processes

Article

Development of High-Fibre, Ready-to-Bake Flour Mixtures from Purple Wheat

Eszter Szőke-Trenyik [1], József Mihalkó [1], Péter Sipos [2,*] and Balázs P. Szabó [1,*]

[1] Department of Food Engineering, Faculty of Engineering, University of Szeged, 6725 Szeged, Hungary
[2] Institute of Nutrition, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, 4032 Debrecen, Hungary
* Correspondence: siposp@agr.unideb.hu (P.S.); szpb@mk.u-szeged.hu (B.P.S.)

Abstract: Nowadays, consumers are paying more and more attention to healthy eating, and unfortunately, insulin resistance and type 2 diabetes are affecting many people. In general, people are paying more attention to the consumption of fibre-rich foods. In our study, we developed high-fibre ready-to-bake flour mixture blends using purple wheat flour (white and wholemeal). For fibre fortification, inulin, chia seed flour and psyllium husk flour were used. After determining the basic nutritional parameters of the raw materials, four series of experiments were carried out to prepare bread rolls and to test the finished products. The correct mixing ratio of the enriching agents were tested, and the final flour mixtures were tested. At the end of our research, three blends (white purple wheat flour + 4% inulin + 2% psyllium husk flour; wholemeal purple wheat flour + white purple wheat flour + 4% inulin + 4% chia seed flour; wholemeal purple wheat flour + 4% inulin + 4% chia seed flour) were developed.

Keywords: purple wheat; flour mixtures; bread roll; inulin; chia seed flour

Citation: Szőke-Trenyik, E.; Mihalkó, J.; Sipos, P.; Szabó, B.P. Development of High-Fibre, Ready-to-Bake Flour Mixtures from Purple Wheat. *Processes* **2023**, *11*, 389. https://doi.org/10.3390/pr11020389

Academic Editors: Yonghui Li and Chi-Fai Chau

Received: 23 December 2022
Revised: 13 January 2023
Accepted: 20 January 2023
Published: 27 January 2023

1. Introduction

Cereals are not only a major source of energy and protein in human nutrition, but also make a significant contribution to the mineral and B vitamin supply [1]. Although they are mainly considered to be high in starch and, therefore, high in calories, they are also high in dietary fibre, and the importance of their other micronutrients is being increasingly appreciated [2]. Thus, research attention has turned to the use of coloured cereals, as their carotenoid content is associated with a greater antioxidant effect, as shown, for example, in maize [3,4], winter wheat, barley [5,6], durum wheat [7] and rice [8]. Of these, wheat contributes the most calories and protein to human diets [9]. Several colour variants of this cereal are known (such as white, red, black, blue, purple and yellow) and the concentrations of their bioactive components are different [9,10].

Purple wheat itself is an ancient cereal that originated in Ethiopia and was discovered along the Red Sea in 1872. It is distinguished by its purple colour, which is due to the anthocyanins present in it as cyanidin-3-glucosides and peonidin-3-glucosides [11]. The purple pigments are stored in the pericarp [12] and, therefore, keeping the bran is necessary to increase the anthocyanin content of the products.

Purple wheat contains a number of nutrients that are beneficial to human health [11,13–15]. Purple wheat is rich in anthocyanins, which exhibit a wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial and anticancer activities. In addition, anthocyanins have multiple effects on blood vessels and platelets, which may reduce the risk of coronary heart disease and, thus, the risk of heart disease overall [16–18]. Many studies have been carried out to confirm their beneficial effects. Examples include anti-inflammatory effects [19], beneficial effects in people with type 2 diabetes [20], lowering total cholesterol, and controlling blood glucose levels in people with insulin resistance [19].

The study of the bioavailability of phenolic compounds, including anthocyanins in foods made from purple wheat, is also warranted. This may allow evidence-based validation of claims about the health benefits of consuming foods made from purple wheat [21]. Several studies tried to describe the overall antioxidant capacities of coloured wheat grains and products, and significant genetic and environmental influences were found [22–24]. These compounds are secondary metabolites and the unfavourable growing conditions can enhance their synthesis [6,25], and significant losses in their concentrations can occur during storage [26] and during utilization as chapattis [27], pastas [28], breads, pancakes and porridges [29]. Although the thermal effects of bread making also reduce the anthocyanin content of purple wheat, the antioxidant capacity of processed products either remains unchanged or increases after processing, presumably due to the Maillard reaction [30,31].

Bread made from wheat flour can contribute significantly to the daily recommended intakes of protein, minerals, vitamins and fibre [32]. Thus, consumers value it more as a healthy and nutritious food than as a basic staple food as it was considered earlier, and it can also be a good carrier for functional ingredients or a tool for targeted nutrition when nutrient deficiencies are detected in the population [33]. Within this, additional fibre fortification helps by providing a more complete nutritional profile. Inulin has been shown in human studies to be an effective prebiotic that promotes gut health, has beneficial effects on lipid metabolism and insulin levels [34,35] and decreases the risk of osteoporosis [38], while it modifies the structure and water binding ability of the dough, and influences the texture and overall acceptance of the product [36]. Psyllium also influences the theological behaviour of dough and improves the bread nutritionally, as psyllium decreases not only the glycaemic index, but the blood cholesterol level and the risks of metabolic syndrome and cardiovascular diseases [37]. Similar health benefits (decreased risk of insulin resistance, dyslipidaemia and cardiovascular diseases, and anti-inflammatory effects) are associated with the consumption of chia flour [38].

Today, as consumers become more conscious of their dietary habits, food science is increasingly focusing on quality nutrition, nutrient intake and healthy lifestyles, with fibre being one of the cornerstones. The current study was intended to develop antioxidant-rich bread prototypes from both white and wholemeal purple wheat flour, and their fibre content was supplemented by inulin, chia seed flour and psyllium husk flour. Our aim was to determine the optimal composition of ingredients from physical and nutritional points of view.

2. Materials and Methods

2.1. Purple Wheat Flour Tests

Wholemeal and white purple wheat flour were used as the base flour in the tests. Inulin, chia seed flour and psyllium husk flour were added to the base flours to increase the fibre content and biological value, and to improve the structure. Qualification tests of the base flours were also carried out. The moisture content of the flours was determined according to AACC 44-15.02. The tested flour was dried in a Memmert UNB 200 drying oven at 130–133 °C for 60 min and the loss in weight was determined. Three parallel measurements were carried out during the test. According to the AACC 44-15.02 [39], the moisture content of flour for use in the baking industry should not exceed 15.0%. The amylolytic state was determined by the Hagberg-Perten falling number test using the AACC 56-81.03 method [40]. The amylolytic state refers to the interaction between the amylase enzymes in the flour and the flour's own starch as a substrate. The apparatus is used to investigate the amylolytic state of high starch flour and the effect of different amylase preparations on the starch.

The microbiological analysis was based on regulation [41], so that Salmonella, mould and Enterobacteriaceae were identified. Flours have a rich and rather heterogeneous microflora. These micro-organisms are mainly derived from the cereal microflora, while the non-cereal part is almost negligible. The microflora of cereals consists predominantly of microorganisms from the soil that adhere to the outer surface of the seeds during cultivation and harvesting. However, the endosperm of healthy cereal grains remains free of all these.

2.2. Dough Tests

A farinograph was used for the determination of instrumental water absorption and baking value; the method is used for the classification of wheat flour, mixtures and for the testing of kneading properties. The time of dough formation, stability and softening can be determined. According to AACC 54-21 [42], the values that can be read from the farinogram obtained as a result of the test are as follows: maximum consistency, water absorption, dough development time, stability, softening rate and the so-called planimetric area, from which the Hungarian Quality Index can be determined. The Hungarian Quality Index is a quality indicator for flour used in the baking industry in Hungary, ranging from 0 to 100, with a minimum value of 55. The total phenol content of the base flours was determined by a gallic acid calibration curve using the photometric method at a wavelength of 725 nm. Three parallel measurements were carried out on the samples.

2.3. Bread Production

The aims of the tests were to form dough using different fibre enrichment materials, to examine the structural properties of the dough, to test the test products and finished products, to qualify the fibre enrichment materials in the finished products and to examine their effect on the finished products. Trial baking is the most complex test in the baking industry, so products were prepared using different fibres. The fibre enrichment materials used in the trial baking were as follows: oat bran, coconut flour, bamboo fibre, inulin, apple fibre, psyllium husk, chia seed and konjac. Preliminary tests showed that inulin, plantain seed husks and chia seeds were suitable for the production of the product. Thus, our experiments were continued with these materials and the results obtained are presented.

The composition of the doughs is as follows: wholemeal purple wheat flour and/or white purple wheat flour, water, salt, dried yeast and powdered sugar. Inulin, chia seed flour and psyllium husk flour were added in varying quantities. The ingredients were measured and then mixed together. The aim was to get a homogeneous dough, which was achieved in 8 min. The resulting dough was left to mature for 15 min at 30 °C. For formatting, we used the promilograph's rounding part. In this way, we obtained shapes and sizes that are identical and fully comparable. This eliminates the errors that can arise from manual moulding. This was mainly important because of the change in volume and the change in shape ratio. Proofing was carried out in the resting part of the promilograph at 30 °C for 30 min (the relative humidity was 85%). Only a slight increase in volume took place during the proofing process. The shape retention of the dough was good. The doughs did not spread or flatten. This is important information for the industry. Baking was carried out in a steam oven at 230 °C for 15 min. During baking, the dough was baked evenly. A nice brown colour was obtained on the surface. The colour of the products made from wholemeal purple wheat flour became substantially darker. This was also true for the crust and the crumb.

Before baking, we waited for the breads to rise. This took about 30 min at room temperature (22 °C). During cooling, care was taken not to deform the products, as this would have affected the subsequent tests (sensory analysis, shape ratio). The finished products were then tested. Quality tests were carried out on the end products (AACC 10-10.03) [43], as well as a determination of the crude fibre content and organoleptic tests [44].

For the volume measurement, the seed displacement measurement was used. The volume of the seed displaced by the product from a marked container was determined using a graduated cylinder. This gives a more detailed picture of the properties of the fibre or high-fibre grist and the volume of the finished product after the rising or baking process. In the test, the volume of the product is equal to the proportion of the grain volume which completely fills the empty weighing pan and is displaced from it after the product has been placed in the weighing pan. For this purpose, mustard seeds were used by filling the measuring vessel with mustard seeds and scooping off the excess, but this is negligible for the measurement. Then the sample was placed in the mustard seed container with the bottom up and the excess was scooped off again, but this was measured back in a measuring cylinder to determine the actual volume of the product.

For the shape ratio, the width of the final product was divided by its height, using a caliper as the instrument. Measurements were taken at the highest and widest points of the product. The shape ratio is a ratio obtained by dividing the latitude value by the height value. If the product had a wide bottom, if its shape ratio was very high, it meant that it was wide, spatial and had poor form stability.

In the first phase of the experiments, the three enriching agents were added separately but in equal proportions to white and wholemeal purple wheat flour to investigate their effect on the loaf. On this basis, we chose to add inulin and psyllium husk flour to the white purple wheat flour, and inulin and chia seed flour to the wholemeal purple wheat flour for further experiments.

In the second phase of the experiments, the combined effect of the two fortifiers on the product was investigated and the crude fibre content of the loaf was measured. The products were successful in all aspects and according to our sensory reviewers, but we wanted to further increase the fibre content of our white flour product and were curious to see what the product would be like when the two flours (70% wholemeal and 30% white bean flour) were mixed. Twenty qualified students of food engineering carried out the sensory evaluation. The sensory reviewers used a simple descriptive method, using descriptive terms to describe the product's characteristics. The resulting quantitative ratio of positive to negative terms was evaluated. The sensory evaluation team consisted of a sensory judging manager, sensory reviewers and preparers. The simple descriptive method was chosen because it is the best way to describe a self-developed product in international practice.

All the tests (amylolytic state, moisture content, microbiological tests, farinograph and final product quality control) were carried out in three parallel measurements.

A statistical analysis (One-Way-ANOVA with Tukey HSD post hoc test) was performed using IBM Statistics 27 (Armond, New York, NY, USA) software. The significance level was 5% ($p < 0.05$). Microsoft 365 Excel (Redmond, Washington, DC, USA) was used for graphical representation.

3. Results

Table 1 contains the results of the qualification tests of the base flours.

Table 1. The results of the qualification tests of the base flours. CFU: Colony Forming Unit; WPWF: White Purple Wheat Flour; WMPWF: Wholemeal Purple Wheat Flour. Data with different letters show significant difference (p <0.05).

Fluor Type	Moisture Content [w/w%]	Falling Number [s]	Salmonella [CFU/25 g]	Mould [CFU/g]	Total Phenol Content [μm/100 mL]
WPWF	14.59 ± 0.15 A	500 ± 13.4 A	0 A	<10 A	262.8 ± 20.4 A
WMPWF	9.68 ± 0.11 B	459 ± 5.7 B	0 A	<10 A	897.4 ± 27.9 B

According to AACC International [41], the maximum moisture content of wheat flour is 15%, so our results show that the flours are suitable for use. Both base flours had a falling number value greater than 400 s (Table 1). For wheat flour this means that the flour is enzyme-poor and when processed alone can be used to produce a crumbly, rapidly ageing product with a crumbly gut structure. The results of Table 1 show that both flours are microbiologically suitable. Over the course of the study, we determined the instrumental water absorption capacity of our basic flours, which was 59% for white and 66% for wholemeal, influenced by the higher fibre content of the latter. There were also significant differences in the initial water retention capacity of the flours, which affected the amount of liquid used in kneading. The initial water absorption capacity of the flours depended on several factors. The first factor was the moisture content of the flour. If a flour contains a few percent more water than the permissible amount, it is not only subject to premature deterioration, but also less water can be used for dough formation in the kneading process, in inverse proportion to the excess water in the flour. In such a case, the specific flour utilisation rate of the baking plant will deteriorate significantly, i.e., less bread and bakery products than with a normal flour moisture content. The water absorption capacity of wheat flour is mainly determined by the amount and properties of the wheat gluten proteins present in the flour, and more specifically by the amount and properties of the wet gluten that can be washed from the flour. From the planimetric area values, the Hungarian Quality Index could be given for the flours, so that they could be classified into value groups. The value of white purple wheat flour is 80.2 and therefore belongs to the A2 group, while the value of wholemeal purple wheat flour is 55.65 and it is a B2 flour. [45]

In the final phase of the multi-stage study, we increased the fibre content of the white fibre samples by adding psyllium husk flour and prepared our 70% wholemeal—30% white purple wheat flour loaf, to which we added inulin and chia seed flour at 4—4% to improve the texture and organoleptic properties.

For both wholemeal and white purple wheat flour, the enriching agents were added first.

As shown in Table 2, the addition of inulin softened the dough, and as the amount of inulin increased, less and less water was needed to achieve a 320PU (Promylograph Unit) consistency for both base flours. The use of the promilograph was justified by the fact that our aim in the production of the products was to achieve the same dough consistency, so that the final products could be fused together. Water absorption was a secondary consideration in our case. Psyllium husk flour increased the water absorption of the flour blends due to its high fibre content, whereas the addition of chia seed flour had no relevant effect on water absorption. After baking the products and testing their quality, the following conclusions were reached. The values for loaves made from different mixtures are shown in Figure 1.

Table 2. The amount of water added to 320 PU consistency for base flours. PU: Promylograph Unit; WPWF: White Purple Wheat Flour; WMPWF: Wholemeal Purple Wheat Flour.

Sample		**The Amount of Water Added to 320PU [cm^3]**	
		WPWF	**WMPWF**
Control		54.2	74.0
Inulin	1.0%	52.0	70.3
	2.0%	49.8	68.9
	4.0%	47.4	66.5
Psyllium husk flour	0.5%	56.1	74.7
	1.0%	58.7	76.9
	2.0%	62.6	83.0
Chia seed flour	1.0%	53.2	73.1
	2.0%	53.4	72.0
	4.0%	53.2	72.1

Our results (Table 3) show that the shape fraction of the enriched samples was lower than the control sample, which suggests that we have improved the known wide substrate of whole grain products by adding fibre. However, increasing the amount of inulin, psyllium husk flour and chia seed flour in the product did not result in significant changes in the shape ratio values ($p > 0.05$).

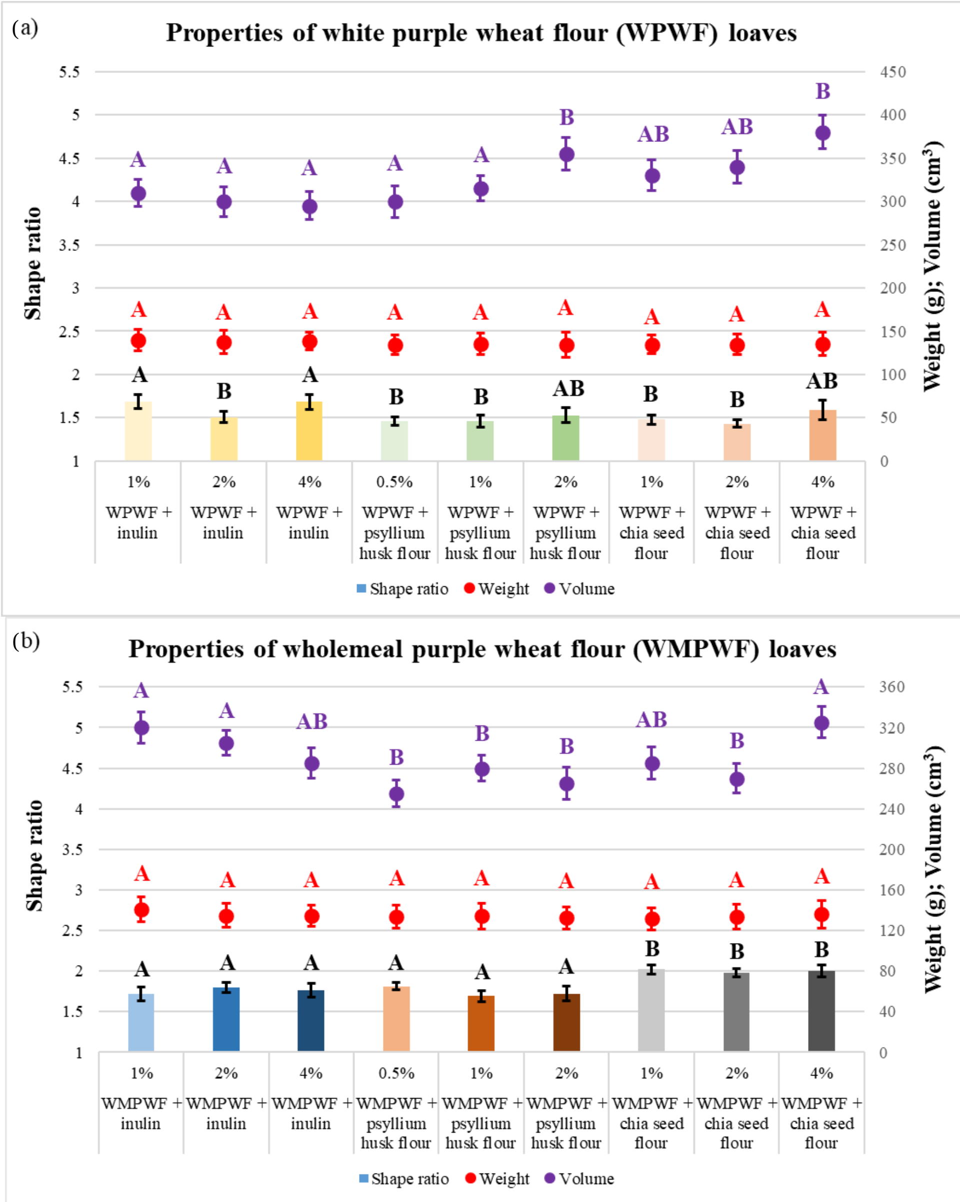

Figure 1. The properties (shape ratio, weight and volume values) of the samples as a result of the addition of enrichments. (**a**) White purple wheat flour (WPWF) loaves, (**b**) Wholemeal purple wheat flour (WMPWF) loaves. Capital letters above the points and the bars show significant difference ($p < 0.05$).

Of course, the tests were also carried out with control flour. In this case, the sample was simple wheat flour, to which inulin, psyllium husk flour and chia seed flour were added in similar proportions. The results (volume [cm^3/g]) obtained are shown in Figure 2.

Table 3. The shape ratio and the volume values of our final products. WPWF: White Purple Wheat Flour; WMPWF: Wholemeal Purple Wheat Flour.

Sample	Width [mm]	Height [mm]	Shape Ratio	Weight [g]	Volume [cm^3]	Volume Values [cm^3/g]
WPWF control	96	64	1.50	135.7	350	2.58
WMPWF control	102	51	2.00	136.1	285	2.57
WPWF 4% inulin + 0.5% psyllium husk flour	96	67	1.43	139.6	420	3.01
WPWF 4% inulin + 2% psyllium husk flour	98	70	1.40	137.5	395	2.87
WPWF 4% inulin + 4% psyllium husk	95	67	1.42	136.4	365	2.68
WMPWF 70% + WPWF 30%	99	59	1.68	136.1	340	2.50
WMPWF 70% + WPWF 30% + 4% inulin + 4% chia seed flour	94	60	1.57	138.5	335	2.42
WMPWF 4% inulin + 4% chia seed flour	95	57	1.67	140.6	345	2.45

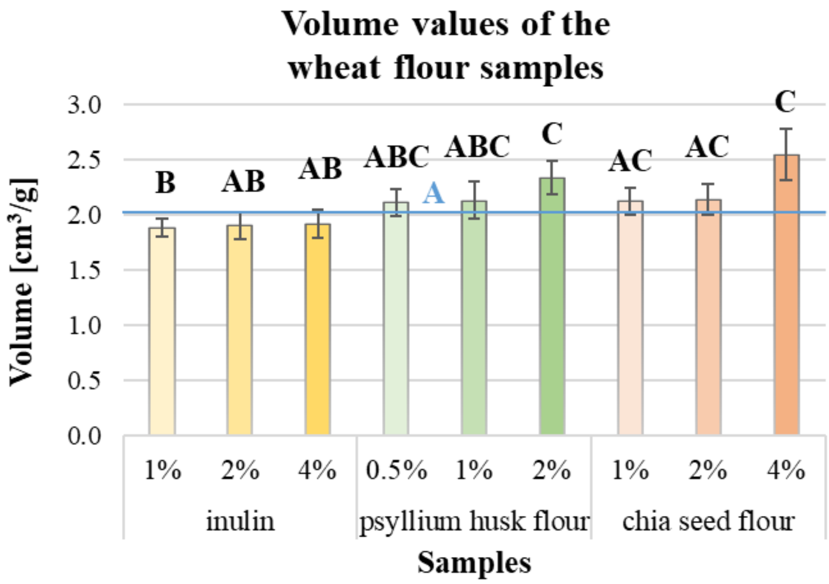

Figure 2. The volume values of the wheat flour samples as a result of the addition of enrichments (the results of the control samples are marked with a blue line). Capital letters above the line and the bars show significant difference ($p < 0.05$).

For the species volume values, it was observed that the addition of fortifiers increased the volume values. The increase in the amount of psyllium husk flour and chia seed flour increased the loaf volume proportionally (Figure 3).

We found that the shape, surface colour, elasticity and taste of our product containing 4% psyllium husk flour made a positive impression on our reviewers, but they criticised the colour of the crumb and its strong aftertaste. We therefore concluded that our blend of 2% psyllium husk flour and 4% inulin should be selected.

Our samples containing both wholemeal and white purple wheat flour were successful both without and with fortification.

As a result of the third experiment, we had three flour mixtures:

- Mixture 1: WPWF + 4% inulin + 2% psyllium husk flour (Figure 4)
- Mixture 2: WMPWF 70% + WPWF 30% + 4% inulin + 4% chia seed flour (Figure 5)
- Mixture 3: WMPWF + 4% inulin + 4% chia seed flour (Figure 6)

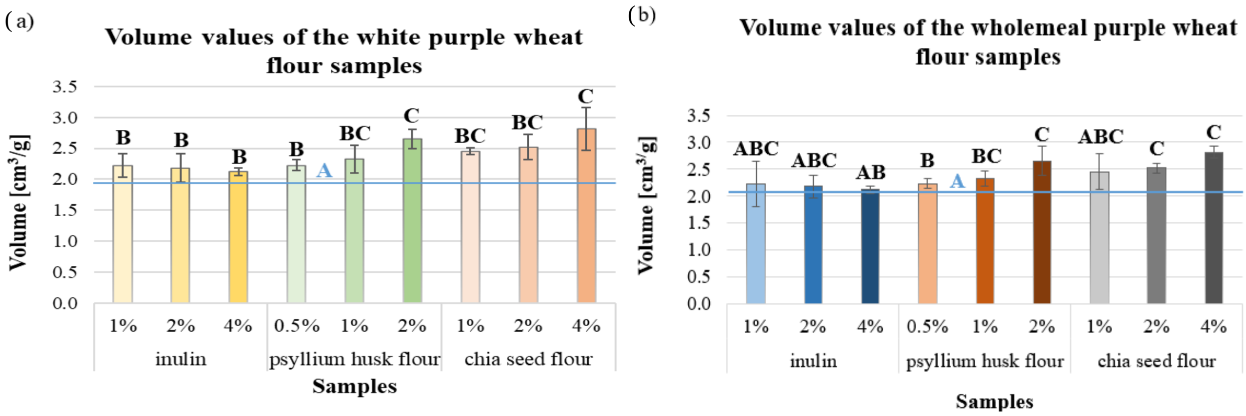

Figure 3. The volume values of the samples as a result of the addition of enrichments (the results of the control samples are marked with a blue line). (**a**) White purple wheat flour, (**b**) Wholemeal purple wheat flour samples. Capital letters above the line and the bars show significant difference ($p < 0.05$).

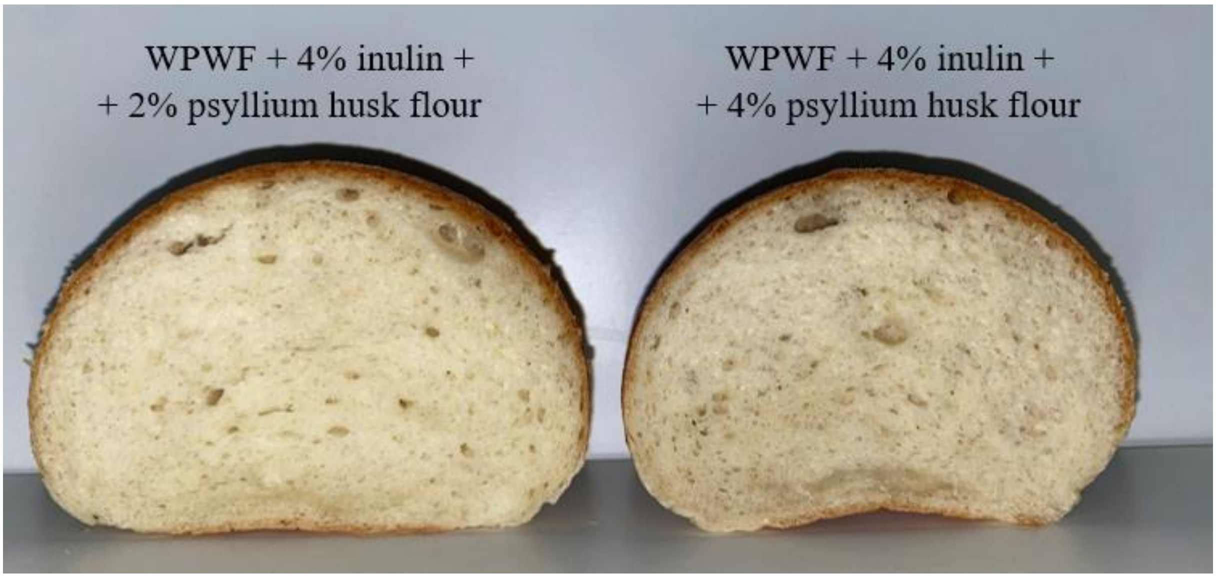

Figure 4. The crumb of the final phase sample made of white purple wheat flour. WPWF: White Purple Wheat Flour.

The crude fibre content of white purple wheat flour was 0.35, and the crude fibre content of wholemeal purple wheat flour was 1.78. The crude fibre content of the final mixture is given in Table 4.

Table 4. The crude fibre content of our final products. WPWF: White Purple Wheat Flour; WMPWF: Wholemeal Purple Wheat Flour.

	Mixture 1 (WPWF + 4% Inulin + 2% Psyllium Husk Flour)	**Mixture 2 (WMPWF 70% + WPWF 30% + 4% Inulin + 4% Chia Seed Flour)**	**Mixture 3 (WMPWF + 4% Inulin + 4% Chia Seed Flour)**
Crude fibre content % (measured with Foss Fibertec 2010)	1.24	1.98	2.12

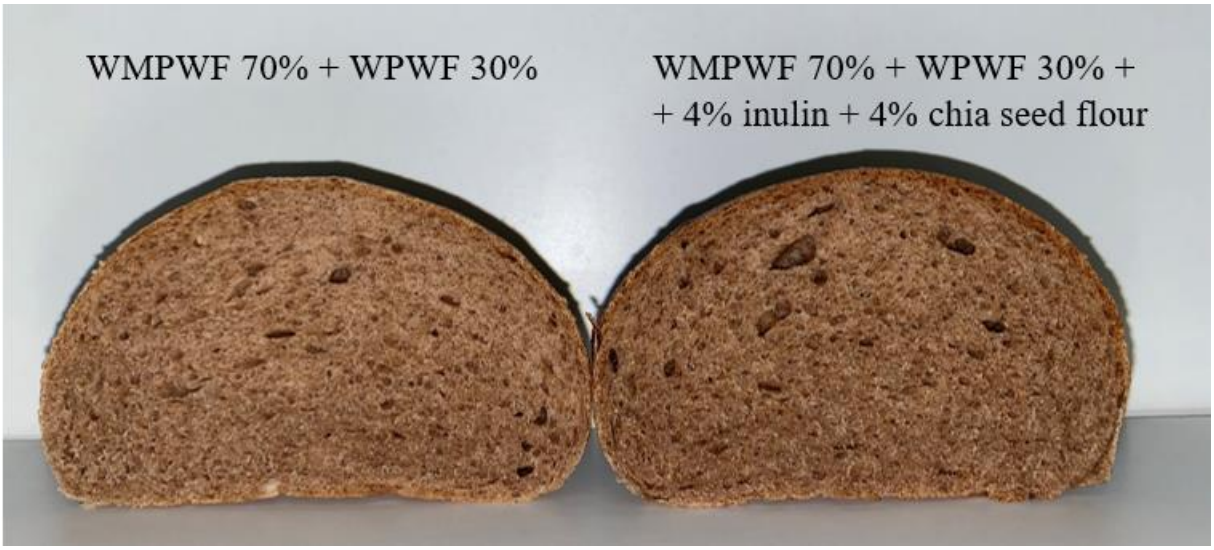

Figure 5. The crumb of our wholemeal purple wheat flour samples from the third phase—Samples also containing wholemeal and white purple wheat flour. WPWF: White Purple Wheat Flour; WMPWF: Wholemeal Purple Wheat Flour.

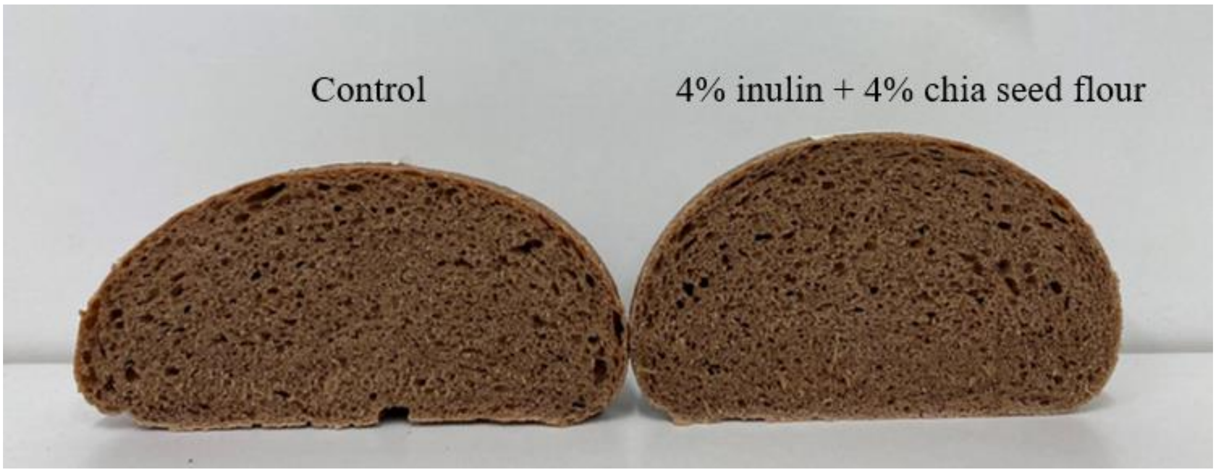

Figure 6. The crumb of the control sample and the sample containing 4% inulin and 4% chia seed flour—wholemeal purple wheat flour.

4. Conclusions

In the final phase of the trials, our white purple malt product contained 4% inulin and 2% psyllium husk flour, which had the right shape, elasticity, and colour of the coating, as well as taste and smell (Mixture 1). Our product, a blend of the two flours, 70% wholemeal and 30% white purple wheat flour, enriched with 4% inulin and 4% chia seed flour, was positively received by our evaluators, as we were able to improve the consistency, taste and smell of the wholemeal product by using enriching agents (Mixture 2). We also selected a blend of pure wholemeal flour containing 4% inulin and 4% chia seed flour (Mixture 3), the result of the second experiment, for consumers who do not wish to consume a product containing white flour at all. The results of the tests show that we had flours with adequate moisture content and microbiological status, but both basic flours had a falling number greater than 400 s, which means that the flour is enzyme-poor, and when processed alone, it can be used to produce a product with a crumbly, rapidly ageing gut structure. Over the course of the study, we determined the instrumental water absorption capacity of our basic flours, which was 59% for white purple wheat flour and 66% for wholemeal purple wheat flour, influenced by the higher fibre content of the latter. From the valorigram and the planimetric area values read, the Hungarian Quality Index could be given for the flours, so that they could be classified into value groups. The value for white purple wheat flour is 80.2 and therefore belongs to the A2 group. The value for wholemeal purple wheat flour is 55.65 and therefore belongs to the B2 group. When the total phenolic content of the flours was examined, the value obtained for wholemeal purple wheat flour (897.4 µg/100g) was more than three times higher than that for white purple wheat flour (262.8 µg/100g). We developed three high-fibre, ready-to-bake flour mixtures (white purple wheat flour mixture, wholemeal purple wheat flour mixture, mixture of the two flours). We increased the fibre content of the white purple wheat flour mixture, achieving a similar fibre content to that of wholemeal purple wheat flour loaves. Research must continue in any case, as consumer needs are constantly changing and growing.

Author Contributions: Conceptualization, B.P.S. and E.S.-T.; methodology, E.S.-T.; software, J.M.; investigation, E.S.-T.; data curation, J.M.; writing—original draft preparation, B.P.S.; writing—review and editing, P.S.; supervision, B.P.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Saldivar, S.S. *Cereals: Dietary Importance*; Elsevier: Amsterdam, The Netherlands, 2016; pp. 703–711. [CrossRef]
2. Poole, N.; Donovan, J.; Erenstein, O. Continuing cereals research for sustainable health and well-being. *Int. J. Agric. Sustain.* **2021**, *20*, 693–704. [CrossRef]
3. Anđelković, V.; Mesarović, J.; Srebrić, M.; Drinić, S.M. Pigmented maize-a potential source of β-carotene and α-tocopherol. *J. Eng. Process. Manag.* **2018**, *10*, 1–7. [CrossRef]
4. Parizad, P.A.; Capraro, J.; Scarafoni, A.; Bonomi, F.; Blandino, M.; Marengo, M.; Iametti, S. The bio-functional properties of pigmented cereals may involve synergies among different bioactive species. *Plant Foods Hum. Nutr.* **2019**, *74*, 128–134. [CrossRef] [PubMed]
5. Nowicka, A.; Kucharska, A.Z.; Sokół-Łętowska, A.; Fecka, I. Comparison of polyphenol content and antioxidant capacity of strawberry fruit from 90 cultivars of *Fragaria* × *ananassa* Duch. *Food Chem.* **2019**, *270*, 32–46. [CrossRef] [PubMed]
6. Paznocht, L.; Kotíková, Z.; Šulc, M.; Lachman, J.; Orsák, M.; Eliášová, M.; Martinek, P. Free and esterified carotenoids in pigmented wheat, tritordeum and barley grains. *Food Chem.* **2018**, *240*, 670–678. [CrossRef]
7. Beleggia, R.; Ficco, D.B.; Nigro, F.M.; Giovanniello, V.; Colecchia, S.A.; Pecorella, I.; De Vita, P. Effect of sowing date on bioactive compounds and grain morphology of three pigmented cereal species. *Agronomy* **2021**, *11*, 591. [CrossRef]
8. Bangar, S.P.; Chaudhary, V.; Singh, T.P.; Özogul, F. Retrospecting the concept and industrial significance of LAB bacteriocins. *Food Biosci.* **2022**, *46*, 101607. [CrossRef]
9. Gupta, R.; Meghwal, M.; Prabhakar, P.K. Bioactive compounds of pigmented wheat (*Triticum aestivum*): Potential benefits in human health. *Trends Food Sci. Technol.* **2021**, *110*, 240–252. [CrossRef]
10. Ficco, D.B.; De Simone, V.; Colecchia, S.A.; Pecorella, I.; Platani, C.; Nigro, F.; De Vita, P. Genetic variability in anthocyanin composition and nutritional properties of blue, purple, and red bread (*Triticum aestivum* L.) and durum (*Triticum turgidum* L. ssp. turgidum convar. durum) wheats. *J. Agric. Food Chem.* **2014**, *62*, 8686–8695. [CrossRef]
11. Abdel-Aal, E.S.M.; Hucl, P.; Rabalski, I. Compositional and antioxidant properties of anthocyanin-rich products prepared from purple wheat. *Food Chem.* **2018**, *254*, 13–19. [CrossRef] [PubMed]

12. Sharma, N.; Kumari, A.; Chunduri, V.; Kaur, S.; Banda, J.; Goyal, A.; Garg, M. Anthocyanin biofortified black, blue and purple wheat exhibited lower amino acid cooking losses than white wheat. *LWT* **2022**, *154*, 112802. [CrossRef]
13. Milder, I.E.; Arts, I.C.; van de Putte, B.; Venema, D.P.; Hollman, P.C. Lignan contents of Dutch plant foods: A database including lariciresinol, pinoresinol, secoisolariciresinol and matairesinol. *Br. J. Nutr.* **2005**, *93*, 393–402. [CrossRef] [PubMed]
14. Hosseinian, F.S.; Li, W.; Beta, T. Measurement of anthocyanins and other phytochemicals in purple wheat. *Food Chem.* **2008**, *109*, 916–924. [CrossRef] [PubMed]
15. Li, W.; Beta, T. Flour and bread from black-, purple-, and blue-colored wheats. In *Flour and Breads and their Fortification in Health and Disease*, 1st ed.; Preedy, V.R., Watson, R.R., Patel, V.B., Eds.; Academic Press: London, UK, 2011; pp. 59–67. [CrossRef]
16. Zeven, A.C. Wheats with purple and blue grains: A review. *Euphytica* **1991**, *56*, 243–258. [CrossRef]
17. Mazza, G.J. Anthocyanins and heart health. *Ann. Ist. Super. Sanita* **2007**, *43*, 369–374. [PubMed]
18. Zheng, Q.; Li, B.; Li, H.; Li, Z. Utilization of blue-grained character in wheat breeding derived from *Thinopyrum poticum*. *J. Genet. Genom.* **2009**, *36*, 575–580. [CrossRef] [PubMed]
19. Sharma, S.; Khare, P.; Kumar, A.; Chunduri, V.; Kumar, A.; Kapoor, P.; Mangal, P.; Kondepudi, K.K.; Bishnoi, M.; Garg, M. Anthocyanin-biofortified Colored Wheat Prevents High Fat Diet-induced Alterations in Mice: Nutrigenomics Studies. *Mol. Nutr. Food Res.* **2020**, *64*, 1900999. [CrossRef] [PubMed]
20. Liu, Y.; Qiu, J.; Yue, Y.; Li, K.; Ren, G. Dietary black-grained wheat intake improves glycemic control and inflammatory profile in patients with type 2 diabetes: A randomized controlled trial. *Ther. Clin. Risk Manag.* **2018**, *14*, 247–256. [CrossRef] [PubMed]
21. Beta, T.; Qiu, Y.; Liu, Q.; Borgen, A.; Apea-Bah, F.B. Purple Wheat (*Triticum* sp.) Seeds: Phenolic Composition and Antioxidant Properties. In *Nuts and Seeds in Health and Disease Prevention*, 2nd ed.; Preedy, V.R., Watson, R.R., Eds.; Elsevier Inc.: London, UK, 2020; pp. 103–125. [CrossRef]
22. Ma, D.; Li, Y.; Zhang, J.; Wang, C.; Qin, H.; Ding, H.; Xie, Y.; Guo, T. Accumulation of Phenolic Compounds and Expression Profiles of Phenolic Acid Biosynthesis-Related Genes in Developing Grains of White, Purple, and Red Wheat. *Front. Plant Sci.* **2016**, *7*, 528. [CrossRef] [PubMed]
23. Lachman, J.; Martinek, P.; Kotíková, Z.; Orsák, M.; Šulc, M. Genetics and chemistry of pigments in wheat grain—A review. *J. Cereal Sci.* **2017**, *74*, 145–154. [CrossRef]
24. Mbarki, S.; Sytar, O.; Zivcak, M.; Abdelly, C.; Cerda, A.; Brestic, M. Anthocyanins of Coloured Wheat Genotypes in Specific Response to SalStress. *Molecules* **2018**, *23*, 1518. [CrossRef] [PubMed]
25. Uarrota, V.G.; Stefen, D.L.V.; Leolato, L.S.; Gindri, D.M.; Nerling, D. Revisiting Carotenoids and Their Role in Plant Stress Responses: From Biosynthesis to Plant Signaling Mechanisms During Stress. In *Antioxidants and Antioxidant Enzymes in Higher Plants*, 1st ed.; Gupta, D.K., Palma, J.M., Corpas, F.J., Eds.; Springer International Publishing AG: Cham, Switzerland, 2018; pp. 207–232. [CrossRef]
26. Zhang, Y.; Truzzi, F.; D'Amen, E.; Dinelli, G. Effect of Storage Conditions and Time on the Polyphenol Content of Wheat Flours. *Processes* **2021**, *9*, 248. [CrossRef]
27. Kumari, A.; Sharma, S.; Sharma, N.; Chunduri, V.; Kapoor, P.; Kaur, S.; Goyal, A.; Garg, M. Influence of Biofortified Colored Wheats (Purple, Blue, Black) on Physicochemical, Antioxidant and Sensory Characteristics of Chapatti (Indian Flatbread). *Molecules* **2020**, *25*, 5071. [CrossRef] [PubMed]
28. Ficco, D.B.M.; De Simone, V.; De Leonardis, A.M.; Giovanniello, V.; Del Nobile, M.A.; Padalino, L.; Lecce, L.; Borrelli, G.M.; De Vita, P. Use of purple durum wheat to produce naturally functional fresh and dry pasta. *Food Chem.* **2016**, *205*, 187–195. [CrossRef] [PubMed]
29. Gamel, T.H.; Wright, A.J.; Pickard, M.; Abdel-Aal, E.S.M. Characterization of anthocyanin-containing purple wheat prototype products as functional foods with potential health benefits. *Cereal Chem.* **2019**, *97*, 34–38. [CrossRef]
30. Yu, L.; Beta, T. Identification and Antioxidant Properties of Phenolic Compounds during Production of Bread from Purple Wheat Grains. *Molecules* **2015**, *20*, 15525–15549. [CrossRef] [PubMed]
31. Li, W.; Pickard, M.D.; Beta, T. Effect of thermal processing on antioxidant properties of purple wheat bran. *Food Chem.* **2007**, *104*, 1080–1086. [CrossRef]
32. Weegels, P.L. The future of bread in view of its contribution to nutrient intake as a starchy staple food. *Plant Foods Hum. Nutr.* **2019**, *74*, 1–9. [CrossRef]
33. Rosell, C.M. Trends in science of doughs and bread quality. In *Flour and Breads and their Fortification in Health and Disease Prevention*; Academic Press: Cambridge, MA, USA, 2019; pp. 333–343. [CrossRef]
34. De Corato, U. Improving the shelf-life and quality of fresh and minimally-processed fruits and vegetables for a modern food industry: A comprehensive critical review from the traditional technologies into the most promising advancements. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 940–975. [CrossRef]
35. Ilievska, N.; Pavlova, V.; Kirovska, V.; Ilievska, J.; Pavlovska, M. Nutritional and health benefits of inulin functional food and prebiotic. *J. Hyg. Eng. Des.* **2020**, 45–48.
36. Mohammadi, F.; Shiri, A.; Tahmouzi, S.; Mollakhalili-Meybodi, N.; Nematollahi, A. Application of inulin in bread: A review of technological properties and factors affecting its stability. *Food Sci. Nutr.* **2022**, *00*, 1–12. [CrossRef]
37. Belorio, M.; Gómez, M. Psyllium: A useful functional ingredient in food systems. *Crit. Rev. Food Sci. Nutr.* **2021**, *62*, 527–538. [CrossRef] [PubMed]

38. Kowalski, S.; Mikulec, A.; Pustkowiak, H. Sensory assessment and physicochemical properties of wheat bread supplemented with chia seeds. *Pol. J. Food Nutr. Sci.* **2020**, *70*, 387–397. [CrossRef]
39. AACC International. *Approved Methods of Analysis*, 11th ed.; Method 44-15.02. Moisture—Air-Oven Methods; AACC International: Nairobi, Kenya, 2010.
40. AACC International. *Approved Methods of Analysis*, 11th ed.; Method 56-81.03 Determination of Falling Number; AACC International: Nairobi, Kenya, 2010.
41. 4/1998. (XI. 11.) Regulation of EüM (Hungarian Ministry of Health) on the permissible level of microbiological contaminants in food. Available online: https://www.informea.org/en/legislation/decree-no-4-1998-ministry-health-allowable-limits-microbiological-contamination (accessed on 20 December 2022).
42. AACC International. *Approved Methods of Analysis*, 11th ed.; Method 54-21. Farinograph Method for Flour; AACC International: Nairobi, Kenya, 2010.
43. AACC International. *Approved Methods of Analysis*, 11th ed.; Method 10-10.03; AACC International: Nairobi, Kenya, 2010.
44. Codex Alimentarius Hungaricus Requirement No. 1-3/16-1 on bakery products 152/2009. (XI. 12.) decree, Ministry of agriculture, Hungary. Available online: https://leap.unep.org/countries/hu/national-legislation/decree-no-152-2009-xi-12-fvm-ministry-agriculture-and-rural (accessed on 20 December 2022).
45. Codex Alimentarius Hungaricus 2-201 Milling Products Directive. Available online: https://elelmiszerlanc.kormany.hu/download/e/64/b1000/2-201_2016-06-09.pdf (accessed on 20 December 2022).