha & Mohan, 2016).

Extruded product having minimum hardness is highly acceptable among the consumers, as it is easier to chew. The minimum force to break the product was found for samples with 10% carrot (16.28 ± 2.80 N) and pumpkin (16.70 ± 1.20 N) addition, and 15% apple (22.42 ± 4.28 N) addition. The hardness of the extruded products is highly dependent on their moisture content and density.

Table 2. Bulk density and hardness of extrudates

Sample	Bulk density, g mL^{-1}	Hardness, N
Control	10.85 ± 0.85 cd*	35.55 ± 2.95 a
A10	11.82 ± 0.18 bc	33.59 ± 2.78 a
A15	14.62 ± 0.35 b	22.42 ± 4.28 b
A20	17.41 ± 0.44 a	18.80 ± 0.42 cd
B10	9.71 ± 0.07 de	16.28 ± 2.80 d
B15	8.80 ± 0.19 e	17.69 ± 3.84 cd
B20	13.70 ± 0.67 b	19.30 ± 3.86 c
P10	8.56 ± 0.47 e	16.70 ± 1.20 cd
P15	8.13 ± 0.04 e	19.29 ± 0.22 c
P20	12.64 ± 0.65 bc	18.95 ± 2.35 c

* Values within the same column sharing the same letters are not significantly different ($P > 0.05$).

Bulk density (Table 2) of extruded products is an important factor in quality acceptance, storage conditions, as well as desired form. Minimum bulk density is desired for an acceptable product. Bulk density is the parameter that shows how much space is between cells of the product and the volume of it; lower bulk density gives a better porosity and extrudate aeration of the structure, which is desirable mainly for cereal snacks (Liu & Yao, 2007). A significantly lower bulk density was found for extruded cereals with 15% pumpkin (8.13 ± 0.04 g mL^{-1}) or carrot (8.80 ± 0.19 g mL^{-1}) and 10% pumpkin (8.56 ± 0.47 g mL^{-1}) addition, whereas addition of apple by-product flour in all tested concentrations gave the samples a higher bulk density compared to control.

Correlation analysis of several parameters (Table 3) reviled that in all samples with added BPF correlation between TDF and bulk density was very strong, i.e., 0.78 ($P < 0.05$), whereas correlation between TDF and hardness showed the negative correlation of -0.28, therefore it can be concluded that addition of dietary fibre-rich ingredients aids in decreasing the hardness of extrudates. Correlation between bulk density and hardness of samples was very week (0.08, $P < 0.05$).

Table 3. Correlation (Pearson's) coefficients between the TDF, bulk density and hardness of samples

Correlation between groups	
TDF and bulk density	0.78 ($P < 0.05$)
TDF and hardness	-0.28 ($P < 0.05$)
bulk density and hardness	0.08 ($P < 0.05$)

Sensory evaluation of extruded cereals enriched with plant by-products

Sensory parameters of foods are important when developing new products or improving the recipes as negative sensory experiences can reduce consumer adherence to purchasing specific food products (Olsen et al., 2012). As BPF contain sugar, they can alter the taste of products (Konrade et al., 2017). Within each group of base recipe replacement with the same fruit/vegetable BPF, the highest taste scores (Table 4) were given to extruded cereal samples with addition of 20% apple by-product flour – 4.2 (A20), 15% carrot BPF – 3.7 (C15) and 15% pumpkin BPF – 3.8 (P15); the taste was significantly more pleasant than that of control sample ($P < 0.05$). Out of samples with 20% addition of BPF, only sample with apple showed potential in terms of taste.

With regards to aftertaste, control sample (3.9) and samples A15 (3.9) and C10 (3.7) scored higher numbers. The lowest preference of taste and aftertaste was found in extruded cereals with 20% addition of carrot and pumpkin BPF.

The addition of BPF caused significant colour changes for all samples. Panellists liked the colour of samples with 20% BPF the most, namely A20 (3.8), C20 (4.5), P20 (3.0), the colour was significantly better than that of control sample ($P < 0.05$). Colour intensity has been previously associated with biologically active carotenoids the composition of which is different in BPF (Delgado-Nieblas et al., 2015). A previous study showed that it is possible to increase the content of carotenes in extruded cereals when adding plant by-product flour from 0.77 ± 0.01 mg 100 g^{-1} (control sample) up to 6.51 ± 0.02 mg 100 g^{-1} in samples with 20% pumpkin BPF (Konrade et al., 2018).

The acceptability of crispiness decreased for all samples with BPF compared to control, which was also observed instrumentally (Table 2). Higher crispiness level was detected in samples with 15% and 20% apple BPF, 4.3 and 4.3, respectively. These sensory data coincide with instrumentally obtained data.

Table 4 ensory properties of extruded cereal samples enriched with by-product flour. Sample abbreviations are summarised in Table 1.

Sample	Colour intensity	Volume	Crispness	Taste	Aftertaste
Control	2.1 d*	3.6 ab	4.1 ab	2.9 cd	3.9 a
A10	3.1 bc	3.8 a	3.7 b	2.8 d	3.5 b
A15	3.6 ab	3.0 bc	4.3 a	3.7 b	3.9 a
A20	3.8 a	2.9 c	4.3 a	4.2 a	3.4 bc
C10	2.2 d	3.6 ab	3.9 ab	2.8 d	3.7 ab
C15	2.9 c	2.9 c	3.6 b	3.7 b	3.1 c
C20	4.5 a	1.9 d	2.6 cd	2.2 e	2.5 d
P10	2.8 c	3.8 a	3.4 bc	3.2 c	3.4 b
P15	2.9 c	3.0 bc	3.2 bc	3.8 ab	3.2 c
P20	3.0 c	2.0 d	3.0 c	2.2 e	1.6 e

* Values within the same column sharing the same letters are not significantly different ($P > 0.05$).

The results of ranking test (1 – most appealing, 4 – least appealing) of products showed the consumers' acceptance for all examples with 15% BPF addition ($P < 0.05$). Consumers ranged sample A15 as the most appealing and samples C20 and P20 as the least appealing.

Based on sensory evaluation results, samples with 15% BPF showed the highest consumer acceptance, therefore, the next step of the research, namely development of fermented beverages, was carried out using production rejects with 15% apple, pumpkin and carrot by-product flour addition.

Quality evaluation of non-alcoholic fermented beverages

Fermentation, being a quite inexpensive technology, plays an important role in food processing of many countries (Misihairabgwi & Cheikhyoussef, 2017). The fermented non-alcoholic beverage best known to Eastern European countries is kvass which has been traditionally made from bread; nowadays, however, such modifications as fruits and vegetables as the main ingredient exist (Lidums et al., 2016). Therefore, the possibility of using product rejects of extruded cereals for kvass-like fermented beverage production was considered.

The obtained pH levels of apple, carrot and pumpkin enriched extruded cereal beverages were within the range of 4.24 to 4.35; ABF beverage had the highest acidity. Dry matter content in ABF, PBF and CBF beverages was 7.0 ± 0.1, 8.1 ± 0.1 and 5.3 ± 0.1, respectively. pH level in experimental fermented beverages was higher compared to traditional kvass (pH 3.88 ± 0.02), whereas dry matter content was similar (7.0 to 8.6 for kvass) (Lidums et al., 2016). Rye bread, which is traditionally used for naturally fermented kvass production in the form of bread rusks, contains higher amounts of sugar, thus explaining the lower pH levels in traditional kvass as more sugar is available for fermentation and acid production by yeasts and lactic acid bacteria (Salovaara & Gänzle, 2011). Other researchers have also shown similar results on pH and dry matter levels of fermented beverages from plant-based ingredients (pearl millet, chickpea, soy) (Misihairabgwi & Cheikhyoussef, 2017; Wang et al., 2018).

The evaluation of the intensity of sensory properties of fermented beverages from extruded cereals enriched with plant by-product flour showed differences within all tested sensory properties (Fig. 3). The most intense colour was found in sample made from cereals with pumpkin by-product flour addition ($P < 0.05$). The intensity of flavour, acidity and aroma was significantly more pronounced in sample with ABF ($P < 0.05$), compared to other samples. The lowest intensity for all sensory properties was found in sample with CBF.

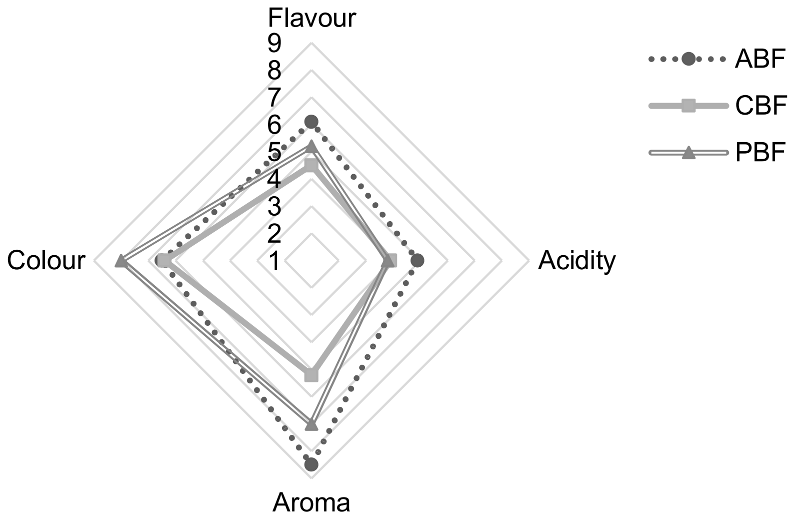

Figure 3. Intensity of sensory properties of fermented beverages from extruded cereals enriched with plant by-product flour. Sample abbreviations are summarised in Table 1.

All sensory properties of the experimental fermented beverage samples were lower than in traditional kvass, especially acidity. Kvass has a slightly more pronounced colour (9.0), flavour (8.9) and aroma (10.4) (Lidums et al., 2016). The mouthfeel and flavour of the experimental fermented beverage samples was more similar to kombucha which is not a traditional beverage in Latvia. A recent research on chickpea as an alternative to soy in fermented plant-based beverages associated lower scores with the cultural background of panellists (Wang et al., 2018); thus, suggesting that consumer habits have a significant effect on acceptance of new products.

CONCLUSIONS

The addition of fruit and vegetable by-product flour can be used to create added value to rye-oat extruded cereals. Increasing the amount of fruit and vegetable by-product flour in the extrusion blend increases total dietary fibre content and bulk density, while decreasing hardness of the extruded cereals enriched with plant by-product flour. Sensory evaluation of extruded cereals enriched with plant by-product flour showed that addition of BPF decreased crispiness and increased colour intensity of products compared to control. The most acceptable products by consumers were extruded cereals enriched with 15% apple, carrot and pumpkin by-product flour, which would form the majority of production rejects.

The results of preliminary research on the production of fermented beverages from production rejects of extruded cereals enriched with plant by-product flour on a pilot scale established that visually defective products could be used to transform this type of food waste into value products, promoting non-waste technology and reducing production costs. However, research on a production scale is necessary, in addition to recipe modification according to sensory properties more accepted by consumers.

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