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QUALITY AND TECHNOLOGICAL PROPERTIES OF FLOUR WITH THE ADDITION OF *AESCULUS HIPPOCASTANUM* AND *CASTANEA SATIVA*

– Research paper –

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Abstract: The study of alternative food sources or ingredients that can partially replace or enrich today's food is a perspective direction. The possibility of using horse chestnut (Aesculus hippocastanum) and chestnut (Castanea sativa) fruits in the baking industry as an admixture to wheat flour has been determined. The addition of flours from these fruits at a level of 10% increases the number of minerals in the flour mixture and also enriches the mixture in saponins, coumarins, and tannins. However, it is necessary to remove excess saponins from horse chestnut. The amylograph has shown that flour from horse chestnut fruit has optimal parameters for baking mixed bread. Farinograph tests showed that a 10% addition of ground horse chestnut to wheat flour had the best baking properties. Mixtures with 10 and 15% chestnut addition showed the best baking characteristic.

Keywords: baking characteristic, flour, horse chestnut, sweet chestnut

INTRODUCTION

The growing tendencies of the human population in the world are forecasted to continue, which will result in an increased demand for food (Lizunkov, 2018; Long et al., 2015). There is also a perspective of increasing agricultural production to cover the market for biofuels and biopolymers (Bernard and Prieur, 2007; Galiano et al., 2018). Agriculture could be gradually relieved by obtaining part of the food from the environment or by establishing more environmentally friendly tree plantations for harvesting seeds for food. This would allow for parallel farming in between. Globally, the demand for healthy and organic food is growing, and consequently, more and more people are paying attention to new cultivars and some more forgotten species (Ditlevsen et al.,2019). Many plant species that we do not perceive as food today once formed the nutritional basis of various population or allowed them to survive periods of hunger and war. Perhaps it is worth remembering them as a valuable element of our nature and culture and we should include them in our diet again (Łuczaj, 2004).

In southern Europe, where the chestnut (*Castanea sativa*) is a common species, it is widely consumed. In areas where the species is rare or only found as a decorative plant, this is far less profitable, but not impossible. In such areas, some people may privately collect the seeds and try to prepare them for consumption. The fruit of this species has one very important advantage, it does not have any harmful or unpleasant tasting substances. Consequently, the chestnut is edible even when raw. A more common species in Poland and northern Europe is the Horse Chestnut (*Aesculus hippocastanum*). The population of this species is numerous and a single tree can bear a large mass of fruit. In Europe, this species could be successfully used extensively in the food industry as a baking additive or animal feed. A problem in the context of chestnut consumption is

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the saponins found in them (Abudayeh et al., 2015). They provide the plant with protection against bacteria and fungi (Kumar et al., 2019). In the human body, in excess, they lead to haemolysis of red blood cells (Lorent et al. 2014). Therefore, it is necessary to remove saponins from chestnuts before consumption. The process is inconvenient, but due to the high fruit weight and its easy harvesting, it can be profitable. Saponins have a positive effect on human health, as exemplified by legumes. Studies have shown that they can reduce the amount of cholesterol in the blood plasma and the risk of various chronic diseases. In addition, they have been shown to have cytotoxic effects on cancer cells (Singh et al., 2017). In addition, these seeds are rich in micro and macronutrients that are necessary for proper human body development and functioning (Dababneh et al. 2017). Some minerals are important because of the essential role they fulfill in the body. Some of them show antioxidant activity, which protects the body from changes caused by free radicals. Such elements include iron, copper, zinc and manganese. For the human body to avoid diseases and disorders caused by a deficiency of minerals, it must consume an appropriate amount with food. Deficiencies of various minerals, such as calcium or iron, but also others, are found in the diet of various individuals (Beck et al., 2000, Brzozowska, 2002, Cappuccio, 2000, Jorde et al., 2000). Wheat, rice, and maize are the most widely grown crops. This has many benefits as well as risks, so it may be worth exploring other potential food sources. Technologically, compared to wheat, chestnut and horse chestnut fruits have fewer carbohydrates and protein, but more fats (FAOSTAT 2017). However, the fruits of these trees have the advantage of being gluten-free (De Vasconcelos et al., 2007; Zhu, 2017).

Gluten is a protein of plant origin. The main sources of gluten are cereals such as wheat and rye. Some people may be unable to tolerate gluten, a condition known as coeliac disease. After consuming food containing gluten, a sick person may experience digestive disorders and discomfort, and in the case of a chronic problem, also developmental disorders and deficiencies in the body. Up to 1% of the world's population can develop the celiac disease (Lohi et al., 2007).

The study aims to determine the technological value of chestnut and horse chestnut fruits, to estimate the best percentage contribution to wheat flour and to evaluate the possibility of using the obtained flour admixtures in the baking industry.

MATERIAL AND METHODS

Characteristics of plant material

Seeds were collected in countryside areas in Poland in the Zachodniopomorskie Voivodship. Chestnuts and horse chestnuts are both deciduous, heavy-seeded tree species. The common chestnut occurs from north-western Africa to the southern borders of Scandinavia, reaching the Caucasus to the east (Conedera et al., 2016). Horse chestnut occurs from Bulgaria to the UK, where its abundance appears to be greatest, but is common in central and western Europe (Thomas et al., 2019). Both species are characterised by large, heavy fruits making harvesting very efficient; the seeds are shielded by spiny bags posing no problem during harvesting.

Color measurement

As described by Chełpiński et al. (2019), the fruits in terms of color (pigment) measurement in the CIE L*a*b* system were examined by photocolori-metric method with a Konica Minolta CM 700D spectrophotometer. Measurements were taken with the aperture diameter of 3 mm, through a 10º observer type and D65 illuminant. The *a** value showed the place of appearing in the colour gamut, in the range from green (−*a**) to red (+*a**). The value of L* parameter ranges from 0 (black) to 100 (white).

Elemental analysis

The content of elements in plants was determined after mineralization - N, Mg, P, K, and Ca were measured after wet mineralization in H_2SO_4 and $HClO_4$. The content of Cu, Al, Mn, Cr, Ni, Zn and Fe were determined after mineralization in HNO_3 and $HClO_4$ in a ratio of plants 3:1 (IUNG, 1990). The total nitrogen concentration in plants was determined by the Kjeldahl distillation method using a Vapodest 30 (Gerhardt GmbH, Germany). P content was determined with the Barton method at wavelength 470 nm, employing spectrophotometer Marcel s 330 PRO. The content of K and Ca was measured with the atomic emission spectrometry, Mg Cu, Al, Mn, Cr, Ni, Zn and Fe content with the flame atomic absorption spectroscopy. P was assessed by the colorimetric method. All tests were performed in three replications.

Extraction procedure

The compounds mixture was extracted from fruit using 70% ethanol, at 20'C, stirring for 60 minutes.

The suspension was centrifuged at 4000 rpm for 10 min. and filtered under reduced pressure through a cellulose membrane with a pore diameter of 1.2 Pm. The resulting supernatant was concentrated at 40 °C in a vacuum evaporator to remove acetone. The plant extract was serially diluted with redistilled water to obtain a concentration gradient for use in analytical and biological activity studies (Oszmiański et al., 2018).

Health promoting and nutritional values

Ferric-Reducing Antioxidant Power (FRAP) was carried out according to the method of Benzie and Strain (1996). The DPPH (1,1-diphenyl-2-picrylhydrazyl) test was performed according to the method of Shimada et al. (1992). The antioxidant capacity was expressed in millimoles of trolox per 100 g of body weight. ABTS- + and FRAP measurements were made using a UV-2401 PC spectrophotometer. All samples were tested in triplicate.

Diethyl ether was used according to the Soxhlet method to denote the fat as the ether extract. The crude ash was determined by burning in a muffle furnace at 580 ° C for 8 h. Crude protein (N×6.25) was determined according to the Kjeldahl method. Organic acids were determined using ultrafast liquid chromatography coupled with a photodiode detector (UFLC-PDA). Detection was performed in DAD, using 215 nm and 245 nm as preferred wavelengths. The occurring organic acids were quantified by comparing their peak areas recorded at 215 nm and 245 nm with calibration curves compared to commercial standards. The results are given in g per 100 g dry weight.

Phenolic acids, flavonoids, coumarins, saponins and tannins compounds were analysed using a UPLC-PDA-ESI-MS/ MS Waters ACQUITY system (Waters, Milford, MA, USA) as the method described by Piwowarczyk et al. (2021).

Farinograph and amylograph Brabender

The farinograph properties of the flours were determined by Brabender farinograph using a type 50 head. Parameters were determined flour water absorption, development time, stability, degree of softening after 10 minutes, after 12 minutes according to ICC, and a quality number (PN-EN ISO 5530-1:2015-01).

Determination of the amylographic properties of flour was performed on the Amylograph Brabender. Parameters determined: beginning of gelatinization, gelatinization maximum, gelatinization temperature (PN-EN ISO 7973: 2016-01).

Statistical Analysis

All statistical analyses were performed using Statistica 13.1 (StatSoft Polska, Cracow, Poland). Statistical significance of the differences between means was determined by testing the homogeneity of variance and normality of distribution, followed by ANOVA with Tukey's post hoc test. The significance was set at $p<0.05$.

RESULTS AND DISCUSSION

Horse chestnut flour can enrich the mixture slightly with phosphorus and manganese and significantly with potassium, calcium, chromium, copper, iron and zinc. This admixture will also lower the N and Mg content. Fruits also contain lower amounts of aluminium, but much higher amounts of Ni compared to wheat flour (Table 1).

Chestnut fruits, on the other hand, can slightly increase the content of magnesium and zinc in the mixture, and significantly increase the content of potassium, calcium, chromium, copper, iron and manganese. On the other hand, it will lower the content of nitrogen, phosphorus, nickel and aluminium (Tables 1 and 2). Results from other scientific studies indicate that the content of individual elements in chestnut fruits can be up to several times higher (Zhu, 2017, Fatih et al., 2013). However, the content of harmful aluminium is low. At the end of the 90s, FAO/WHO experts conducted studies, which showed that with the PTWI parameter for aluminum, which is 7 mg/kg body weight, children consume 2-6 mg/kg daily, and adults 6-14 mg/kg. White flour is also very low in Cr, an element that accelerates the burning of fats. It is therefore very important for people who have a diet rich in fats. With the daily requirement of Cr in adults of 0.2 mg/day (Nascimento et al., 2015), its level in fresh fruit was found to be 0.007-0.008 mg/1000 g (Rose et al., 2010) The nickel content found should not have a negative effect on humans. It is an element that significantly causes allergies in humans, especially in highly developed countries where it is commonly used in everyday items such as jewellery. In the 1970s, the level of nickel in food was 0.33 mg/day. By the 1980s it decreased significantly and has remained stable ever since. In fresh food, its amount should not exceed 0.5 mg/1000 g (GB 2762-2012), but studies show that it is less - on average 0.079 mg/1000 g (Rose et al., 2010).

Wheat flour contains almost twice as many carbohydrates as chestnut flour and horse chestnut flour (Table 3). It also contains more protein. Chestnut flour has the highest fat content, up to seven times more than wheat flour. Based on a study in India, it has been shown that the fruit of the Indian chestnut cultivar (Aesculus indica Colebr) contains 80.71% carbohydrate, 2.85% fat and 7.69% protein (Shafi et al., 2016). The carbohydrate content of chestnut fruit is 79.39%, protein 4.73% and fat 4.81% (Wani et al., 2017). In comparison, acorns of different oak species can contain 75.22-84.09% carbohydrates, 4.32-5% proteins and 8.44-13.86% fats (Szabłowska and Tańska, 2021). This shows that given species, especially those growing in different parts of the world, can differ in their fruit composition, even if they are closely related.

Table 1. Macroelements and heavy metals concentration in seed samples

		Flour 650	*A. hippocastanum*	*C. sativa*
N	g/100 g	1.96 c*	0.47 a	0.67 b
P		0.17 b	0.22 c	0.13 a
K		0.23 a	1.03 c	0.84 b
Ca		0.02 a	0.24 c	0.11 b
Mg		0.05 a	0.045 a	0.074 b
Zn	mg/1000 g	2.18 a	6.25 c	2.70 b
Mn		1.46 a	2.06 b	5.13 c
Cu		1.17 a	6.34 c	2.38 b
Fe		2.22 a	43.3 c	22.47 b
Cr		0.004 a	0.082 c	0.054 b
Ni		0.28 b	0.66 c	0.17 a
Al		1.68 c	0.67 b	0.38 a

*Mean values denoted by the same letter do not differ statistically significantly at 0.05 according to Tukey's test.

Table 2. Percent (%) change in the content of micro and macro elements in wheat flour mixture with seed samples

	A. hippocastanum			*C. sativa*		
	5%	10%	15%	5%	10%	15%
N	-3.80	-7.60	-11.40	-3.29	-6.58	-9.87
P	1.41	2.82	4.23	-1.21	-2.42	-3.64
K	17.27	34.53	51.80	13.16	26.32	39.47
Ca	48.72	97.44	146.15	19.62	39.24	58.86
Mg	-0.52	-1.04	-1.56	2.36	4.73	7.09
Zn	9.33	18.67	28.00	1.19	2.39	3.58
Mn	2.05	4.11	6.16	12.57	25.14	37.71
Cu	22.09	44.19	66.28	5.17	10.34	15.51
Fe	92.52	185.05	277.57	45.61	91.22	136.82
Cr	95.00	190.00	285.00	57.50	115.00	172.50
Ni	6.79	13.57	20.36	-1.96	-3.93	-5.89
Al	-3.01	-6.01	-9.02	-3.87	-7.74	-11.61

Table 3. Ingredient content of the flour and seed samples

		Flour 650	*A. hippocastanum*	*C. sativa*
Carbohydrates	g/100 g	85.86 b	44.52 a*	42.47 a
Protein		11.69 c	7.15 b	4.55 a
Fat		1.03 a	7.05 c	1.79 b
Ash		0.49 a	3.56 C	2.11 b

*See Table 1

After the addition of 5, 10 and 15% of the tested admixtures to wheat flour, it can be observed that the resulting mixture contains fewer carbohydrates and proteins, but more fats (Table 4). The calorific value of the flour decreases with the increase of the admixture used. This is due to the lower proportion of essential nutrients in the total weight of the fruits tested. Carbohydrates, proteins and fats constitute 98.58% of the composition in the case of wheat, while in the case of the tested admixtures it is 58.72% for horse chestnut and 48.81% for chestnut. However, the calorie losses are relatively small compared to the increase in micro and macronutrient content. Wheat flour contains 399.47 kcal per 100 g. A 5% contribution of horse chestnut fruit reduces caloricity by 6.467 kcal, while a contribution of chestnut reduces caloricity by 9.764 kcal for each 5% contribution. The use of this type of admixture could enrich the bread and its value as a functional food.

Phenolic compounds have antioxidant and antimicrobial properties. They may help control infectious diseases, cancer, or cardiovascular diseases (Ozcan et al., 2014). The increased amount of phenolic acids and flavonoids in bakery products may benefit the health-promoting aspects of foods that are consumed by humans almost daily. In horse chestnut fruit, 133.92 mg/100 g of phenolic acids were detected, while in chestnut fruit, 79.88 mg/100 g (table 5). In wheat, phenolic acids have been shown to range from 72.8 to 90 mg/100 g (Fernandez-Orozco et al., 2010). Coumarin is a naturally occurring substance in cinnamon, blueberries, or tea, but due to the possibility of poisoning after consuming larger amounts, it is recommended to limit its intake. Coumarin also shows antioxidant and anticancer properties (Bielawska et al., 2014). In bakery products with cinnamon, it is permitted at 50 mg/kg, but in most, the permissible limit is 2 mg/kg. For a 60 kg person, the daily dose of coumarin was calculated to be 4.085 mg or 0.07 mg per kg body weight (European Parliament and Council, 2008). The coumarin content of the tested fruits is many times higher than the EU standards, but they are intended only as an additive to flour.

Saponins are present in horse chestnut fruit in large quantities. Harmful excess should be washed away as it is dangerous to human health. Saponins can cause haemolysis of the blood, but consumption of smaller amounts is safe. Saponins are found in legumes, vegetables and cereals. Saponins, if consumed in small amounts, have a positive effect on health - reducing the risk of cancer and regulating cholesterol levels (Rao and Gurfinkel, 2000; Gemede and Ratta, 2014). Saponins are present in horse chestnut fruit at 2422 mg/100 g, but these can be reduced not only by washing themselves, but also by the cooking process. High amounts of saponins negatively affect the taste of the flour mixture - they give a soapy aftertaste.

Tannins, like saponins, are non-nutritive substances. They have a bitter taste and, as in the case of saponins, excess amounts should be removed. Tannins show antioxidant, anticancer, anti-inflammatory, immunomodulatory, anticoagulant and vasodilatory effects (de Morais Cardoso et al., 2017, Floegel et al., 2010). In horse chestnut fruit, the amount of tannin was found to be 13.54 mg/100 g and in chestnut fruit, 21.38 mg/100 g. In amounts added to wheat flour, they do not worsen its taste, but can be a valuable contribution with health-promoting effects.

Organic acids are widely used to regulate the acidity of foods and also to improve flavour. The antioxidant and preservative properties of these compounds make them highly preferred in the food industry. Fumaric acid is used in the food industry as additive E297. It has preservative and antioxidant effects (Gill and Kolson, 2013). Its presence was only found in chestnut fruit at 0.92 mg/100 g.

Malic acid exhibits anticoagulant effects and is also used in the food industry as a preservative (Zhang et al., 2014). In the fruits studied, it was detected at 138.42 mg/100 g in horse chestnut fruit and 42.11 mg/100 g in chestnut fruit (Table 5). Citric acid shows antioxidant properties, in the food industry it is used as an acidity regulator (Korotkova et al., 2002). It was found in horse chestnut fruit at 316.05 mg/100 g and in chestnut fruit at 113.84 mg/100 g. A substance that not only has antioxidant properties, but also protects against heart disease, high cholesterol, high blood pressure and has an anti-cancer effect is ascorbic acid (Campos et al., 2013). Fruits contain high amounts of ascorbic acid, orange juice contains approximately 39.25 mg/100 mL.

Rosehips contain high amounts of vitamin C Wild rose (Rosa canina) has been shown to contain 417 mg/100 g of ascorbic acid (Bekele and Geleta, 2015; Nojavan et al., 2008). The vitamin C content of the fruits tested is much lower. It is 12.37 mg/100 g for horse chestnut fruit and 5.88 mg/100 g for chestnut fruit, but any increase in the number of vitamins in the food can have positive effects. Oxalic acid was also present in the fruits of C. sativa. Shikimic and quinic acids were also found in the fruits of A. hippocastanum. Very valuable is the presence of quinic acid showing very strong antioxidant activity.

The higher content of polyphenolic compounds and organic acids influenced the higher free radical binding capacity of A. hippocastanum fruits (Table 5). The DPPH index for horse chestnut fruits was 7.38 mg/mL, while FRAP was 29.53 mg/mL. For chestnut fruit, the values were significantly higher; DPPH 29.53 and FRAP 43.88. For wheat, the DPPH index is 44.1 mg/mL and FRAP 110 mg/mL, while for bread made from its flour, DPPH is 14.1 and FRAP 81.7 (Alvarez-Jubete et al., 2010). The lower values of both indices for the chestnut and horse chestnut fruits studied indicate that they may have better antioxidant and health-promoting properties than wheat.

Chestnut and chestnut flours have high *a** and *b** parameters and are significantly darker than wheat flour (Figures 1 and 2). The higher the L index value, the lighter is the test object. A score of 100 indicates white color, while 0 indicates black color. Wheat flour obtained a score of L parameter 93.9, so it is very bright, while pure flours from chestnut and horse chestnut were 71.2 and 74.6, indicating that they are much darker. With increasing the percentage of tree fruit admixtures, the flour becomes darker, but this should not significantly affect the quality of the baked product.

Chestnut and chestnut flours were subjected to amylographic analysis under identical conditions as wheat flour. The most important information is the germination capacity of the starch. Bread made from flours with suspension gelatinization maximum below 250 AU are characterized by a flat loaf and a moist and sticky crumb with a dark color. Bread made from flour with suspension gelatinization maximum above 1000 AU is characterized by a spherical shape, dry crumb and crispness. Good quality bread is obtained from flour with intermediate values of suspension gelatinization maximum in the range 300-700 AU (PN-EN ISO 7973:2016-01). The maximum germination of flour from horse chestnut fruit is 493 AU (Table 6), so it is within the optimal range. This guarantees the use of the admixture without worrying about baking quality. The maximum germination of chestnut fruit flour is as high as 1874 AU. This result is well above the optimum levels of suspension gelatinization maximum, so for optimal baking, the addition of this flour should be limited in quantity. Mixtures of chestnut flour and wheat flour at 5 to 15% addition have suspension gelatinization maximum values between 470 and 560 AU (Gil, 2015).

Table 4. Variation of nutrient and calorie content in a flour blend

Type of flour	Flour 650	Flour with *A. hippocastanum*			Flour with *C. sativa*		
		5%	10%	15%	5%	10%	15%
Carbohydrates	85.86	83.79	81.73	79.66	83.69	81.52	79.35
Protein	11.69	11.46	11.24	11.01	11.33	10.98	10.62
Fat	1.03	1.33	1.63	1.93	1.07	1.11	1.14
Ash	0.49	0.64	0.80	0.95	0.57	0.65	0.73
				Calories			
Carbohydrates	343.4	335.2	326.9	318.6	334.7	326.1	317.4
Protein	46.76	45.85	44.94	44.04	45.33	43.90	42.48
Fat	9.27	11.98	14.69	17.40	9.61	9.95	10.30
Sum (kcal)	**399.5**	**393.0**	**386.5**	**380.1**	**389.2**	**380.0**	**370.2**

Table 5. Contents of polyphenolic compounds and organic acids in the fruits of the studied species

			A. hippocastanum	*C. sativa*
	Phenolic acids	mg/100 g	133.92 b	79.88 a
	Coumarins		40.05 b	24.61 a
	Flavonoids		158.52 b	38.72 a
	Saponins		2 422	nd
	Tannins		13.54 a	21.38 b
Organic acids	Fumaric		n.d	0.92
	Malic		138.42 b	42.11 a
	Citric		316.05 b	113.84 a
	Ascorbic		12.37 b	5.88 a
	Shikimic		0.93	n.d.
	Oxalic		0.18 b	0.13 a
	Quinic		6.83	n.d.
	DPPH	mg/mL	7.38 a	25.3 b
	FRAP		29.53 a	43.88 b

* see Tab. 1

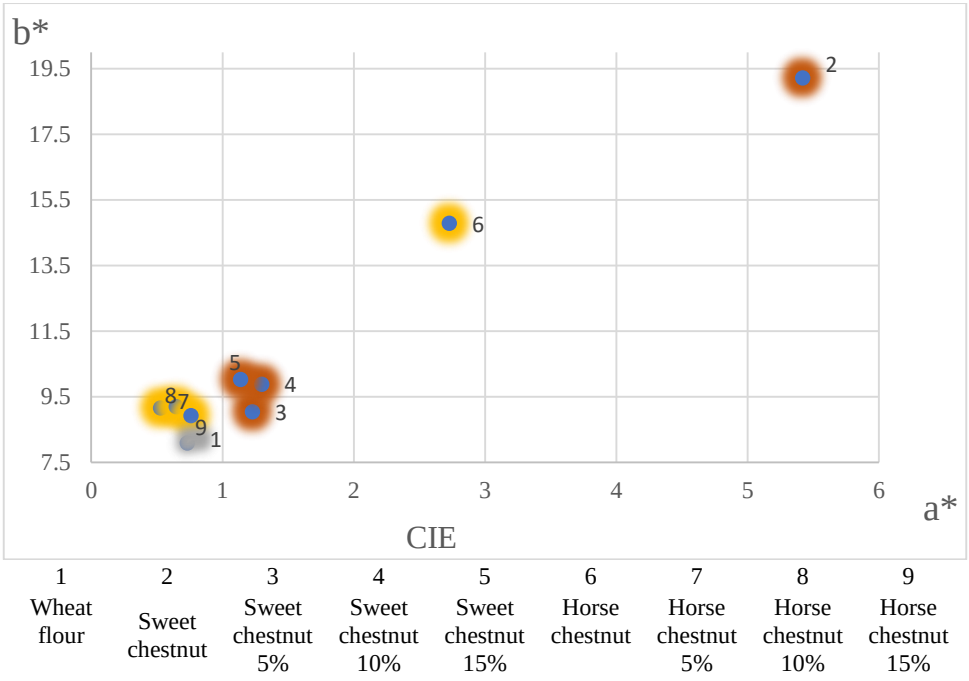


Figure 1. Changes in CIE chromatic color a* and b* parameters

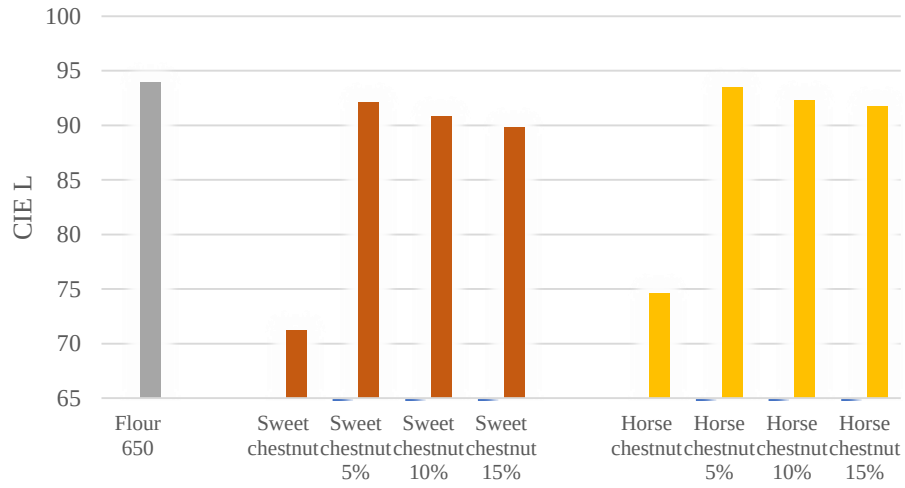


Figure 2. Changes in monochromatic color L* parameter

Table 6. Amylographic properties of the seed samples

NR	*A. hippocastanum*	*C. sativa*
Beginning of gelatinization (ºC)	64.5 b*	58.4 a
Gelatinization temperature (ºC)	72.6 a	90.5 b
Gelatinization maximum (AU)	493 a	1874 b

* see Tab. 1

Farinographic evaluation was carried out according to standards for wheat flour. The farinographic evaluation determines the water absorption of flour and studies the changes in consistency and elasticity of dough obtained from wheat flour and water during its formation: dough development time and constancy, dough softening and quality number. One of the most important characteristics of dough is water absorption. Flour can bind water while maintaining optimal dough consistency. Water absorption is mainly dependent on ash content, quantity and quality of gluten proteins, starch and flour granulation (Sobczyk, 2012). The moisture content of the samples was 9.6%, as Table 7 shows. According to the recommendations of PN-ISO 712 standard, flour moisture content should not exceed 15%. Exceeded moisture content may cause a decrease in the technological value of flour and contribute to microbial growth.

Table 7. Farinographic properties of the flour and seed samples

Type of flour	Flour 650	Flour with *A. hippocastanum*			Flour with *C. sativa*		
		5%	10%	15%	5%	10%	15%
Water absorption	51.9 ac*	52.0 bc	51.8 ac	53.2 c	51.6 ab	52.8 bc	50.5 a
Development time	2.8 a	5.3 b	5.5 b	6.9 c	6.6 c	4.9 b	14.6 d
Stability	5.8 a	10.1 c	12.6 d	11.0 c	7.8 b	10.0 c	19.2 e
Degree of softening after 10 min	60.5 bd	53.0 b	35.0 a	63.5 cd	66.0 d	55.0 bc	32.5 a
Degree of softening after 12 min	109.5 c	76.0 a	74.0 a	105.0 c	132.5 d	92.5 b	65.0 a
Quality number	43.0 a	64.5 b	70.5 bc	84.0 d	74.5 cd	77.0 cd	146.0 e

* see Tab. 1

Wheat flour type 650 used in this study showed water absorption of 51.9%. Wheat flour admixed with 5, 10 and 15% horse chestnut flour obtained water absorption at a similar level of 51.8-53.2%. These results indicate a gentle increase in water absorption of the mixture. For the chestnut additive, the water absorption was in the range of 50.5-52.8% (Table 7). Table 3 shows the ash content, which was 0.49 g/100 g for wheat flour, 3.56 g/100 g for horse chestnut fruit and 2.11 g/100 g for chestnut fruit, respectively. Other studies also showed high ash content in chestnut fruit (2.51 g/100 g) horse chestnut (1.6-2.2 g/100 g) (Borges et al., 2008, Foca et al., 2011). The ash content of the studied input is several times higher than that of wheat flour, moreover, the studied fruits are gluten-free inputs and contain lower amounts of starch. The preservation of water absorption capacity at a similar level and even its increase after taking into account the added flours may be due to the increased amount of ash fraction in the obtained mixture.

Following the guidelines of PN-EN ISO 5530-1:2015-01, the classification of the obtained mixtures was carried out. The water absorption of the wheat comparison flour at the level of 51.9% indicates that it is a medium flour. The other samples that contain gluten-free additives also fall within the ranges of this parameter for medium flour.

The development time and dough solidity after adding horse chestnut and chestnut flours increased significantly. For wheat flour, the development time was 2.8 min and the dough reached firmness after 5.8 min. In terms of development time, wheat flour is a medium flour whereas in terms of time to reach solidity, it is a satisfactory flour. The development time of flour with chestnut fruit admixture varied from 5.3 to 6.9 min depending on the percentage contribution.

These results allow us to classify these mixtures as strong flours. The time for the dough to reach constancy for these mixtures is between 10.1 and 12.6 minutes. Flours in which dough reaches constancy in more than 10 minutes are very good flours, and this is how these mixtures can be classified. The dough of flours containing chestnut fruit admixtures developed in 4.9 to 14.6 min, depending on the amount of addition. The sample with the addition of 5 and 10% is a strong flour, while the sample with the addition of 15%, which development time significantly differs from the others, is in this aspect a very strong flour.

These mixtures reached dough stability after 7.8 to 19.2 min. Flour with a 5% contribution in achieving dough stability is a good flour, flour with a 10% contribution is on the border between a good and a very good flour, while flour with a 15% contribution is a very good flour.

Wheat flour considering dough softening after 10 minutes is satisfactory flour while after 12 minutes is weak flour. Flour with 5 and 15% of horse chestnut admixture after 10 minutes showed the characteristics of satisfactory flour, while after 12 minutes it showed the characteristics of poor flour. Flour with 10% admixture showed the characteristics of good flour after 10 minutes, while after 12 minutes it showed the characteristics of poor flour.

Flour with the addition of 5 and 10% chestnut fruit showed the characteristics of satisfactory flour after 10 minutes and poor flour after 12 minutes. The addition of 15% caused the flour after 10 minutes showed the characteristics of good flour and after 12 minutes of satisfactory flour.

The quality number for wheat flour indicates that it is a strong flour. All blends containing chestnut fruit and flours with 5 and 10% chestnut fruit input can be classified as medium flours, only the blend containing 15% chestnut fruit input showed the characteristics of weak flour. Wheat flour with the addition of 5 to 15% horse chestnut flour was characterized by a water absorption of 56.7-58.4%. This is a sign of medium flour. Its development time was determined at 1.5-2 minutes, and the clotting time at 0.7-2 minutes, which is typical for weak flours. The qualitative number was set at 40-48, which characterizes strong flours (Gil, 2015). These results differ significantly from those obtained in our own research.

Medium/strong flour is the most suitable for baking bread. Technologically the best is the mixture with 10% addition of horse chestnut fruits. Its parameters only slightly differ from wheat flour. As far as the degree of softening after 10 minutes is concerned, the mixture turned out to be more efficient than wheat flour, however its quality number is worse. The best mixtures containing the addition of chestnut fruit are those with an input of 10 and 15%. (Table 8) Regarding development time, these mixtures are worse than wheat flour, but the 10% variant presents better. Dough stability time is better than wheat flour in both variants, but the 15% variant shows better. In terms of the degree of softening after 10 and 12 minutes, the best mixture is the 15% variant, but it loses in terms of quality number. Probably the optimum of this mixture is between 10 and 15%, where there is a possibility to obtain the best results and technological parameters of this mixture (Table 8). Mixtures with these parameters are suitable for baking mixed bread.

Table 8. Evaluation of flour mixtures

Type of flour	Flour Type 650	Wheat flour +5% Horse chestnut	Wheat flour +10% Horse chestnut	Wheat flour +15% Horse chestnut	Wheat flour +5% Sweet chestnut	Wheat flour +10% Sweet chestnut	Wheat flour +15% Sweet chestnut
Water absorption**	2	2	2	2	2	2	2
Development time**	2	3	3	3	3	3	4
Stability*	3	5	5	5	4	4/5	5
Degree of softening after 10 min*	3	3	4	3	3	3	4
Degree of softening after 12 min*	2	2	2	2	2	2	3
Quality number**	3	2	2	2	2	2	1

*Stability, Degree of softening (5-point scale) 1 - very poor, 2 - poor, 3 - satisfactory, 4 - good, 5 - very good,
**Waterabsorption, development time, quality numer (4-point scale) 1 - weak, 2 - medium, 3 - strong, 4 - very strong.

CONCLUSIONS

The studied fruits of the common chestnut and the horse chestnut can significantly improve the composition of wheat flour in micro and macroelements. The amounts of mineral components and heavy metals in the amount of 5-15% of the flour input do not exceed the consumption standards. The chemical composition of the tested additives shows health-promoting and antioxidant properties. The biggest problem in the case of horse chestnut fruits is saponins, which should be washed out and their amount reduced. In small quantities, they can be a valuable health-promoting additive. A colour change towards brown was recorded after adding the input to wheat flour. Amylographic studies have shown that the tested flour from horse chestnut fruit has adequate technological/baking parameters. Flour from chestnut fruit significantly exceeds the optimal parameters. As an addition in the amount of 5-15%, it will overestimate the parameters of the mixture based on wheat flour, which may cause a deterioration of the shape of the finished baked product and its quality. Farinographic analysis showed that the best technical properties were demonstrated by an admixture of 10% horse chestnut fruit. In the case of chestnut fruit, both 10 and 15% admixture showed good technical parameters, probably the optimum amount of this input is somewhere between the tested values.

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Conflict of interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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

Declaration of competing interest
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