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THE APPLICATION OF NON-BAKERY RAW MATERIALS TO BAKERY FLOURS, THEIR EFFECT ON THE TECHNOLOGICAL QUALITY AND THE COST OF INNOVATIVE PRODUCTS

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ABSTRACT

The paper describes the possibilities of designing breads and pastries produced according to a basic recipe from wheat or wheat-rye flour to improve their nutritional potential. The basic principle is the partial replacement of wheat or rye with non-bakery raw materials, which are valued thanks to the content of beneficial components. In this way, it is possible to create diverse products with the potential for positive effects on consumer health. However, the application of such raw materials affects the technological parameters of composite flours and subsequent intermediates of the production process, and it also changes cost items and, consequently, the production price of the products. Therefore, efforts should be made to find the right balance and recommend procedures and recipes that allow the final product to be prepared with the required quality and an affordable price. In our research, the additions of various non-bakery ingredients were verified, and the presented results show how these ingredients affected the selected rheological properties of the dough, and how these changes in the basic recipe affected the costs of the final product. During the experiments, the following raw materials were added: spelt wheat flour, amaranth flour, flour from selected legumes (common bean, broad bean, chickpea, lentil) and lyophilised homogenized red fruits (elderberry fruits, blackcurrant fruits, black chokeberry, and serviceberry fruits, or in the case of elderberry also flowers). The addition of these non-bakery ingredients, depending on the amount of their addition, changed both the water absorption and the rheological properties of the dough (dough development time, dough stability), or baking loss or bread yield. Non-bakery raw materials increase the financial cost of innovative products, and the question arises as to how willing consumers are to pay extra for such foods with added nutritional value. Nevertheless, we believe that designing and producing modern foods with nutritional benefits to meet the demanding needs of modern consumers has a promising future.

Keywords: bread, non-bakery raw materials, water absorption, dough development time, dough stability, bread yield, cost

INTRODUCTION

Cereals are plants from the *Poaceae* family, grown primarily for grain, which in our conditions form a key group of crops for crop production. The main types of temperate cereals include wheat, barley, oats, rye, triticale, and corn (***Karabínová et al.*, 1997**). Wheat is a basic cereal that is used in the production of daily food consumed in the Slovak Republic, especially bread and pastries. The difference between bread and pastries is based primarily on the weight of the products, with products weighing more than 400g being referred to as bread and products weighing less than 400g as pastries (**Bulletin MARD SR, 2014**). However, the difference is often also in the applied raw materials because bread in Slovakia is usually made from a mixture of wheat and rye flour and pastries are mostly made only from wheat flour. Both products (bread and pastries) are very popular and are part of the daily diet. They are consumed in the morning as part of breakfast (in salty or sweet form), but they are also common as part of snacks and as a side dish to some typical soups consumed as lunch. Bread also constitutes a common part of an evening meal.

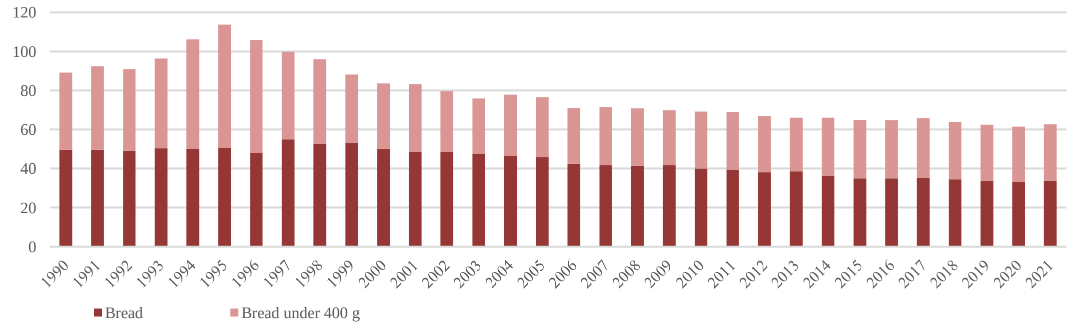


Figure 1 Consumption of bread and pastries per person per year in Slovakia (**DATAcube, 2023**)

However, bread consumption in Slovakia has undergone a significant development over the last 30 years, and as can be seen from Figure 1, there is a relatively significant decrease in consumption. From 1990 to 2020, the consumption decreased by almost 28 kg per person per year (**DATAcube, 2023**), which can be explained by several reasons. On one hand, information or myths have emerged that bread is not a valuable food, that it is exclusively a source of energy and does not provide any other nutritional benefits, that it causes weight gain and is responsible for the growing obesity and other related health problems of the population. The attack on gluten and the foods that contain it can also be considered a significant factor. Of course, there are diagnoses and, consequently, consumers who cannot consume foods containing celiac active proteins, but for most of the population such restrictions are not necessary.
Despite the above issues, bread is considered a staple food to pay attention to, and without which it is impossible to imagine eating in Slovakia. There are several

ways to popularize bread and similar cereal products and highlight their nutritional benefits. Within the framework of modern technologies, it is very promising to use composite flours based on wheat and other cereals and non-grain, as well as other raw materials with nutritional benefits. Currently, considerable attention is being paid to building consumer awareness of the importance of healthy food containing bioactive ingredients with potential preventive effects on health. There are several types of plants whose consumption reduces oxidative stress, strengthens the body's immune system, or has other defined effects due to the content of active bioactive substances. Such species include, for example, pseudocereals, legumes, but also small berries (red fruits) or plants that can be considered medicinal (milk thistle, hemp seeds, etc.), also archaic cereals, or non-bakery cereals, e.g., oats or barley, or malt (***Tebben et al*., 2018; *Torbica et al*., 2018; *Boukid et al*., 2019; *Bonafaccia et al*., 2000*;* *Calín-Sánchez et al*., 2020**).

Finding ways to replace a certain proportion of wheat with raw materials that have nutritional benefits and can make "ordinary" bread more attractive is not quite an easy task, primarily due to the unique property of wheat proteins to create gluten during dough kneading, capable of capturing fermentation gases during dough rising, and ultimately forming a porous crumb and its large volume. By adding more raw materials, gluten-forming proteins are diluted, causing technological deficiencies in such products (***Banu et al*., 2011; *Švec and Hrušková*, 2015; *Turfani et.al*., 2017; *Bresciani and Marti*, 2019**). Another issue is the increasing cost of a product when non-traditional raw materials are used that are usually more expensive. It is also necessary to raise the question of what prices for such products are still acceptable to consumers.

The aim of the research, which is presented in this paper, was to verify the addition of non-bakery raw materials to wheat or wheat-rye flour and to evaluate their impact on economically significant rheological properties of doughs, the quality properties of the final products and to determine the financial costs of such innovative foods.

MATERIAL AND METHODS

In the framework of the analyses and bakery experiments, commercially available flours were used:

WF $^{\text{WA, LF, FFF}}$ bread wheat flour T650 (Mlyn Zrno, Veľké Hoste, Slovak Republic),

WF I $^{\text{SF}}$ and **WF II** $^{\text{SF}}$ wheat flour T 650 (Mlyn Pohronský Ruskov, a.s., Slovak Republic),

WF III $^{\text{AF}}$ bread wheat flour T650 (Mlyn Zrno, Veľké Hoste, Slovak Republic),

WF IV $^{\text{AF}}$ bread wheat flour Babičkina voľba (Vitaflora, Mlyn Kolárovo, a.s., Slovak Republic),

WF V $^{\text{FFF}}$ and **WF VI** $^{\text{FFF}}$ bread wheat flour T650 smooth (Mlyn Zrno, Veľké Hoste, Slovak Republic),

RF $^{\text{WA, LF, FFF}}$ rye flour T500 (Mlyn Zrno, Veľké Hoste, Slovak Republic),

RF $^{\text{AF}}$ bread rye flour (Vitaflora, Mlyn Kolárovo, a.s., Slovak Republic),

SF spelt wholemeal flour (J. Vince, s.r.o. Slovak Republic),

ChF $^{\text{LF}}$ (Mlyn Zrno, Veľké Hoste, Slovak Republic),

BBF $^{\text{LF}}$ (Mlyn Zrno, Veľké Hoste, Slovak Republic),

CBF $^{\text{LF}}$ (Mlyn Zrno, Veľké Hoste, Slovak Republic),

RLF $^{\text{LF}}$ (Mlyn Zrno, Veľké Hoste, Slovak Republic),

AF amaranth flour was prepared in laboratory conditions from amaranth seeds, Zobor variety. The laboratory mill CD 1 auto (Chopin Technologies) was used for grinding, fractions I and II were incorporated into the composite flours.

FFF fruits and flower flours: red fruits (elderberry fruits, serviceberry fruits, chokeberry fruits, blackcurrant fruits) were lyophilized under laboratory conditions (TFD5503, ilShinBioBase), subsequently homogenized. Elderberry flowers were naturally air-dried at room temperature.

All commercially available flours have defined quality parameters (Table 1).

Table 1 Quality parameters of commercial flours

	Energy value [kJ]	Carbohydrate content [g/100g]	- of which sugars	Fiber content [g/100g]	Protein content [g/100g]	Fat content [g/100g]	- of which saturated	Salt [g/100g]
WF $^{\text{WA, LF, FFF, AF(III)}}$	1464	71	1.59	3.3	11.0	1.3	0.30	0.01
WF $^{\text{SF}}$	1447	73	2.01	3.15	11.3	1.53	0,23	0.01
WF $^{\text{AF(IV)}}$	1461	69	2.0	3.1	12.0	1.7	0.2	0.01
RF $^{\text{WA, LF, FFF}}$	1396	68	3.00	11.0	7.5	1.1	0.20	0.01
RF $^{\text{AF}}$	1535	76	3.0	8.4	7.7	1.2	0.2	0.01
SF	1446	63.9	0.10	8.16	16.7	2.04	0.10	0.01
ChF $^{\text{LF}}$	1322	59	-	-	16.7	4.8	0.5	0.07
BBF $^{\text{LF}}$	1300	49.7	3.3	-	28.0	2.5	0.4	0.01
CBF $^{\text{LF}}$	1354	49	3.2	-	25.0	1.5	0.5	0.01
RLF $^{\text{LF}}$	1263	54	2.0	-	17.0	2.5	0.5	0.01

Legend: WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], and RLF [red lentil flour] $^{\text{WA}}$ use for water absorption, $^{\text{SF}}$ use for the experiment with spelt flour, $^{\text{AF}}$ use for the experiment with amaranth flour, $^{\text{FFF}}$ use for the experiment with fruits and flower flours, $^{\text{LF}}$ use for the experiment with legumes flours.

The following ratios for composite flours were used in the experiments (Table 2):

Table 2 Experimental variants of composite flours

With the addition of spelt flour	With the addition of amaranth flour	With the addition of legumes flours	With the addition of red fruits and elderberry flowers
WF I $^{\text{SF}}$70:SF30	WF III $^{\text{AF}}$95:AF5	WF $^{\text{LF}}$50:RF $^{\text{LF}}$35:CBF15	WF $^{\text{FFF}}$85:EFlo15
WF II $^{\text{SF}}$70:SF30	WF III $^{\text{AF}}$90:AF10	WF $^{\text{LF}}$50:RF $^{\text{LF}}$35:ChF15	WF $^{\text{FFF}}$85:EFru15
	WF III $^{\text{AF}}$85:AF15	WF $^{\text{LF}}$50:RF $^{\text{LF}}$35:BBF15	WF $^{\text{FFF}}$85:BFru15
	WF IV $^{\text{AF}}$50:RF $^{\text{AF}}$45:AF5	WF $^{\text{LF}}$50:RF $^{\text{LF}}$35:RLF15	WF $^{\text{FFF}}$85:ChFru15
	WF IV $^{\text{AF}}$50:RF $^{\text{AF}}$40:AF10		WF $^{\text{FFF}}$85:SFru15
	WF IV $^{\text{AF}}$50:RF $^{\text{AF}}$35:AF15		

Legend: WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], and RLF [red lentil flour] $^{\text{SF}}$ use for the experiment with spelt flour, $^{\text{AF}}$ use for the experiment with amaranth flour, $^{\text{FFF}}$ use for the experiment with fruits and flower flours, $^{\text{LF}}$ use $^{\text{the}}$ for experiment with legumes flours.

In addition to flour, other ingredients such as salt (K.S. Czech Republic, a.s.), and dry yeast of the species *Saccharomyces cerevisiae* (Saf-Instant, Lesaffre, SR) were used in the bakery experiments. They were purchased from the local market. To get as close as possible to the real cost of the products, flour prices from the trade network were used for economic calculations (obchod.mlyn-zrno.sk, 29.6.2023). When calculating the cost of freeze-dried fruit powders and dried elderberry flowers, prices of similar material available in the retail network were used (diana-company.sk, 3.8.2023). The prices ranged from € 45.55 per 1 kg to € 53.95 per 1 kg. An indicative price of €53 per 1 kg or €19.20 per 1 kg of dried elderberry flowers was used in the calculations.

For calculating the price differences of the production of bread with additions compared to conventional bread, the calculation formula was used in the following structure:

1. Direct material – representing material costs (flour, additives, and other ingredients),
2. Personnel costs – representing wages and social health security costs using the institute of current average wage,
3. Energy costs – representing the standard electricity consumption of the production equipment used (mixer, acid plant, furnace),
4. Overhead costs – representing overheads of production, administration, and sales character + trade margin. For determining the final prices and the resulting price differences for individual products and because the number of overheads in individual bakeries is highly individual, as is the marketing margin, the number of overheads was derived from the average selling price of the bread as the difference between that selling price and the sum of the direct costs (points 1 to 3).

Values used for the calculation: average price of bread 2.1 €/kg, average electricity price 0.199 €/kWh (it is not possible to set a relevant energy price that would be universal for all customers, so we modelled with a price at the level of 0.199

€/kWh, Regulation of the Government of the Slovak Republic no. 18/2023), personnel costs 1.795 €/month // 40 hours / week // 160 hours / month, 11 €/hour.

To determine the technological quality of the flour used, the following was determined: dry matter (ICC Standard 110/1), ash content (ICC Standard 104/1), nitrogen content according to Kjeldahl (AACC Method 46-12.01), amount of gluten and its properties (ICC Standard 106/2), decrease number (ICC Standard 107/1), sedimentation index according to Zeleny (ICC Standard 116/1).
The rheological behaviours of the composite flours were determined in a Mixolab 2 (Chopin Technologies, France) according to the ICC Standard Method 173 using the "Chopin „S"-protocol. The evaluated parameters from the mixolab curves were water absorption (WA), dough development time (DDT)and stability (DS, mixing resistance of dough).
Bread-making procedure: wheat, rye and other flours blends as shown in Table 2 were used for baking tests mixed with water (based on water absorption); 2.0% NaCl, and 1.4% dry yeast. The percentages are based on 100% of the flour mixture. All components were kneaded in a spiral kneader type SP 12 D (Diosna Dierks & Söhne GmbH, Osnabrück, Germany), the kneading time was determined by a mixolab. After 40 min of fermentation (35 °C) the samples were baked for 40 min as follows: at 180 °C for 7 min, at 200 °C for 20 min, and at 160 °C for 13 min, with steam (250 mL) (MIWE Condo).
The bread loaves were cooled at room temperature and analysed by a Volscan Profiler volume analyser (Stable Mycrosystems, Surrey, UK) two hours after baking. The selected parameters were evaluated: weight of the bread (g), specific volume (mL/g), volume yield (mL/100 g flour). Bread yield (%) and baking loss (%) were calculated based on the weight of the bread, the weight of the flour and the weight of the dough:

Bread yield = weight of the bread x 100 / weight of the flour (%)
Baking loss = [(weight of the dough - weight of the bread) / weight of the dough] x 100 (%)

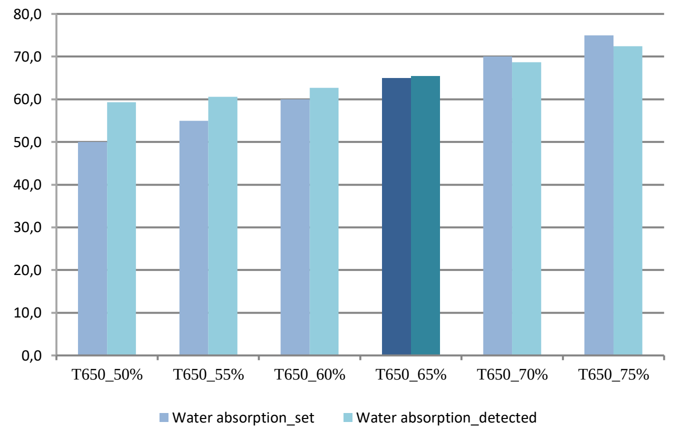
An analysis of variance (ANOVA) and a Fisher's multiple range test were applied at a significance level of 5% to describe the significance of the differences between the reference and the samples with different levels of non-bakery flours incorporated. All analyses were performed in triplicate and average values were calculated. XLSTAT 2020.5.1 by Addinsoft was used as the statistical analysis software. A linear regression (Microsoft Excel 2010, Microsoft Corporation, Redmond, Washington, U.S.) was used to display the trend line and the calculated correlation coefficient was evaluated at the significance level α = 0.05 (Microsoft Excel 2010).

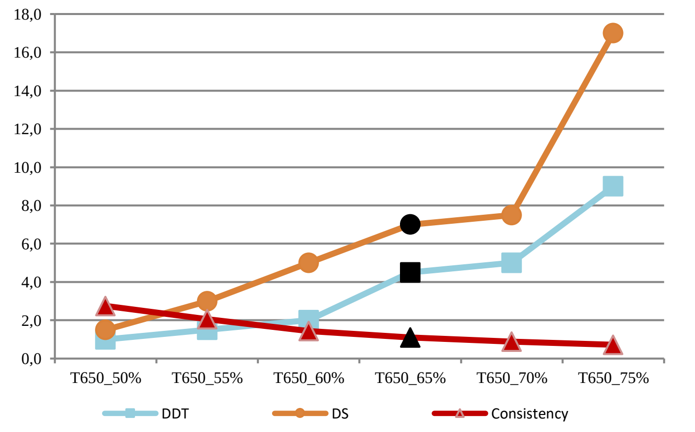
RESULTS AND DISCUSSION

Currently, there is a trend of enriching individual types of cereal foods with health-promoting components. Researchers devote a lot of effort to increase the content of fibre, since its share in ground flour is low by removing bran in the grinding process, but this has its technological justification. The fractions of flour in cereals that are technologically usable are characterized by a high content of starch and protein, while the fractions of bran have a higher content of fibre, lipids, vitamins, mineral compounds, and biologically active substances (***Evers and Millar*, 2002**).
Natural sources of fibre added to compound flours can be, for example, homogenized seeds of pseudocereals (buckwheat, amaranth), legumes (common beans, chickpeas, lentils, beans, and others) or other plants (e.g., milk thistle, hemp flour, sunflower pomace flour). It is also possible to add defined sources of fibre, e.g., inulin, beta glucan, or fibre isolated from by-products of the food industry (potatoes, sugar beet, blueberry fibre, etc.). In all cases, the added fibre affects the properties of the dough, primarily the water absorption and rheological properties (***Bojňanská et al*., 2021**).
The research into the enrichment of cereal products is also aimed at increasing other biologically valuable substances, e.g., proteins with a more balanced amino acid composition compared to cereals. In this regard, legumes are excellent ingredients. Replacing wheat flour with legume flour significantly improves the nutritional value by increasing the protein, mineral, and fibre content of bread and decreasing the glycaemic index (***Wyrwisz*, 2015*; Fendri et al*., 2016; *Erbersdobler et al*., 2017; *Turfani et al*., 2017; *Bresciani et al*., 2019; *Edwards et al*., 2020**).
Red fruits are small/small fruits that are characterized by a reddish-purple colour, a sour-sweet taste, and health benefits. Red fruits are especially popular for their attractive taste, pleasant appearance, and valuable composition (**Martinsen et al., *2020*).** These berries have a significant content of phenolic compounds, the main classes of which are phenolic acids (hydroxycinnamic acid and hydroxybenzoic acid), flavonoids (flavonoids, flavanols and anthocyanins) and stilbenes (resveratrol), and are known to contain high amounts of anthocyanins, which are mainly responsible for their colour (***Albuquerque et al*., 2020**).
On the other hand, all these non-bakery ingredients change the technological parameters of flour, dough, and final products, mostly in a negative way. Bread dough is a viscoelastic material that exhibits a medium rheological behaviour between a viscous liquid and an elastic solid. The viscoelastic mesh plays a predominant role in the workability of the dough and the textural properties of the finished bread. In general, replacing wheat flour with non-bakery flour reduces the overall amount of gluten, resulting in the formation of a weaker protein network (***Dapcevic Hadnadev et al*., 2011**).

Water absorption

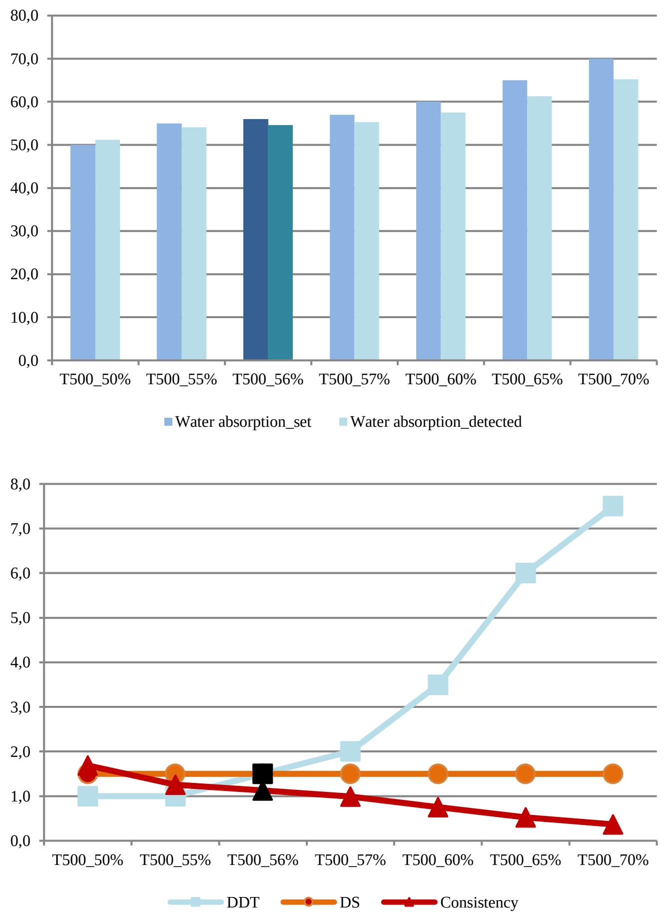
Water absorption (WA) is an important parameter that shows the ability of flour compounds to absorb water and form a dough of optimal consistency. Water absorption, as well as the mechanical properties of dough with added non-bakery flour, are influenced by various factors such as gluten dilution or natural starch properties (***Dapcevic Hadnadev et al*., 2011; *Guzman et al*., 2015**). Moreover, the effect of the amount of water added to the flour greatly affects the rheological properties of the kneaded dough, as shown in Figure 2. The addition of water to T650 wheat flour at a set water binding of 50% and a gradual increase of the set binding to 55%, 60%, 65%, 70% and 75% is manifested by an increase in dough development time and dough stability, however, the consistency of the dough expressed in Nm gradually decreases. For dough suitable for breadmaking, the recommended consistency value is 1.1 Nm, and such a value has been found for this flour at a WA value of 65%, however, the optimal WA values vary depending on the specific flour. This value (WA) is part of every analysis and has an economic impact on the production of the product. The higher the water absorption value, the more water the flour can receive, and the higher the weight of the dough will be. At WA 65% it is necessary to add 65 l of water per 100 kg of flour to obtain dough weighing 165 kg which gives 330 clones (pieces) of dough weighing 500 g each.





(a) (b)
Figure 2 Water absorption (a) and dough characteristics (b) depending on water addition – wheat flour
DDT – dough development time [minutes]; DS – dough stability [minutes]

In the case of rye flour, the determination of an appropriate water absorption is more difficult, mainly due to the different behaviour of rye dough in the kneading process. Due to the high proportion of pectin substances in rye flour, gluten proteins are not able to cross-link, so a solid gluten structure is not formed during kneading (***Ocieczek et al*., 2009; *Voicu et al*., 2012; *Stepniewska et al*., 2019; *Bojňanská et al*., 2022**). As shown in Figure 3, the most suitable dough consistency was found for a particular T500 flour at a water absorption value of 56%. This means that per 100 kg of flour it is necessary to add 56 l of water to obtain dough weighing 156 kg which gives 312 clones (pieces) of dough weighing 500 g each. With an increasing water absorption, the development time of the dough increased, however, its stability was low, which is typical for rye flour.



(a) (b)

Figure 3 Water absorption (a) and dough properties (b) depending on water addition – rye flour
DDT – dough development time [minutes]; DS – dough stability [minutes]

Thanks to the efficient use of the basic raw materials, wheat flour is preferable to rye flour due to its higher binding capacity, because we obtain more dough and an overall higher yield of its final products.
The addition of non-bakery ingredients to wheat or wheat-rye flour is usually chosen so that the prepared final product is exceptional in the content of valuable ingredients. From this point of view, the aim is to increase the proportion of non-bakery raw material as much as possible so that the nutritional effect is as significant as possible. But to preserve the technological and sensory properties of the final product, it is necessary to find the right ratio of bakery and non-bakery raw materials.

The addition of archaic wheat

An interesting and inspiring area of research is the application of ancient, archaic cereals, such as spelt wheat, which are returning to the spotlight as sources of forgotten properties. Spelt wheat (*Triticum spelta* L.) is a husk wheat that belongs to alternative cultivated species that are undemanding as to its growing conditions. For bakery use, the protein and wet gluten content is very important, which is higher in the case of spelt wheat than in the case of the control wheat (***Moudrý and Dvořáček*, 1999; *Wang et al.*, 2020**). However, gluten is more soluble and has a lower elasticity. Due to the greater proportion of the aleurone layer, it contains more protein (16-17%) than common wheat, but there are no significant differences in the amino acid composition between them (***Smolkova et al.*, 2000**). Its use in the production of bread is possible, bread with the addition of spelt flour has a distinctive bread aroma, a large volume, tastes great and remains soft and fresh for a long time (***Bojňanská and Frančáková*, 2002; *Callejo et al.*, 2015**). Bonafaccia (***Bonafaccia et al.*, 2000**) report that bread or spelt flour dough has a different complex of carbohydrates and proteins, has a more quickly soluble starch and a less quickly soluble protein than common wheat dough.
Research by Bojňanská and Frančáková (***Bojňanská and Frančáková*, 2002)** compared five varieties of spelt wheat (Rouquin, Bauländer spelz, Schwabenkorn, Franckenkorn and Holstenkorn) grown in an organic system. Selected grain quality characteristics were monitored. The Schwabenkorn and Rouquin varieties were classified as the most suitable for bakery, they were of the highest quality. In general, however, all varieties of spelt wheat were characterized by a high content of N-substances (ø = 15.46%) and gluten (ø = 37.12%). However, the disadvantages were lower gluten swelling (ø = 9.3 ml) and a lower SDS sedimentation test (ø = 37.4 ml).
A suitable option is to mix spelt wheat in a certain amount with common wheat. For bakery use, not only the protein content is very important, but also the gluten content, the proportion of which is higher in spelt wheat than in common wheat. However, doughs prepared from spelt flour have a lower stability, elasticity and higher ductility compared to regular wheat dough. The spelt dough formed is very sticky and soft, so it is more difficult to handle, and the volumes of these products are generally smaller (***Abdel-Aal et al.*, 1997; *Prussia-Kedzior et al.*, 2008; *Bonafaccia et al.*, 2000**).
Water absorption of doughs with the addition of whole wheat flour from spelt wheat in the amount of 30% increase compared to the control wheat flour, which can also be considered a valuable benefit. Two control wheat flours of different quality (WF I and WF II) were used. However, both cases involved the same type of T650 flour, the technological characteristics of which are given in Table 3, and the addition of spelt wheat increased binding in both cases (Table 4).

Table 3 Technological properties of wheat flours

Wheat flour T650	Moisture [%]	HPx5.7 [%]	Ash content [%]	Acidity [mmol/kg]	G 30 [%]	ZI [mL]	Falling number [s]
WF I.	13.8a	11.5a	0.49a	30.9a	32.6a	40.0a	324.0a
WF II.	12.9b	13.5b	0.48a	32.4a	37.9a	32.0b	361.0b

Values followed by the same letter in the column are not significantly different ($p > 0.05$).
Legend: WF [wheat flour], HP [crude protein], G_{30} [gluten content after 30´ resting], ZI [sedimentation test Zelenyho index]

Table 4 Rheological properties of wheat flours

	Water absorption [%]	DDT [min]	SD [min]
WFI.	60.1a	2.2a	8.0a
WFI.70:SF 30	65.2b	5.0b	6.2b
WFII.	59.8a	4.0c	6.5b
WFII.70:SF 30	62.0b	5.3b	7.7c

Values followed by the same letter in the column are not significantly different ($p > 0.05$).
Legend: DDT – dough development time [minutes]; DS – dough stability [minutes]
WF [wheat flour], SF [spelt flour]

The water absorption of composite flours with the addition of spelt flour was mainly influenced by the hydration ability of proteins as indicated in a sedimentation test referred to as the Zeleny index, The amount of protein alone or the amount of gluten in this case was not a good indicator of the binding ability. In both cases, however, the addition of spelt flour increased the water absorption, by 3.7 to 8.5%, which can be considered as positive. Higher WA values were found in composite flours using WF I, which had a higher ZI than WF II. For DDT and SD, changes after the addition of spelt flour resulted in a prolongation of DDS, no significant changes occurred in DS. The addition of spelt flour did not seriously affect dough kneading and handling during the further processing steps.

Table 5 Properties of loaf of bread with the addition of spelt wheat flour

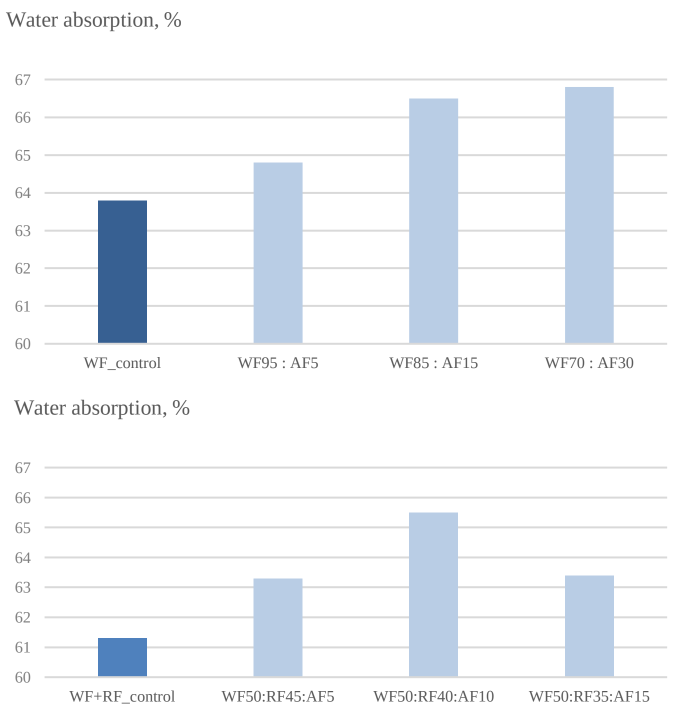
	Specific volume [mL/g]	Volume yield [mL/100 g flour]	Bread yield [%]	Baking loss [%]
WFI.	2.97a	420.0a	141.3a	13.2a
WFI.70:SF30	2.99a	420.0a	140.0a	13.8a
WFII.	2.31b	320.0b	138.3a	14.6b
WFII.70:SF30	2.26b	320.0b	141.1a	14.6b

Values followed by the same letter in the column are not significantly different ($p > 0.05$).
Legend: WF [wheat flour], SF [spelt flour]

A bakery experiment showed that the addition of spelt wheat gives satisfactory products with the required volume and other parameters (Table 5). From the point of view of the efficiency of such production, in addition to volume yield (mL/100 g flour) and pastry yield (%) baking losses are also important, which in this case ranged from 13.2% to 14.6% (on average 14.2% for breads with added spelt flour). These values are at the upper limit of the acceptable level.

The addition of amaranth flour

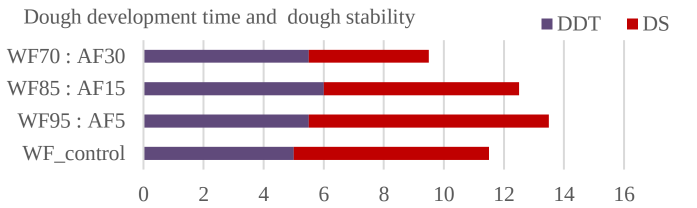
An interesting group of ingredients that can potentially serve as non-traditional non-bakery supplements to classic bread and similar products are pseudocereals. Pseudocereals can be defined as seeds or fruits of non-grassy species that can be consumed similarly to cereals. The most widely used pseudocereals include quinoa, chia, buckwheat and amaranth. All of them have good nutritional and bioactive compounds such as essential amino acids, essential fatty acids, phenolic acids, flavonoids, minerals, and vitamins (***Lamacchia et al.*, 2010; *Guardianellia et al.*, 2019; *Torbicaet al.*, 2019; *Yadav and Yadav*, 2022**). Their addition to composite flour for producing bread and pastries is nutritionally sufficiently justified and indisputable. The impact of adding buckwheat on the rheological properties of dough and related recommendations have been published (***Bojňanská et al.*, 2022**). The addition of buckwheat to ordinary bread as a very popular food consumed daily , has proven to be a very convenient way to make bread more attractive from a nutritional point of view.
In addition to buckwheat, another popular pseudo-cereal in Slovakia is amaranth (*Amaranthus sp.*), which includes several food-usable types. As part of the research, amaranth flour was added to wheat flour T650 in amounts of 5%, 15% and 30% and to wheat-rye flour (50% wheat flour : 50% rye flour) so that it replaced a certain proportion of rye flour, and in composite flour it eventually accounted for 5%, 10% and 15%. It is worth mentioning that rye flour is fundamentally different from wheat flour, and it has different properties. Mainly, it does not form gluten, and therefore is not able to retain fermentation gases. In addition, it has a high proportion of pectin and other polysaccharides and is characterized by a high enzymatic activity (***Ocieczek and Kostek*, 2009; *Voicu et al.*, 2012; *Stepniewska et al.*, 2019**). This means that the mixture of wheat and rye has other properties than wheat flour, and the aim of this experiment was to see how the addition of amaranth flour affects the mixture of wheat and rye.
In the first series of experiments, T650 wheat flour was used to which amaranth flour was added in the amount of 5%, 15% and 30%. The binding was optimised to the desired consistency (1.100 Nm) and increased with the addition of amaranth flour in proportion to the amount of addition (Figure 4). Thus, the addition of amaranth introduces components into the system that have the ability to bind water, which can be considered a desirable charcteristic, since such composite flour will give more dough. Per 100 kg of flour with a proportion of amaranth flour of 30%, it is necessary to add 66.8 l of water to obtaindough weighing 166.8 kg, which gives 333 clones (pieces) of dough weighing 500 g each).



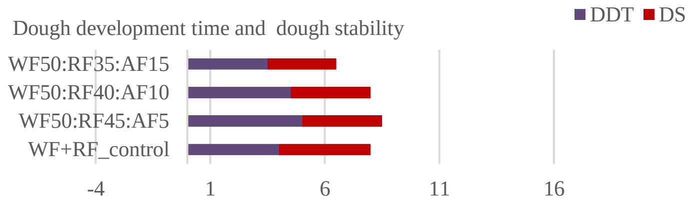
4a 4b

Figure 4a, 4b Water absorption of composite flours with the addition of amaranth flour
WF [wheat flour], RF [rye flour], AF [amaranth flour]

During the observation of the rheological properties of the doughs, it was found that the development time of the dough with the addition of amaranth flour slightly increased, however, with the addition of amaranth flour of 30%, this was no longer in proportion to the amount of the addition. The recommended kneading time of such composite flours is at least 6 minutes. As for the stability of composite flours with the addition of amaranth flour, the lowest addition of 5% prolonged the stability by 1.5 minutes compared to the control wheat flour, which is an advantageous change. With higher additions, there was already a stability decrease, with the addition of 30% significantly, by 2.5 minutes compared to the control wheat flour (Figure 5a). If higher additions of amaranth flour are used, we recommend extending the kneading time and shortening the handling time before baking the products.



a)



b)

Figure 5a, 5b The effect of the addition of amaranth flour on the dough development time and dough stability
DDT – dough development time [minutes]; DS – dough stability [minutes]
WF [wheat flour], RF [rye flour], AF [amaranth flour]

In other experiments, the added amount of amaranth flour was adjusted to a maximum of 15% and wheat-rye flour in a ratio of 50: 50 was used as a control flour. The results of the evaluation of the technological quality of the composite flours prepared in this way are given in Table 6. The addition of amaranth flour primarily affected the enzymatic activity of composite flours (with a higher value of the falling number, the enzymatic activity of the flours decreases), the amount of wet gluten (decrease due to the absence of gluten-forming proteins in amaranth flour) and the quality properties of gluten (Q_{30}, ZI). The detected values indicate worse technological properties compared to wheat-rye flour, but the values are still acceptable and give a prerequisite for the workability of composite flours with amaranth for bakery purposes.
As expected, the addition of amaranth flour changed the water absorption and consistency of the dough, as well as the time required for the dough to develop and its stability. A basic water intake of 60% was not sufficient to create a dough with an optimal consistency (1.1 Nm) and all flours analysed needed a higher addition of water. The dough development time and dough stability were longer in doughs in which the water absorption was optimized, so this step contributed to increasing the time that the dough has an optimal consistency (in terms of bakery properties). The higher the addition of amaranth flour, the more important the optimized WA was for the consistency of the dough.
The water absorption of flour with added amaranth was higher than that of the control mixture (wheat + rye), by 3.3% to 6.9%, depending on the amount of amaranth flour added (Figure 4b). However, the water absorption rate increases with the addition of amaranth in the amount of 5% and 10%, but the addition of 15% no longer increases the WA. From 100 kg of such composite flour with the addition of amaranth in the amount of 10%, 331 loaves of dough weighing 500 g can be prepared.
The fact that in such composite flours the addition of amaranth increases the water absorption is a desirable property with economic impacts. However, in composite flour with wheat, the water absorption was higher than in flour, where the base was a mixture of wheat-rye (Figure 4).
The dough development time and dough stability (Figure 5b) were 5% and 10% longer for amaranth flour additions respectively, or the same as for the control wheat-rye flour, respectively. A higher addition of amaranth flour (15%) shortened the dough development time, but also its stability. In general, the stability of wheat-rye dough is significantly shorter than that of wheat dough, which is due to the properties of rye flour. The addition of amaranth flour increased the dough development time and shortened its stability, but in the end the parameters, except for the highest addition (15%), were similar to those of the control sample with wheat-rye flour or wheat flour.
Based on the above, we recommend setting the kneading process of such flours to a minimum of 6 minutes and a maximum of 8-9 minutes, and in the case of the addition of amaranth 15%, reduce the maximum kneading time to about 5.5 minutes. These results and recommendations can be viewed positively, as it is the addition of non-bakery ingredients that often increases the dough development time, which in turn requires a longer kneading time to create a dough of optimal consistency and increases the energy costs of the dough preparation. Such a situation occurs, for example, when preparing dough with buckwheat, milk thistle flour, oat flour, but also with fibre, e.g., with inulin (***Bojňanská et al.*, 2010; *Tokár***

***et al.*, 2011; *Tokár et al.*, 2012; *Bojňanská et al.*, 2014; *Bojňanská et al.*, 2020; *Bojňanská et al.*, 2022**).

Table 6 Technological properties of composite flours with the addition of amaranth

Composite flour	Moisture [%]	Falling number [s]	G_{30} [%]	T_{30} [cm]	Q_{30} [mL]	ZI [mL]
WF50:RF50_control	11,9a	364a	25,0a	10a	13a	27a
WF50:RF45:AF5	11,9a	384ab	22,7b	10a	12a	27a
WF50:RF40:AF10	11,8a	399b	22,7b	10a	12a	26a
WF50:RF35:AF15	11,8a	402b	22,7b	10a	9b	24b

Values followed by the same letter in the column are not significantly different ($p > 0.05$).
Legend: WF [wheat flour], RF [rye flour], AF [amaranth flour], G_{30} [gluten content after 30´ resting], ZI [sedimentation test Zelenyho index], T_{30} [extensibility of gluten], Q_{30} [swelling of gluten]

As part of the bakery experiment, experimental loaves were prepared, in which wheat-rye flour was the basis, and the addition of amaranth flour was 5%, 10% and 15%. Parameters influencing the most important production costs were evaluated and are clearly summarized in Table 7.

Table 7 Properties of loaf of bread with the addition of amaranth flour

	Specific volume (mL/g)	Volume yield (mL/100 g flour)	Bread yield [%]	Baking loss [%]
WF+RF_control	2,6a	370,6a	142,4a	11,0a
WF50:RF45:AF5	2,3b	332,6b	141,9a	11,5a
WF50:RF40:AF10	2,2b	309,6b	142,2a	11,3a
WF50:RF35:AF15	2,2b	314,7b	141,5a	11,1a

Values followed by the same letter in the column are not significantly different ($p > 0.05$).
Legend: WF [wheat flour], RF [rye flour], AF [amaranth flour]

The addition of amaranth flour to classic bakery ingredients significantly reduced both the specific volume and volume yield, which are important parameters in terms of the expected quality of the bakery production. As for the losses during baking, some differences have been found, however, if the values range from 10% to 15%, they are considered standard and acceptable. None of the raw materials applied increased losses above these values.
Based on the results found, we recommend adding amaranth flour to wheat flour, rather than mixed wheat-rye flours.

The addition of legume flour

Replacing wheat/wheat-rye flour with legume flour significantly improves the nutritional value of the bread produced by increasing the protein, mineral, and fibre content, and decreasing the glycaemic index (***Wyrwisz*, 2015; *Fendri et al.*, 2016; *Erbersdobler et al.*, 2017; *Turfani et al.*, 2017; *Bresciani and Marti*, 2019**). However, even in this type of flour, the absence of gluten causes problems related to the technological properties of the flour, the dough, and the final product. Differences between proteins that do not form gluten cause thinning and subsequent weakening of the wheat dough. Nevertheless, enriching wheat flour with legumes to develop new healthy food products may be the right trend. In relation to the environmental sustainability of agriculture, leguminous crops are also a source of low-carbon proteins produced with a low water consumption. Bread made from mixtures containing legumes has an improved nutritional composition and satisfactory technological and sensory properties (***Sabanis and Tzia*, 2009; *Coda et al.*, 2017; *Boukid et al.*, 2019).**
As part of the research aimed at changing the binding of composite flours and the rheological properties affecting the dough processing, the effect of adding chickpea flour, lentil flour, common bean flour and broad bean flour in the amount of 15% to wheat-rye flour (WF50:RF35:LF15) was evaluated, and the WA results are summarized in Figure 6. The addition of chickpea flour and red lentil flour reduced the water absorption of the composite flour. The addition of broad bean flour to the contrary, especially common bean flour, increased the water absorption of composite flours. Turfani et al. (***Turfani et al.*, 2017**) reported elevated WA in mixtures containing carob flour, while it remained like the control sample of wheat in mixtures with lentil flour, which is rich in protein but contains only a small amount of soluble fibre (2.9%, slightly more than wheat flour) and about 40% starch. In contrast to these results, Bourkit et al. (***Boukid et al.*, 2019**) report an increase of the water absorption by adding flour from chickpeas, lentils, and common beans. The increased water absorption was attributed to the higher water retention capacity of legume flour, which is associated with an increased amount of protein and pentosan. This could result in a change of the water distribution and dynamics in the dough (***Kohajdová et al.*, 2013**). The experiments of Du et al. (***Du et al.*, 2014**) confirmed that variations in the functional properties between legume flours may be associated with different ratios of protein to starch and other components in flour.

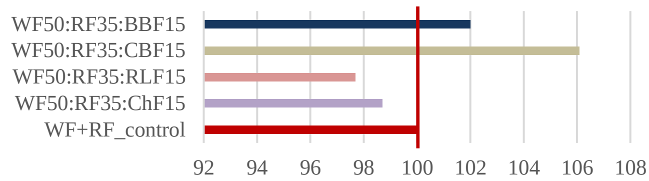


Figure 6 Water absorption in composite flours with the addition of legumes (%)
WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], RLF [red lentil flour]

The addition of legume flours to the mixtures resulted in different viscoelastic properties of the dough. The results showed a weakening of the protein network depending on the amount of legume flour added. In terms of dough development time (DDT) and dough stability (DS), the stability of our doughs was relatively short (Figure 7), including the control flour, because we worked with wheat-rye flour. During the dough development, pentosans disrupt the formation of a protein network and affect the properties of the dough. In wheat flours, the dough formation is mainly achieved by hydrating gluten and gliadin proteins and forming a disulfide bond between them. In the case of rye species, the lower protein content requires less time to hydrate, despite the presence of fibre. Rye flours are not able to form a continuous gluten network, therefore rye flour and whole wheat rye flour have low DDT and DS values (***Bucsella et al.*, 2016**). As to the application of legumes, these deliberately increase the proportion of fibre, and the effect on the rheological behaviour of the dough can be attributed to interactions between the fibre structure and the wheat proteins (***Rubel et al.*, 2015**).
Even with the control wheat-rye flour, its stability was short, and the addition of legume flour with the exception of bean flour did not change it or shortened it even more (chickpea flour). Such composite flours with the addition of legumes in an amount of 15%, which is already a high proportion, need to be processed by kneading very quickly, about 3 minutes in the case of red lentil flour and chickpea flour, and about 5.5 minutes in the case of composite flour with the addition of common bean flour.

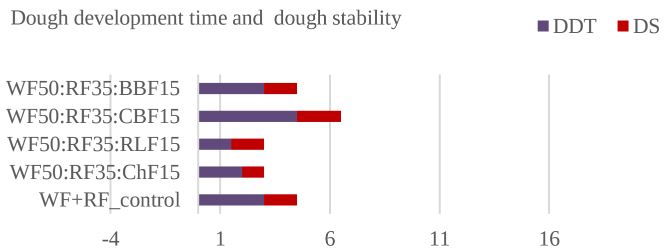


Figure 7 The effect of the addition of legumes flour on the dough development time and dough stability
DDT – dough development time [minutes]; DS – dough stability [minutes]
WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], RLF [red lentil flour]

The expected positive benefit of replacing a certain proportion of rye flour with legume flour was an improved DDT and dough stability. However, the results showed that none of the additives (legume flours) that replace the proportion of rye flour in composite flours had a potentiating effect on the dough stability, nor improved the dough properties by an input of protein structures (Figure 7).
A bakery experiment and the evaluation of parameters important from an economic point of view showed that, as in the case of previous non-bakery ingredients, such a high proportion of non-bakery raw materials reduces both the specific volume and volume yield, but the yield of baked goods does not decrease. Baking losses in dough with an addition of legume flours are not significantly affected (Table 8).

Table 8 Properties of loaf of bread with the addition of legumes flour

	Specific volume (mL/g)	Volume yield (mL/100 g flour)	Bread yield [%]	Baking loss [%]
WF50:RF50_control_CBF	1,94a	295,49a	150.9a	6.7a
WF50:RF35:CBF15	1,82a	284,07a	153.8a	7.6a
WF50:RF50_control_ChF	1,91a	287,97a	148.5a	8.1a
WF50:RF35:ChF15	1,68b	254,15b	149.3a	7.7a
WF50:RF50_control_BBF	2,38a	352,05a	141.9a	11.3a
WF50:RF35:BBF15	1,77b	262,74b	146.5a	10.5a
WF50:RF50_control_RLF	2,48a	360,79a	143.7a	11.7a
WF50:RF35:RLF15	2,15b	309,57b	142.3a	11.1a

Values followed by the same letter in the column are not significantly different (p > 0.05).
Legend: WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], RLF [red lentil flour]

Sabanis and Tzia (***Sabanis and Tzia*, 2009)** suggest that incorporating non-bakery ingredients into bread wheat flour up to a 10% level results in bread without any negative impact on quality attributes such as colour, hardness, and taste, and their reasonable acceptance offers consumers a promising nutritious and healthy alternative. When the level of addition increases above 20%, the quality characteristics of the bread deteriorate proportionally (low volume of the loaf, lack of taste, black spots, coarse breadcrumbs, and hard texture) due to the replacement of gluten with another added protein. However, regardless of the different workability and manipulation, the results of experimental mixtures can result in bread with an acceptable taste and texture, without the excessive taste of legumes (***Turfani et al.*, 2017).**

The addition of prepared fruit and flowers

The addition of fruit or fruit ingredients to flour used to make bread and similar products is not common practice and this approach can be considered innovative. Nevertheless, our research has found interesting findings that lead to positive recommendations. Red fruits have many health benefits, are rich in bioactive compounds, especially polyphenols, flavonoids, anthocyanins and others, which have antibacterial, antiviral, antimutagenic properties, and play an essential role in protecting against oxidative stress and biotic stress (Karjalainen et al., ***2009; Tabart et al.*, 2012; *Kim et al.*, 2013; *Soy et al.*, 2013; *Duymus et al.*, 2014; *Szopa et al.*, 2017; *Paunović et al.*, 2017; *Lachowicz et al.*, 2017a; *Lachowicz et al.*, 2017b; *Mlynarczyk et al.*, 2018; *Ferreira et al.*, 2020**).
Since these are unsustainable crops with a significantly limited shelf life, lyophilisation is considered an excellent way to preserve biologically valuable substances in them. Basically, it concerns sublimation drying (removal of water by sublimation, i.e., transition from solid state directly to gaseous state) at low pressure and low temperature. One of the main advantages of lyophilised food is that it can subsequently be stored at room temperature for a long time. Important advantages of products processed using the lyophilisation technology compared to the classic method of drying and freezing are the preservation of colour, aroma, taste, and nutritional value of the original raw material thanks to the preservation of biologically valuable substances (***Calín-Sánchez et al.*, 2020**).
All selected non-bakery ingredients (red fruit plus elderberry flower) can be suitable materials for the food industry. The main benefit of their addition is to increase the attractiveness of food products and the possibility of developing new products. It is also considered important that they are raw materials which are produced locally, without a significant burden on the environment and without increasing the carbon footprint of food.
The addition of lyophilised fruits and dried flowers (elderberry) in the amount of 15% affected both the water absorption and rheological properties of the dough. The water absorption depended on the specific raw material added. In the case of the addition of elderberry flowers, a significant increase of the water absorption was found, almost up to 12% compared to the control flour. With the addition of blackcurrant fruits, the water absorption fluctuated at approximately the same values as the control flour. For other raw materials, the addition resulted in a **lower water absorption** (elderberry fruits, black chokeberry fruits and blueberry fruits), up to 8.6% (elderberry fruits), 9.7% (blueberry fruits) and 10.8% (black chokeberry fruits) (Figure 8). This fact can negatively affect the yield of dough prepared with the addition of red fruits, since strong flours have a greater absorption of water. The dough from them is easy to process, does not stick, is well formed and more stable (***Robertson and Cao*, 2001**). Weak flours have a lower water absorption and are less stable. Bread and pastries made from weak flour are usually less fermented, have less volume and a less suitable texture (***Bojňanská et al.*, 2013**). The addition of chokeberry fruits most significantly reduced the pastry yield and increased the baking losses (Table 9).

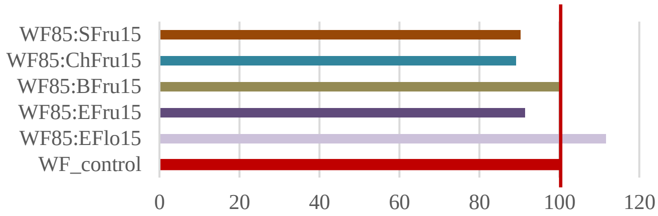


Figure 8 Water absorption in composite flours with the addition of lyophilised fruits and dried flowers
WF [wheat flour], EFlo [elderberry flower], EFru [elderberry fruits], BFru [blackcurrant fruits], ChFru [chokeberry fruits], SFru [serviceberry fruits]

The addition of freeze-dried fruit to composite flours also affected the dough development time and dough stability, which must be considered when determining the kneading time in the technological process (Figure 9). Except for chokeberry fruits, all other additions of fruit flowers and fruits in the amount of 15% increased the development time of the dough, quite significantly, by 2 minutes (elderberry fruits) to more than 6 minutes (blackcurrant fruits), and this makes the preparation of the dough more time and energy consuming.

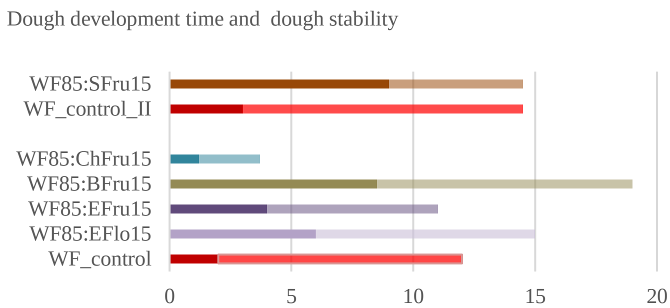


Figure 9 Effect of the addition of lyophilized red fruits and elderberry flowers on the dough development time and dough stability
WF [wheat flour], EFlo [elderberry flower], EFru [elderberry fruits], BFru [blackcurrant fruits], ChFru [chokeberry fruits], SFru [serviceberry fruits]

As for the stability of such doughs, it varies depending on the specific addition. Except for blackcurrant fruits, it is shorter than the control flour, but significantly shorter for elderberry fruits, serviceberry fruits and especially chokeberry fruits. Such doughs need to be processed faster into final products, otherwise there is a deterioration of the rheological properties and the ability to retain fermentation gases and the required volume of the products.
Based on the analyses carried out and their evaluation, it can be concluded that the addition of red fruit, or in the case of elderberry also flowers (which are very popular in Slovakia and are used in many ways, e.g., to produce soft drinks, or as heat-treated food, etc.) is promising for the design of modern foods with nutritional benefits. Their addition to flour specifically changes the rheological properties of the processed doughs. With an appropriate kneading procedure, mainly by optimizing its length, doughs with acceptable properties can be obtained. Combined with an interesting dough colour, these innovative non-bakery ingredients can contribute to the attractiveness of the products and can be used to design new products with an increased potential for health benefits.

Table 9 Properties of loaf of bread with the addition of red fruits and elderberry flowers flours

	Specific volume (mL/g)	Volume yield (mL/100 g flour)	Bread yield [%]	Baking loss [%]
WF_control	2.01a	288.9a	143.5a	14.8a
WF85:EFlo15	1.95a	300.0a	153.7b	12.5b
WF85:EFru15	2.10a	293.9a	139.0c	12.0b
WF85:BFru15	1.20b	173.6b	145.0a	12.7b
WF85:ChFru15	1.50b	192.9b	132.3c	15.7a
WF_control II	1.85a	304.7a	155.0a	8.4a
WF85:SFru15	1.50b	233.1b	152.0a	9.5a

Values followed by the same letter in the column are not significantly different (p > 0.05).
Legend: WF [wheat flour], EFlo [elderberry flower], EFru [elderberry fruits], BFru [blackcurrant fruits], ChFru [chokeberry fruits], SFru [serviceberry fruits]

With regard to the bakery experiments adding red fruits and elderberry flowers flours, significant reductions in specific volume and volume yield occurred mainly after adding blackcurrant fruits, chokeberry fruits and serviceberry fruits. Excellent results, comparable to the control flour, were obtained with elderberry flower and elderberry fruits. These are the raw materials that deserve attention while being both local and at the same time easily available, growing abundantly even in the wild.

Impact of additions of non-bakery raw materials on the economic parameters of the production

In the development of innovative foods, in the case of bakery products enriched with non-bakery raw materials with expected nutritional potential, it is undoubtedly necessary to consider the inputs of raw materials and their prices, as well as the time and energy demands of the production, or losses incurred during production.

As for the prices of the used raw materials, they are calculated during an identical period in order to avoid possible errors caused by price movements depending on the time of purchase. Energy costs are calculated based on the energy consumption of individual devices, so a unit price of electricity for vulnerable non-household customers was chosen, in accordance with the Regulation of the Government of the Slovak Republic No. 139/2023 of 19.4.2023 in the amount of 199 €/1MWh. Of course, it should be stressed that the real energy consumption may vary depending on the specific equipment used and its energy intensity.

In the case of the calculation of personnel costs, which include labour costs, including compulsory insurance for social and health security, the data of the Statistical Office of the Slovak Republic on the average monthly salary of an employee for the 1st quarter of 2023, which amounted to € 1,327 (**DATAcube, 2023)**, was used. With regard to the overheads and trade margins, these were indirectly derived from the average selling price of classic bread, as the difference between this selling price and the direct costs of this type of bread calculated by us. Based on the above, the presented data are initially converted to 100 kg of flour, and subsequently converted to 1 kg of finished product (bread) for a more illustrative comparison of the price increases in the final.

Table 10 (a) Effect of the addition of spelt wheat on the price of the final product (cost per 100 kg of composite flour finally expressed per 1 kg of bread)

	WF I ^{SF}	**WF II ^{SF}**	**WF I 70 : SF 30**	**WF II 70 : SF 30**
Cost of raw materials (€)	110.55	110.55	197.6	197.6
Optimal dough preparation time (min)	5	6	7	7
Dough fermentation time (min)	40	40	40	40
Baking time (min)	35	35	35	35
Energy costs (€)	29.78	29.84	29.92	29.92
Personnel costs (€)	22.88	22.06	23.24	23.24
The cost of 1 kg of product (€)	1.15	1.17	1.79	1.78
Overhead + Trade Margin (€)	0.96	0.96	0.96	0.96
Together (€)	**2.11**	**2.13**	**2.75**	**2.74**
Percentage price increase (%)	100	100	130.3	128.6

Legend: WF [wheat flour], SF [spelt flour]

Table 10 b) Effect of the addition of amaranth flour on the price of the final product (cost of 100 kg of composite flour finally expressed per 1 kg of bread)

	WF III A^F + RF^{AF}	**AF5**	**AF10**	**AF15**
Cost of raw materials (€)	110.55	128.30	146.05	163.80
Optimal dough preparation time (min)	6	7	6.5	5.5
Dough fermentation time (min)	40	40	40	40
Baking time (min)	35	35	35	35
Energy costs (€)	29.84	29.92	29.88	29.81
Personnel costs (€)	22.06	23.24	23.15	22.97
The cost of 1 kg of product (€)	1.14	1.29	1.40	1.53
Overhead + Trade Margin (€)	0.96	0.96	0.96	0.96
Together (€)	**2.10**	**2.25**	**2.36**	**2.49**
Percentage price increase (%)	100	107.1	112.4	118.6

Legend: WF [wheat flour], RF [rye flour], AF [amaranth flour]

Table 10 c) Effect of the addition of legumes flours on the price of the final product (cost of 100 kg of composite flour finally expressed per 1 kg of bread)

	WF^{LF} + RF^{LF}	**CBF15**	**ChF15**	**BBF15**	**RLF15**
Cost of raw materials (€)	110.55	124.95	141.75	158.85	145.35
Optimal dough preparation time (min)	4	5.5	3	4	3
Dough fermentation time (min)	40	40	40	40	40
Baking time (min)	35	35	35	35	35
Energy costs (€)	29.70	29.81	29.63	29.70	29.63
Personnel costs (€)	22.69	22.97	22.51	22.69	22.51
The cost of 1 kg of product (€)	1.11	1.16	1.30	1.44	1.39
Overhead + Trade Margin (€)	0.96	0.96	0.96	0.96	0.96
Together (€)	**2.07**	**2.12**	**2.26**	**2.40**	**2.35**
Percentage price increase (%)	100	102.4	109.2	115.9	113.5

Legend: WF [wheat flour], RF [rye flour], ChF [chickpea flour], BBF [broad bean flour], CBF [common bean flour], RLF [red lentil flour]

Table 10 d) Effect of the addition of red fruits and elderberry flowers flours on the price of the final product (cost of 100 kg of composite flour finally expressed per 1 kg of bread)

	WF^{FFF}	**EFlo15**	**EFru15**	**BFru15**	**ChFru15**	**Sfru15**
Cost of raw materials (€)	110.55	365.35	872.35	872.35	872.35	872.35
Optimal dough preparation time (min)	5	8	6	10.5	3	11
Dough fermentation time (min)	40	40	40	40	40	40
Baking time (min)	35	35	35	35	35	35
Energy costs (€)	29.78	29.99	29.84	30.17	29.63	30.21
Personnel costs (€)	22.88	23.42	22.06	23.88	22.51	23.97
The cost of 1 kg of product (€)	1.09	2.72	6.65	6.39	7.00	6.10
Overhead + Trade Margin (€)	0.96	0.96	0.96	0.96	0.96	0.96
Together (€)	**2.05**	**3.68**	**7.61**	**7.35**	**7.96**	**7.06**
Percentage price increase (%)	100	179.5	371.2	358.5	388.3	344.4

Legend: WF [wheat flour], EFlo [elderberry flower], EFru [elderberry fruits], BFru [blackcurrant fruits], ChFru [chokeberry fruits], SFru [serviceberry fruits]

From the data in Table 9, which is broken down by bakery experiments (a, b, c, d) and the data is counted per 100 kg of flour, it is possible to assess the percentage increase in the price of 1 kg of the final innovative product. The most significant price increase was in the case of the application of fruit and flower flours, which is not surprising, since these are very popular and demanded commercial products which, together with the complexity of the lyophilising process, are responsible for high prices. Nevertheless, we believe that the input costs of raw materials can be reduced by an appropriate and effective way of treating raw materials, especially the local ones that are extremely undemanding for cultivation and harvesting. After comprehensive evaluation, elderberry flower and elderberry fruits, which are abundant and wild raw materials in Slovakia, are the most suitable raw materials, and we recommend further research on their use. Other non-bakery ingredients increase the price compared to the average value of bread (**DATAcube, 2023**) to about 130% for the addition of spelt wheat of 30%, which can be considered perfectly acceptable. Even lower increases were found for the addition of amaranth flour of 15% (118.6%) and for legume flour (from 102.4% for bean flour to 115.9% for bean flour).
We believe that the percentage increase in the price of 1 kg of bread, excluding red fruits and elderberry flowers flours, is fully acceptable, and consumers benefit from such innovative products with added nutritional value at a fair price.

CONCLUSION

Based on technological, rheological and bakery analyses and economic calculations, it is possible to make recommendations regarding technological steps in the production of innovative bakery products with added nutritional value.
A very important indicator in dough production is the water absorption, which varies depending on the specific flour or composite flour applied. In the case of the composite flours analysed, the water absorption significantly increased the amount of additions of spelt flour, amaranth flour, common bean flour, bread bean flour, and elderberry flowers flour. The water absorption was not affected by the addition of blackcurrant fruits. The water absorption reduced the addition of chickpea flour, red lentil flour, elderberry fruits, chokeberry fruits and serviceberry fruits.
Kneading time is equally important in the case of products with the application of non-bakery raw materials, and it can be stated that the addition of spelt flour and amaranth flour did not seriously affect the kneading and handling of the dough during the next processing steps, but the higher addition of amaranth flour (15%, 30%) slightly shortened the stability of the dough. Unlike these flours, the addition of other non-bakery ingredients changed the dough development time or dough stability. In the case of legume flours, the addition of common bean flour prolonged both the dough development time and dough stability compared to the control wheat rye flour, which can be considered a benefit of this raw material. The addition of chickpea flour and red lentil flours shortened the dough development time and dough stability, and such doughs need to be processed quickly. The 15% additions of red fruits and elderberry flowers flours had a very specific effect: all except chokeberry fruits extended the dough development time, with elderberry flower, blackcurrant fruits and serviceberry fruits very significantly. Such doughs need to be processed longer, 8-11 minutes, but subsequently have a good stability. On the other hand, the dough with the addition of chokeberry fruits needs to be processed extremely quickly (3 minutes), which does not provide time for more lengthy handling.
The addition of non-bakery ingredients specifically changes the rheological properties of the process doughs, but by an appropriate kneading procedure, mainly by optimizing its length, it is possible to obtain doughs with acceptable properties. Consequently, these innovative non-bakery ingredients can contribute to the attractiveness of the products and can be used to design new products with an increased potential for health benefits.
From an economic point of view, baking loss and bread yield are also important. In general, non-bakery additions (except for spelt wheat) significantly reduced both the specific volume and volume yield of experimental loaves, however, the bread yield in accordance with all characteristics was not comprehensively reduced with the additions of amaranth flour or legume flour, and most red fruits and elderberry flowers flours. Significantly lower bread yield values were found for the addition of chokeberry fruits.
The calculated price of the final products (innovative breads) increased compared to the average price of bread (in Slovakia) from 102.4% for the addition of common bean flour (15%) to 388.5% for the addition of chokeberry fruits flour (15%). The additions of red fruits and elderberry flowers flours increased the price inadequately, and it will be necessary to find options for their more efficient processing. Other prices may be considered acceptable.

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