Wageningen Academic Publishers

Enrichment of wheat bread with apple pomace as a way to increase pro-health constituents

D. Gumul*, J. Korus, R. Ziobro and M. Kruczek

Department of Carbohydrates Technology, Faculty of Food Technology, University of Agriculture in Krakow, Balicka 122 St., 30-149 Kraków, Poland; rrgumul@cyf-kr.edu.pl, gumuldorota@gmail.com

Received: 10 July 2018 / Accepted: 5 December 2018

RESEARCH ARTICLE

Abstract

Apple pomace is a good source of bioactive components. Therefore, the use of dried apple pomace for the biofortification of wheat bread is highly justified. The aim of this work is to analyse the effect of different levels of the additive (5, 10, 15%) of whole and ground pomace on the chemical composition and the content of pro-health ingredients and also on physical characteristics and sensory evaluation of wheat bread. Among all analysed samples, the wheat bread with 5% whole pomace received the best scores (good volume, small baking loss, low crumb hardness in comparison to control on the day of baking and during storage). Although 5% addition of pomace did not guarantee such an increase of bioactive compounds as other applied levels, it caused an increase in total polyphenol content, flavonoids and anthocyanins by 55, 200 and 160% as compared to control, respectively. The addition of 5% whole apple pomace to wheat bread could be advised on industrial scale because of high consumer acceptance of such products.

Keywords: apple pomace, pro-health components, quality, wheat bread

1. Introduction

Global apple production has increased in the last decade by 38% from 55 to 76 million tonnes (http://www.fao.org/faostat), while average annual production of apples in the EU, estimated to be 10 million tonnes, is harvested mostly in the countries which specialise in their production, i.e. Poland, France, Italy and Germany (European Commission, 2014). Apples are mostly utilised in the production of juice, fruit wine, cider, spirit and vinegar, and the remaining off-product, i.e. apple pomace, is microbiologically unstable. This causes a problem, because large amounts of pomace that are produced in a short time, have to be dried, pressed, or ensilaged in order to be further utilised (Fronc and Nawirska, 1994). Such preserved pomace consisting of seeds, petioles, flesh with peel and husk, and seed nests, constitutes a heterogeneous fraction, which is a rich source of many compounds, such as protein, minerals, fibre, lipids, vitamins, phyto-compounds including polyphenols, etc. (Fronc and Nawirska, 1994; Waldbauer *et al.*, 2017). The ease of acquiring this off-product, its low cost and the presence of many of the above-mentioned nutrients, health-promoting and bioactive substances make it an attractive material for further conversion (e.g. drying). Up to now, the most common uses of apple pomace have covered the production of feed for farm animals, biofuels and biogas, pectins, dyes, etc. (Tarko *et al.*, 2012). Considering the fact that dried apple pomace is an excellent source of dietary fibre with preferably balanced soluble and insoluble fractions (1:2) (McKee and Latner, 2000), the resulting fibre preparations have been used for the production of wheat products (breads and cakes). However, attention should be paid to the second component, i.e. bioactive compounds from the group of polyphenols, which are an integral part of the fibre and reveal a pro-health character. Polyphenols have anti-inflammatory, anti-allergic, antithrombotic, antiviral and anti-carcinogenic properties. Many properties of phenolic acids and flavonoids result mainly from their antioxidant functions and the ability to modify enzymes responsible for immunological activity, carcinogenesis and cellular transformations (Mink *et al.*, 2007; Yokohira *et al.*, 2008). Therefore, the use of dried apple pomace for the biofortification of wheat bread is highly justified. The purpose of this work is to analyse the effect of different levels of the additive (5, 10, 15%) of whole and ground pomace on the chemical composition and the content of pro-health ingredients (fibre and polyphenols) of wheat bread. In addition, the analysis of the impact of the above mentioned additive on physical characteristics and sensory evaluation of wheat bread was performed.

2. Materials and methods

Materials

Materials consisted of wheat bread samples with a varying share of apple pomace. They were evaluated in terms of the content of nutritional components, the content of dietary fibre, the content of bioactive components, as well as physical characteristics and sensory evaluation. The characteristics of apple pomace as an additive is presented in Table 1.

Methods

Bread preparation

Bread was baked with wheat flour (PZZ Kraków, Krakow, Poland), yeast Saf-instant (Lesaffre, Marcq-en-Baroeul, France), salt (commercial) and whole or milled apple pomace (ZPOW HORTINO Leżajsk sp. z o.o., Leżajsk, Poland). Basic formulation contained 700 g of wheat flour, 31 g yeast, 10.5 g salt and water (its addition was adjusted for each dough, so as to obtain the same farinographic consistency as for control dough). It was modified by replacing 5, 10 and 15% wheat flour with an equivalent mass of apple pomace (in the case of whole apple pomace, it was first soaked with water at 20 °C for 90 minutes, drained on the sieve, and then added to the other constituents of the dough). The dough was prepared by a straight method, i.e. all ingredients were combined together for 10 minutes in a spiral mixer SP 12 (Diosna, Osnabrück, Germany). Then it was fermented in bulk for 20 minutes at 33 °C, 80% relative humidity, divided into 250 g portions, formed and left in metal pans for final fermentation which was continued under the above mentioned conditions for 30 minutes. Baking was performed in an electric oven MIWE Condo type CO 2 0608 (MIWE Michael Wenz GmbH, Arnstein, Germany), for 30 minutes at 230 °C. Baked loaves were removed from pans, weighted, cooled at ambient temperature for 90 minutes, reweighted and analysed or stored in polyethylene bags at 22±2 °C for further analyses. Each formulation was baked in two independent batches consisting of 7 loaves in each batch.

Chemical evaluation

The following analyses were performed on each sample of wheat breads with a share of apple pomace (additionally in apple pomace):

1. Chemical composition
   Content of basic nutritional components was performed by the methods of AOAC (2006). Protein (Nx5.7) was determined by Kjeldahl method (AOAC No. 950.36, using the extraction system Büchi B324; Büchi Labortechnik, Flawil, Switzerland), total carbohydrates by AOAC No 974.06, fat by Soxhlet method (AOAC No 953.38, using the Büchi B811), and ash by AOAC No 923.03. The content of non-starch polysaccharides, i.e. total, soluble and insoluble dietary fibre, was determined

Table 1. Characteristics of apple pomace.

	Apple pomace	Whole apple pomace	Milled apple pomace
Protein (g/100 g)	5.2		
Total sugar (g/100 g)	4.23		
Ash (g/100 g)	1.17		
Total dietary fibre (g/100 g)	44.9		
Soluble dietary fibre (g/100 g)	11.9		
Insoluble dietary fibre (g/100 g)	43		
Content of polyphenols (mg catechin/g dm) (without F-C reagent)[1]		4.03	5.27
Total flavonoids content (mg rutin/g dm)		3.21	3.92
Content of phenolic acids (mg ferulic acid/g dm)		0.09	0.14
Content of flavonols (mg quercetin/g dm)		0.08	0.13
Content of anthocyanins (mg cyanidin-3-glucoside/g dm)		0.17	0.24
TEAC[2] [μMTx/kg dm]		39.12	45.34
Water holding capacity (g/g)		5.12	3.38

[1] F-C = Folin-Ciocalteu.
[2] TEAC = Trolox equivalent antioxidant capacity.

by the method 32-07 of AACCI (2012). Each of the above mentioned determinations was repeated twice.

2. Antioxidant constituents
   Antiradical activity was determined in the ethanol extracts. 0.6 g of the sample was dissolved in 30 cm^3 80% ethanol, shaken in darkness for 120 minutes (electric shaker type WB22; Memmert, Schwabach, Germany), and centrifuged (15 minutes, 4,000 rpm, in centrifuge type MPW-350; MPW MED. Instruments, Warsaw, Poland). The supernatant was decanted and stored at -20 °C for further analyses.
   Determination of total polyphenols content (TPC) was done by two spectrophotometric methods: (1) using Folin-Ciocalteu reagent, according to Singleton *et al.* (1999); and (2) without using Folin-Ciocalteu, according to Mazza *et al.* (1999), with the modification of Oomah *et al.* (2005). The content of phenolic acids, flavonols and anthocyanins was measured using a spectrophotometrical method, according to Mazza *et al.* (1999), with the modification of Oomah *et al.* (2005). The content of flavonoids was evaluated using a spectrophotometrical method, according to El Hariri *et al.* (1991).

Additionally antiradical activity was assessed using analytical methods with ABTS (2,2'-azino-bis(3-ethylobenzothiazoline-6-sulphonic acid)-diamonium salt) (Re *et al.*, 1999). Results of antiradical activity were expressed as TEAC (trolox equivalent antioxidant capacity; μMTx/kg dry mass of sample). Each of the above mentioned determinations was repeated four times.

Water holding capacity of apple pomace

Water holding capacity was determined using the method proposed by Stojceska *et al.* (2008). A centrifugal tube with 3 g sample was filled with 50 cm^3 of distilled water and left for 90 minutes at ambient temperature. Samples were centrifuged for 5 minutes at 4,000 rpm. Mass of sediment was used to determine water holding capacity of apple pomace. Each of the above mentioned determinations was repeated four times.

Bread volume, oven loss, baking loss

Bread volume and height were measured with the use of Volscan Profiler (Stable Micro Systems, Godalming, UK). Oven loss (during baking) and total baking loss (during baking and cooling) was calculated according to Korus *et al.* (2006). Each of the above mentioned determinations was done on 10 samples acquired in two independent batches (5 loaves in each batch).

Texture profile analysis of bread crumb

Texture profile analysis of bread crumb of one loaf from each batch was performed, using texture analyzer TA-XT2plus (Stable Micro Systems), according to the standard program, at the compression rate of 5 mm/s. A sample of bread crumb, taken from the centre of the loaf with a height of 2 cm (and diameter of 1.5 cm) was pressed to reach 50% deformation by a P/20 aluminium cylinder probe with a diameter of 2 cm, in two cycles with a 5s delay. Two independent measurements were done for each loaf. The resulting hardness and cohesiveness of the crumb were used as indicators of textural changes during storage. The calculations were performed using the attached software Texture Exponent (Stable Micro Systems). The analysis were performed after 2, 24 and 48 hours after baking. The measurements were done on four samples acquired in two independent batches (2 samples from each batch).

Sensory evaluation

Sensory evaluation was carried out according to the Polish Standard PN-A-74108: 1996 (PKN, 1996) by a group of 12 panellists, who considered the following characteristics of the product: appearance (maximum score: 5 points), crust colour (3 points) and thickness (4 points), crumb elasticity (4 points) and porosity (3 points), smell and taste (6 points) and also other features of crust (concerning proper or improper crust formation, presence of fractures and air bubbles; 4 points) and other features of crumb (concerning uniform colour, dryness or moistness, its adhesion to crust and slicing ability; 3 points). Analyses were done in a laboratory designed and equipped with respect to PN-ISO 8589: 1998 (PKN, 1998).

Statistical analysis

The experimental data were subjected to analysis of variance (Duncan's test), at the confidence level of 0.05, by the use of software Statistica v. 8.0 (Statsoft, Inc., Tulsa, OK., USA). All measurements were done at least in duplicate (the number of replicates for each determination has been mentioned above). Correlation coefficient was determined with the use of Statistica 8.0PL software.

3. Results and discussion

The influence of apple pomace on chemical composition of wheat breads

Basic chemical composition of bread with milled and whole pomace is shown in Table 2. It could be observed that the content of protein in breads with the addition of pomace varied in the range 13.1-14.4% (around the average determined for control), but the observed changes were quite random. Total fat in bread containing milled and whole pomace decreased in comparison to control by 20-29%, except for bread containing 5% milled pomace, where the level of fat was not changed significantly. The content of ash increased in bread with 5% of milled and 10% whole pomace, while in other samples it was not changed in comparison to control. On the other hand, total sugar content decreased in bread supplemented with apple pomace as compared to control in the range 8-35%. As it could be expected from the fact that apple pomace is mainly composed of dietary fibre, the addition of this by-product caused a significant rise in the level of fibre fractions in bread, as compared to control. This increase reached 118-210; 100-250; 107-240% for soluble (SDF), insoluble (IDF) and total dietary fibre (TDF), respectively (Table 2). Such a change is important because of hypocholesterolemic, hypoglycemic and anticancer effects on humans. Epidemiological studies suggest correlations between the decline in the consumption of the dietary fibre, and the increase in gastrointestinal disease (Mendeloff, 1987), hypercholesterolemia (Tinker *et al.,* 1991) and colorectal cancer (Cassidy *et al.,* 1994). In addition, the introduction of fibre with very favourable proportions (soluble to insoluble ratio 1:2) such as apple fibre is an additional advantage, because it will guarantee the pro-health nature of products with its participation.

Reis *et al.* (2012) also reported an increase in TDF in the range of 53 to 127% in baked products with 10-30% apple pomace in comparison to the control. According to Rupasinghe *et al.* (2008) wheat muffins with the share of 8-24% apple skin powder were characterised by a higher insoluble fibre content (on average by 85%) compared to control. In the case of soluble fibre and total fibre fraction, the amount of this component was 11 and 6 times higher in relation to the control, respectively. In the study on bread with banana peels, there was a 2-fold increase in TDF compared to control (Sodchit *et al.,* 2013). And in the case of grape pomace, the TDF and SDF levels increased 2 times and the IDF 3 times compared to the control (Martins *et al.,* 2017).

Considering the content of ash and fat in baked products with apple pomace Reis *et al.* (2012) observed no changes of these components compared to control, in contrast to the protein content which decreased. Also in research by Rupasinghe *et al.* (2008) regarding wheat muffins with 8-24% apple skin powder, the share of this additive did not affect the fat and ash content but decreased the protein content. On the other hand, in breads with banana peels (5 and 10%) there was an increase in protein (by 11%), fat (by 20%) and a 3-fold increase in ash, and a decrease in carbohydrates (2-fold) in relation to control (Sodchit *et al.,* 2013). In the case of bread from capuassu peels (3-9%), there was no change in protein content, a slight decrease in carbohydrates and a slight increase in fat and ash with regard to control (Salgado *et al.,* 2011).

The influence of apple pomace on bioactive compounds

Taking into account polyphenols, it was found that their contents increased significantly in breads with the use of apple pomace in comparison to the control (Table 3). Regardless of the form in which the additive was used (whole or ground apple pomace), the amount of polyphenols increased by 55, 106 and 127% in breads with a share of 5, 10 and 15% of the above-mentioned additive in relation to the control (Table 3). The total content of polyphenols determined by spectrophotometric method using the Folin-Ciocalteu reagent is a value useful for correlating the content of phenolic compounds with their antiradical activity, although according to many authors (Gallardo *et al.,* 2006; Shahidi and Naczk, 1995) the results obtained by this method may be biased, because Folin-Ciocalteu reagent may interact not only with polyphenols, but also with other compounds, e.g. vitamin C, some alkaloids, amino acids, proteins, polysaccharides, and organic acids. Therefore,

Table 2. Chemical composition of wheat bread with a share of apple pomace (g/100 g d.m.).[1,2]

Samples	Content of protein	Content of fat	Content of ash	Content of total sugars	Insoluble dietary fibre	Soluble dietary fibre	Total dietary fibre
Control	13.63±0.15b	2.16±0.08c	2.26±0.03a	2.03±0.02f	2.92±0.03a	1.02±0.01a	3.94±0.02a
B5W	14.37±0.04d	1.72±0.08b	2.30±0.02a	1.87±0.03e	5.90±0.06b	2.28±0.05b	8.18±0.02b
B5M	13.59±0.05b	2.04±0.04c	2.39±0.01c	1.45±0 b	6.08±0.02c	2.23±0.01b	8.31±0.01c
B10W	14.24±0c	1.70±0.10b	2.40±0.01c	1.61±0.01d	8.06±0.02d	2.78±0.08c	10.84±0.09d
B10M	13.19±0.03a	1.60±0.04b	2.28±0.02a	1.35±0.02a	8.18±0.05e	2.76±0.03c	10.94±0.02d
B15W	13.71±0.03b	1.53±0.08a	2.35±0.01ab	1.53±0c	9.93±0.02f	3.01±0.02d	12.95±0.04e
B15M	13.76±0.15b	1.64±0b	2.34±0ab	1.32±0a	10.19±0.02g	3.16±0.02d	13.35±0.04f

[1] Presented data are mean values ± standard deviation (values followed by the same letters in particular columns are not significant different at 0.05 level of confidence).
[2] Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.

the total polyphenol content was also determined using the method without Folin-Ciocalteu reagent according to Mazza *et al.* (1999) with the modification of Oomah *et al.* (2005). It was found that the content of polyphenols, determined using the method without Folin-Ciocalteu reagent, increased significantly in the range from 39 to 280% in wheat breads with apple pomace in comparison to the control (Table 3). It could also be observed that the level of polyphenols determined by this method in the loaves produced with the use of whole pomace was on average 16% higher in comparison to one found in bread manufactured with milled pomace (Table 3). Taking into account the fact, that the content of polyphenols in the whole pomace was lower than in the milled pomace (Table 1), it should be noticed that the whole, non-milled apple pomace used in bread formulations could form a natural protective layer for polyphenols (maybe also for nitrogen compounds, as it was observed while discussing changes in protein level). Although many authors (Alvarez-Jubete *et al.*, 2010; Zieliński *et al.*, 2009) reports the loss of polyphenols during baking, its extent could be influenced by the form in which they are introduced to bread formulation. In this case thermal degradation was greater when they were added in the milled form, probably because they were more exposed to contact with hot air.

Wheat bread with apple pomace was characterised by a higher content of phenolic acids by 131% on average compared to the control, except for those with 5 and 10% milled pomace. At the same time, it was noticed that the use of whole pomace guarantees higher content of polyphenols and phenolic acids in the analysed material (Table 3). In contrast the content of two flavonoid fractions, i.e. flavonols and anthocyanins, increased in wheat breads especially after using milled pomace. On the other hand, bread with whole pomace was characterised by a higher content of flavonoids compared to bread with milled pomace and control (Table 3). These discrepancies should be explained by the fact that in this work, only the flavonols and anthocyanins have been labelled as markers of the whole range of flavonoids. It can therefore be suggested that the remaining flavonoid fractions could have been greater after using unmilled pomace in baked bread, which resulted in a higher content of total flavonoids and polyphenols in these breads in relation to wheat bread in which milled apple pomace was applied. It should also be added as it has already been mentioned, that whole apple pomace constitutes a specific protective barrier for bioactive substances, which prevents excessive losses during baking.

According to Zieliński *et al.* (2009) and Alvarez-Jubete *et al.* (2010) the loss of phenolic compounds during baking could reach even 60%, due to thermal, oxidative and enzymatic degradations (Alvarez-Jubete *et al.*, 2010). Anthocyanins are most susceptible to degradation during thermal treatment, and their loss depends on: processing time, temperature, pH, presence of enzymes such as polyphenol oxidase (Alvarez-Jubete *et al.*, 2010) Despite of these losses during baking the introduction of apple pomace resulted in an increase of phenolic compounds in wheat bread. This observation should be explained by high concentration of phenolic compounds in the pomace (Table 1). Similarly in the experiments of Smith and Yu (2015) concerning bread containing different quantities of grape pomace an increase in total phenolic content could be observed. Similar studies of Hoye and Ross (2011) proved that bread with 10% grape seed flour was characterised with higher TPC than control. In the study of Reis *et al.* (2012) on bread with apple pomace an increase in TPC, flavonoids and anthocyanins was 175, 192, and 115% respectively as

Table 3. Content of polyphenolic compounds and antiradical activity of wheat bread with a share of apple pomace.[1,2,3]

Samples	Total polifenolic content (mg catechin/g dm) (with F-C reagent)	Total flavonoids content (mg rutin/g dm)	Content of polyphenols (mg catechin/g dm) (without F-C reagent)	Content of phenolic acids (mg ferulic acid/g dm)	Content of flavonols (mg quercetin/g dm)	Content of anthocyanins (mg cyanidin-3-glucoside/g dm)	TEAC [µMTx/kg dm]
Control	0.29±0.06a	0.07±0.02a	0.082±0.002a	0.012±0c	0±0a	0.010±0a	7.80±0a
B5W	0.45±0.03b	0.21±0.01d	0.179±0.006c	0.017±0.001d	0.001±0b	0.026±0.003b	18.97±0.08c
B5M	0.45±0.04b	0.07±0a	0.114±0.001b	0.006±0a	0.018±0.002d	0.042±0.003c	17.37±0.1b
B10W	0.60±0.02c	0.36±0.02e	0.294±0.004f	0.026±0.003e	0.012±0.002c	0.034±0.005c	22.17±0e
B10M	0.62±0c	0.07±0c	0.269±0.004d	0.007±0b	0.021±0.003de	0.104±0.003e	19.77±0.13d
B15W	0.68±0.02d	0.11±0.04ab	0.312±0.003g	0.036±0.004f	0.035±0.004g	0.072±0d	24.57±0.05f
B15M	0.64±0.04cd	0.10±0.04a	0.281±0.003e	0.031±0.002f	0.024±0.002f	0.143±0.010f	25.37±0g

[1] Presented data are mean values ± standard deviation (values followed by the same letters in particular columns are not significant different at 0.05 level of confidence).
[2] Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.
[3] F-C = Folin-Ciocalteu; TEAC = Trolox equivalent antioxidant capacity; Tx = Trolox.

compared to control. Altunkaya *et al.* (2013) observed an increase in TPC with bread with pomegranate peel powder, which was parallel to the increase in antioxidant activity of the product in comparison to control. Analogical tendency was observed in our analyses. The increase of antioxidant activity was in range 171-217% in bread with a share of apple pomace (Table 3). Chang *et al.* (2015) observed an increase in TPC in the range 41-50% in bread with lemon pomace fibre, which was accompanied with 6-32% increase of antioxidant activity in comparison to control. High antioxidant activity of bread with apple pomace in comparison to standard was also confirmed in the study of Reis *et al.* (2012). The correlation coefficients between total phenolic content (TPC with Folin-Ciocalteu reagent) and ABTS, content of flavonoids and ABTS, content of anthocyanins and ABTS determined in bread samples equalled: 0.93; 0.11; 0.67 respectively. It should be stressed that some discrepancies between the reported results could be caused by the products of Maillard's reaction, which have significant influence on antioxidant activity of bread.

The influence of apple pomace on physical properties of wheat breads

Basic technological indices of control wheat bread and wheat breads with a share of whole and milled apple pomace are presented in Table 4.

The addition of apple pomace to wheat bread caused an increase in moisture content of the crumb from 5.8% (in the case of 5% share of whole pomace) to 19.2% (15% share of milled pomace) (Table 4). The same relationship was observed by Baca *et al.* (2011) who examined breads with the addition of apple fibre, and by Reis *et al.* (2012) who studied bread with apple pomace. Parallel increase in moisture was also recorded in bread from capuassu peels (3-9%) (Salgado *et al.,* 2011). On the other hand, in breads with banana peels (5 and 10%), the increase in moisture was 3 times in relation to control (Sodchit *et al.,* 2013). The increase in the moisture content of breads with the participation of apple pomace is explained by the high water-binding capacity of dietary fibre, which is a valuable component of this pomace. Hydration capacity of fibre depends strongly on its botanical origin and composition, so the amount of water which could be bound by one gram of fibre ranges from 3 to 10 grams (Raghavendra *et al.,* 2006). The crumb of bread with milled pomace tended to be more moist in comparison to the loaves with non-milled pomace, although the significant difference was observed only at the highest level of addition (15%). It could again reflect the non-uniformity of the samples. The crumb taken from loaves containing milled pomace contained more hydrated parts of pomace while one isolated from loaves with whole pomace contained less pomace which was also less hydrated during dough preparation and baking.

Apple pomace significantly affected bread volume, which decreased by 13.2-41.9% in the case of bread with milled pomace and 3.5-22.8% in the case of bread with whole pomace (Table 4). The decrease in bread volume together with the increase in the share of apple pomace in bread was also observed by Wojciechowicz and Gil (2009). Baca *et al.* (2011) also found such dependence in bread with apple fibre. The addition of milled pomace caused more decrease in volume of the loaves in comparison to the same addition of whole pomace. This observation agrees with earlier reports on wheat-rye bread (90%-10%) with an addition of whole and milled seeds of legumes (Achremowicz *et al.,* 2000). Such result was due to the presence of a large number of small particles which could mechanically interrupt formation of gluten network, responsible for internal structure of wheat bread. Similar dependence was not found for rye-wheat bread (70%-30%) because its structure is formed mainly by starch and pentosans (hydrocolloids) and not gluten proteins (Korus *et al.,* 2002).

The dilution of gluten and interactions between gluten and fibre (TDF) from apple pomace result in weakening

Table 4. Physical properties of wheat bread with a share of apple pomace.[1,2]

Samples	Moisture (%)	Volume of bread (cm^3)	Oven loss (%)	Baking loss (%)
Control	43.00±0.83a	731.67±22.90f	12.80±0.47c	15.60±0.49bc
B5W	45.49±1.07b	706.25±10.61e	12.85±0.33c	16.04±0.42c
B5M	46.86±0.50bc	635.00±42.03d	12.14±0.10b	14.81±0.38a
B10W	47.12±1.07bc	616.25±16.20cd	11.69±0.28a	14.70±0.32a
B10M	48.73±0.72bc	607.50±2.89c	13.04±0.33c	15.55±0.47b
B15W	48.37±0.47c	565.00±20.70b	11.98±0.31ab	14.84±0.47a
B15M	51.24±0.07d	425.00±10.80a	14.19±0.53d	16.60±0.59d

[1] Presented data are mean values ± standard deviation (values followed by the same letters in particular columns are not significant different at 0.05 level of confidence).

[2] Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.

of gluten network in wheat bread (Chen *et al.*, 1988) which has consequences in bread structure and impairs CO_2 retention. It could be observed that wheat bread with milled apple pomace contains high levels of TDF, which is the main reason for a decrease of their volume (Table 2 and 4) confirming the results of earlier works (Chen *et al.*, 1988; Pomeranz *et al.*, 1977; Wu and Shiau, 2015).

The oven loss characterising bread with a share of whole apple pomace was reduced by 6.4-8.7% in comparison to control. On the other hand, 2.6% increase of total baking loss could be observed after 5% addition of whole pomace, while at higher levels of its additions this parameter decreased by 4.9-5.8% in comparison to control (with exception of bread with a share of 15% milled apple pomace). In bread with 5% addition of milled pomace, oven loss and total baking loss decreased by 3.1 and 5%, respectively, while at larger addition levels the parameters increased by 1.9-10.9% (oven loss) and by 6.4% (total baking loss). Only the bread with 10% addition of milled pomace was characterised by the total loss practically unchanged in comparison to control (Table 4). The values of oven loss and baking loss were in most cases larger in the cases of bread with milled pomace as compared to the loaves with whole pomace, although the moisture content measured two hours after baking was also higher in the first case. The smaller values of both loss indices determined for bread with whole pomace could be due to a fact that larger parts of fibre could absorb more water than small fragments, and the absorbed water is less likely to migrate during baking period. This is confirmed by the values of water holding capacity (whole pomace: 5,12 g/g water, milled pomace: 3,38 g/g water; Table 1), and further supported by the results of the study on bread containing grasspea (*Lathyrus sativus*) seeds, in which the increase in moisture content on the last day of storage could be observed, contrary to the samples with no seeds or milled seeds(Korus *et al.*, 2002). The observed phenomenon was explained by the migration of water absorbed by the seeds to the crumb.

Table 5 shows bread quality levels, calculated on the basis of the score obtained from the organoleptic assessment, the bread quality levels by PN-A-74108: 1996. Control bread and all breads with the use of whole apple pomace, both in the amount of 5, 10 and 15% were classified as I quality class. Breads with 5 and 10% share of milled pomace were assigned to the second class, while bread with 15% share to the third quality class. Similar relations were obtained by Baca *et al.* (2011) examining breads with the addition of apple fibre, where the increase in the fibre level resulted in lowering the organoleptic evaluation of the bread. The bread with 10% share of apple pomace was in the second quality class, while the one with the largest share (15%) was unacceptable due to significant reduction of the volume of loaves, compact, hard crumb, dark colour of the bread and its bitter taste (Table 5; Figure 1). However, the best assessment was given to bread with 5% addition of whole pomace, because it was characterised by the best overall appearance, crust colour and elastic crumb of all breads with pomace and was comparable to the control. The above

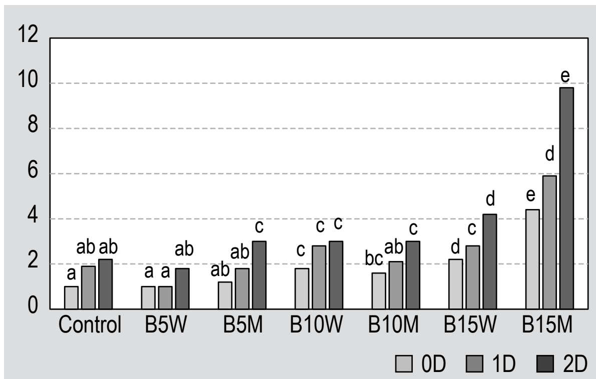

Figure 1. Hardness of wheat bread with a share of apple pomace (Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.; OD = day of baking; 1D, 2D = 1, 2 days after baking). Statistical analysis was calculated separately for each day.

Table 5. Sensory evaluation of wheat bread with a share of apple pomace.[1]

Samples	The level of quality of bread	Appearance	Colour of crust	Crust thickness	Other features of crust	Elasticity of crumb	Porosity of crumb	Other features of crumb	Smell and taste
Control	I	4.95	3	3.5	3.5	3.7	2.5	2.8	5.6
B5W	I	5	2.75	3.9	3.9	3.8	2.9	2.3	5.4
B5M	II	4.4	2.2	3.2	3.5	2.9	2.5	2.4	5.1
B10W	I	4.4	2.75	3.8	3.8	3.8	2.7	2.3	5.1
B10M	II	4.4	2.4	3.5	3.3	2.9	1.7	2.4	4.5
B15W	I	4.3	2.9	3.8	3.2	3.5	2.5	2.3	5.2
B15M	III	0.7	1.6	1.8	2.9	2.1	1.7	1.7	4.9

[1] Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.

mentioned bread had the best porosity of all analysed loaves, and its taste and smell were not worse than the control (Table 5). In the studies of Massodi and Chauchan (1998) and He and Lu (2015) concerning wheat bread with apple pomace, it was also observed that the sensory evaluation was correlated inversely to the quantitative share of apple pomace in these breads.

Hardness of the crumb is the most frequently determined texture parameter of bread, because it is recognised as the main indicator of its freshness. It is usually defined as the maximum force occurring during the first pressing of the crumb (Romankiewicz *et al.*, 2014). Hardness depends on many factors, such as chemical composition of the samples, technological processing, storage conditions. Even amylose/amylopectin ratio may contribute to overall bread texture (Schiraldi and Fessas, 2000). According to Gomez *et al.* (2003) hardness could be significantly influenced by the interactions of gluten with TDF originating from the additive and water absorption properties of the fibre, in our case the apple pomace. The results showed that only 5% addition of whole and milled apple pomace did not significantly increase the hardness of the bread on the day of baking (Figure 1). Higher levels of addition resulted in a significant increase in hardness, and in the case of 15% share of milled apple pomace, the hardness of bread was more than four times higher than that of the control bread (Figure 1). Hardness of all tested bread samples increased during storage. Only the hardness of bread with 5% share of milled pomace and 5% share of whole pomace did not increase significantly after one day of storage compared to the hardness on the day of baking. After two days of storage a significant increase in hardness was not observed only in the case of bread with 5% whole pomace. In addition, this bread was characterised by significantly lower hardness both after one and two days of storage compared to the control bread (Figure 1). Taking into account hardness of loaves with milled pomace it could be observed that its values were larger on the day of baking and throughout the whole storage period in comparison to those characterising bread with whole pomace (with the exception of 10% addition level). It could probably be explained by the fact that parts of whole apple pomace absorb more water than the milled fragments (Table 1) which reduces the resulting hardness of bread crumb. As it was already mentioned whole pomace could release the absorbed water to adjacent crumb throughout the whole storage period which could inversely affect its hardness.

According to Jung *et al.* (2015), cookies with 15 and 20% of apple were characterised by a slight decrease in hardness compared to the control. Also Min *et al.* (2010) observed that 10-30% apple pomace additive caused a significant decrease in the hardness of cookies in relation to the control. On the other hand an increase in hardness corresponding to the additive was noticed by Chang *et al.* (2015), in the studies concerning bread with lemon pomace fibre.

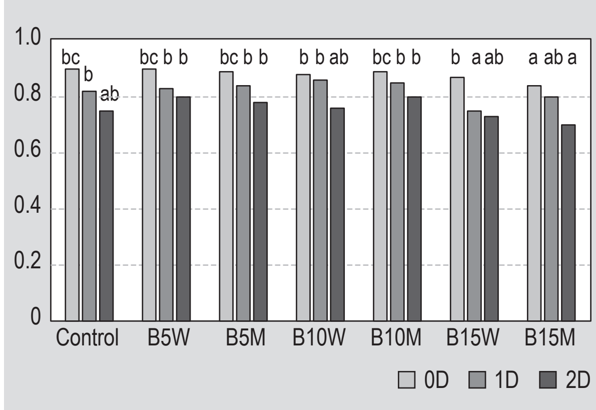

Figure 2. Cohesiveness of wheat bread with a share of apple pomace (Control = control bread; B5W = wheat bread with a share of 5% whole apple pomace; B5M = wheat bread with a share of 5% milled apple pomace; etc.; OD = day of baking; 1D, 2D = 1, 2 day after baking). Statistical analysis was calculated separately for each day.

Almost all the loaves did not differ significantly among themselves in terms of second significant textural parameter, i.e. cohesiveness. The exception was bread with 15% share of milled pomace, which revealed the lowest value of this parameter (Figure 2). On consecutive days of storage, this cohesiveness significantly decreased in comparison to the previous day in all cases. The exception was again the bread with 15% milled pomace, in which, after the first day, the cohesiveness did not significantly diminish, but after the second day it significantly decreased (Figure 2). After two days of storage the bread with 5% and 10% share of milled pomace and with 5% share of whole pomace was slightly more cohesive than control, while bread with 15% share of powdered pomace revealed the lowest cohesiveness, which was slightly different from the control (Figure 2).

4. Conclusions

Among all analysed samples, the wheat bread with a share of 5% whole pomace received the best scores. This was the result of several factors: good volume, small baking loss, low crumb hardness in comparison to control on the day of baking (though hardness increased during storage, it was still lower than control), and significant level of protein and total sugar.

Although 5% addition of pomace did not guarantee such an increase of bioactive compounds as other applied levels, it caused an increase in TPC, flavonoids and anthocyanins by 55, 200 and 160% as compared to control, respectively. At the same time it caused a significant increase of antioxidant activity.

The addition of 5% whole apple pomace to wheat bread could be advised on industrial scale because of high consumer acceptance of such products.

Acknowledgements

This Research was financed by the Ministry of Science and Higher Education of the Republic of Poland.

Conflict of interest

The authors declare that they have no conflict of interest.

Compliance with ethics requirements

This article does not contain any studies with human or animal subjects.

References

Achremowicz, B., Korus, J. and Curyło, K., 2000. The effect of different pulse additives to bread products. EJPAU 3(2): 6.

Altunkaya, A., Hedegaard, R.V., Brimer, L., Gokmen, V. and Skibsted, H., 2013. Antioxidant capacity versus chemical safety of wheat bread enriched with pomegranate peel powder. Food and Function 4: 722-727.

Alvarez-Jubete, L., Wijngaard, H., Arendt, E.K. and Gallagher, E., 2010. Polyphenol composition and *in vitro* antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. Food Chemistry 119: 770-778.

American Association of Cereal Chemists International (AACCI), 2012. Approved methods (11th Ed.). AACCI, St. Paul, MN, USA.

Association of Official Analytical Chemists International (AOAC), 2006. Official methods of analysis (18th Ed.). AOAC, Gaithersburg, MD, USA.

Baca, E., Kapka, A., Karaś, M. and Zielińska, D., 2011. Wpływ dodatku błonnika jabłkowego do mąki pszennej na właściwości funkcjonalne ciasta i jakość chleba. Problemy Higieny i Epidemiologii 92: 868-871.

Cassidy, A., Bingham, S.A. and Cummings, J.H., 1994. Starch intake and colorectal cancer risk: an international comparison. British Journal of Cancer 69: 937-942.

Chang, R.-Ch., Li, Ch.-Y. and Shiau, S.-Y., 2015. Physico-chemical and sensory properties of bread enriched with lemon pomace fiber. Czech Journal of Food Sciences 2: 180185

Chen, H., Rubenthaler, G.L. and Schanus, E.G., 1988. Effect of apple fiber and cellulose on the physical properties of wheat flour. Journal of Food Science 53: 304-305.

El Hariri, B., Sallé, G. and Andary, C., 1991. Involvement of flavonoids in the resistance of two poplar cultivars to mistletoe (*Viscum album* L.). Protoplasm 162: 20-26.

European Commission, 2014. The European Union explained agriculture. Publications Office of the European Union, Luxembourg, Luxembourg.

Fronc, A. and Nawirska, A., 1994. Możliwości wykorzystania odpadów z przetwórstwa owoców. Ochrona środowiska 2(53): 31-32.

Gallardo, C., Jiménez, L. and García-Conesa, M.T., 2006. Hydroxycinnamic acid composition and *in vitro* antioxidant activity of selected grain fraction. Food Chemistry 99: 455-463.

Gomez, M., Ronda, F., Bianco, C.A., Caballero, P.A. and Apesteguia, A., 2003. Effect of dietary fibre on dough rheology and bread quality. European Food Research and Technology 216: 51-56.

He, Y. and Lu, Q., 2015. Impact of apple pomace on the property of French bread. Journal of Food Science and Technology 8: 162-172.

Hoye, C. and Ross, C.F., 2011. Total phenolic content, consumer acceptance and instrumental analysis of bread made with grape seed flour. Journal of Food Science 76: S428-S436.

Jung, J., Cavender, G. and Zhao, Y., 2015. Impingement drying for preparing dried apple pomace flour and its fortification in bakery and meat products. Journal of Food Science and Technology 52: 5568-5578.

Korus, J., Achremowicz, B. and Grzesik, W., 2002. Wpływ dodatku lędźwianu siewnego (*Lahthyrus sativus* L.) na wybrane cechy pieczywa mieszanego. Żywność 2: 88-98.

Korus, J., Grzelak, K., Achremowicz, K. and Sabat, R., 2006. Influence of prebiotic additions on the quality of gluten-free bread and on the content of inulin and fructooligosaccharides. Food Science and Technology International 12: 489-495.

Martins, Z.E., Pinho, O. and Ferreira, I.M.P.L.V.O., 2017. Food industry by-products used as functional ingredients of bakery products. Trends in Food Science and Technology 67: 106-128.

Massodi, F.A. and Chauhan, G.S., 1998. Use of apple pomace as a source of dietary fiber in wheat bread. Journal of Food Processing and Preservation 22: 255-263.

Mazza, G., Fukumoto, L., Delaquis, P., Girard, B. and Ewert, B., 1999. Anthocyanins, phenolics, and color of Cabernet Franc, Merlot, and Pinot Noir wines from British Columbia. Journal of Agricultural and Food Chemistry 47: 4009-4017.

McKee, L.H. and Latner, T.A., 2000. Underutilized sources of dietary fibre. a review. Plant Foods for Human Nutrition 55: 285-304.

Mendeloff, A.I., 1987. Dietary fibre and gastrointestinal disease. American Journal of Clinical Nutrition 45: 1267-1270.

Min, B., Bae, I.Y., Lee, H.-G., Yoo, S.-H. and Lee, S., 2010. Utilization of pectin-enriched materials from apple pomace as a fat replacer in a model food system. Bioresources Technology 101: 5414-5418.

Mink, P.J., Scrafford, C.G., Barraj, L.M., Harnack, L., Hong, C.P., Nettleton, J.A. and Jacobs Jr., D.R., 2007. Flavonoid intake and cardiovascular disease mortality. A prospective study in postmenopausal women. American Journal of Clinical Nutrition 85: 895-909.

Oomah, B., Cardador-Martínez, A. and Loarca-Piña, G., 2005. Phenolics and antioxidative activities in common beans (*Phaseolus vulgaris* L). Journal of Agricultural and Food Chemistry 85: 935-942.

Polish Standard (PKN), 1996. PN-A-74108: 1996. Pieczywo-metody badań i ocena punktowa. PKN, Warszawa, Poland. [in Polish, English abstract]

Polish Standard (PKN), 1998. PN-ISO 8589. Analiza sensoryczna – ogólne wytyczne dotyczące projektowania pracowni analizy sensorycznej. PKN, Warszawa, Poland. [in Polish, English abstract]

Pomeranz, Y., Shogren, M.D., Finney, K.F. and Bechtel, D.B., 1977. Fiber in breadmaking: effects on functional properties. Cereal Chemistry 54: 25-41.

Raghavendra, S.R., Ramachandra, S., Rastogi, N.K., Raghavarao, K.S.M.S, Sourav, K. and Tharanathan, R.N., 2006. Grinding characteristics and hydration properties of coconut residue: a source of dietary fiber. Journal of Food Engineering 72: 281-286.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C., 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology & Medicine 26: 1231-1237.

Reis, S.F., Rai, D.K. and Abu-Ghannam, N., 2012. Apple pomace as a potential ingredient for the development of new functional foods. In: Proceedings of the International Conference on Food Safety, Quality and Nutrition (ICFSQN), April 11-13, 2012, Manchester, UK, pp. 61-66.

Romankiewicz, D., Cacak-Pietrzak, G. and Kania, K., 2014. Wpływ metody prowadzenia ciasta na zmiany tekstury przechowywanego pieczywa pszennego. Zeszyty Problemowe Postępów Nauk Rolniczych 579: 67-77.

Rupasinghe, H.P.V., Wang, L., Huber, G.M. and Pitts, N.L., 2008. Effect of baking on dietary fibre and phenolics of muffins incorporated with apple skin powder. Food Chemistry 107: 1217-1224.

Salgado, J.M., Rodrigues, B.S., Donado-Pestana, C.M., Santos Dias, C.T. and Morzeile, M.C., 2011. Cupuassu (*Theobroma grandiflorum)* peel as potential source of dietary fiber and phytochemicals in whole-bread preparation. Plant Foods for Human Nutrition 66: 384-390.

Schiraldi, A. and Fessas, D., 2000. Mechanism of staling. In: Pavinee, C. and Vodovotz, Y. (eds.) Bread staling. CRC Press, New York, NY, USA.

Shahidi, F. and Naczk, M., 1995. Food phenolic: sources, chemistry, effects and applications. Technomic Publishing Company Inc., Lancaster, UK.

Singleton, V., Orthofer, R. and Lamuela-Raventós, R., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. Methods in Enzymology 299: 152-178.

Smith, I.N. and Yu, J., 2015. Nutritional and sensory quality of bread containing different quantities of grape pomace from different grape cultivars. EC – Nutrition 2: 1-2.

Sodchit, C., Tochampa, W., Kongbangkerd, T. and Singanusong, R., 2013. Effect of banana peel cellulose as a dietary fiber supplement on baking and sensory qualities of butter cake. Songklanakarin Journal of Science and Technology 35: 641-646.

Stojceska, V., Ainsworth, P., Plunkett, A., Ibanoğlu, E. and Ibanoğlu, S., 2008. Cauliflower byproducts as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks. Journal of Food Engineering 87: 554-563.

Tarko, T., Duda-Chodak, A. and Bebak, A., 2012. Aktywność biologiczna wybranych wytłoków owocowych oraz warzywnych. Żywność. Nauka. Technologia. Jakość 4(83): 55-65.

Tinker, L.F., Schneeman, B.O., Davis, P.A., Gallaher, D.D. and Waggoner, C.R., 1991. Consumption of prunes as a source of dietary fibre in men with mild hypercholesterolemia. American Journal of Clinical Nutrition 53: 1259-1265.

Waldbauer, K., McKinnon, R. and Kopp, B., 2017. Apple pomace as potential source of natural active compounds. Planta Medica 83(12-13): 994-1010.

Wojciechowicz, A. and Gil, Z., 2009. Jakość pieczywa pszennego z udziałem błonnika pokarmowego różnego pochodzenia. Żywność Nauka Technologia Jakość 67: 102-111.

Wu, M.-Y. and Shiau, S.-Y., 2015. Effect of the amount and particie size of pineapple peel fiber on dough rheology and steam bread quality. Journal of Food Processing and Preservation 39: 549-558.

Yokohira, M., Yamakawa, K., Saoo, K., Matsuda, Y., Hosokawa, K., Hashimoto, N., Kuno, T. and Imaida, K., 2008. Antioxidant effects of flavonoids used as food additives (purple corn color, enzymatically modified isoquercitrin, and isoquercitrin) on liver carcinogenesis in a rat medium-term bioassay. Journal of Food Science 73(7): C561-C568.

Zieliński, H., Michalska, A., Amigo-Benaven, M., Castillo, M. and Piskula, M., 2009. Changes in protein quality and antioxidant properties of buckwheat seeds and groats induced by roasting. Journal of Agricultural and Food Chemistry 57*:* 4771-4776.