Theses of doctoral (PhD) dissertation

QUALITY OF BREADS AND THEIR INGREDIENTS ENRICHED WITH SPICES AND VEGETABLE JUICE MADE FROM WHEAT AND RYE FLOUR

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1. Background and objectives of the doctoral dissertation

Cereals include the floury seed crops (Radics, 2003), which have been cultivated since BC. Population growth and the development and survival of empires and countries were also due to the availability of food raw materials. These floury seed crops were and still are the main source of foodstuffs (Balla et al.2010), from which humans have created one of the oldest processed foods, the bread (Gisslen, 2016). The domestic bread baking was dominant in Hungary and all around the world for centuries. The industrial production developed slowly (Kovácsné, 2012). As a result, technology and recipes have evolved continuously and rapidly (Gisslen, 2016). The consumption of bread, due to the present healthy lifestyle trend, is constantly decreasing, although cereal products are necessary for a balanced diet, which is also stated on the website of the National Association of Dietitians (Okostányér, 2022). The aim was to develop a product, consisting of basic and auxiliary ingredients available in stores and shops, which would add value to the consumer. I wanted to prove this by examining the nutritional values of the products prepared.

Although bread basically contains high amounts of carbohydrate, it also contains other nutrients that are important for us. At the beginning of my research, I have found numerous publications that examined bread. Several studies examined enriched products too.

During my search, I read several other articles. I decided to enrich breads with different spices. I was also curious to see how the enrichment might change the textural characteristics of the products, when using natural colourings.

2. Material and methods

The raw materials were obtained from stores and shops, while the different breads were prepared and examined at the Institute of Food Science, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen. In each case, the measurements were performed in triplicate.

The following samples were tested:

Vegetable juices (dry matter, total polyphenol, flavonoids and macro element content):

- 3 types of bell peppers (green, red, yellow), red cabbage, baby spinach, beetroot, carrot, red onion, and sweet potato

Spices (total polyphenol, flavonoids and macro element content):

- basil, dill, oregano, cumin, chives, rosemary, parsley, garlic granules

After examined the raw and enrichment, I prepared breads based on the following recipe: 500 g BL 55/ RL 90 flour, 5 g salt, 44 g sunflower oil, 8 g 10% vinegar, 30 g yeast, 150 ml 2.8% cow's milk, 100 ml water, 5 g sugar.

For the enrichment, I used different quantities and types of spices (basil, dill, oregano, caraway, chives, rosemary, parsley and garlic granules) and vegetable juices (beetroot, baby spinach, red cabbage, carrots) (substituting water). After cooling, the following parameters were determined from breads: dry matter, total polyphenols, flavonoids, crude fat, crude protein and element content. Based on the results obtained and the tasting scores (breads with a given amount of spices and coloured breads), I chose the quantities and types of herbs and vegetable juices for further analysis.

In the case of products made from spiced and coloured wheat flour and rye flour, in addition to the determination of the above mentioned parameters, carbohydrate and dietary fibre content of the samples were also analysed, and thus the energy content and the daily intake were calculated.

The quantity of spices in case of the **basil test breads** (g): 0; 4,25; 8,5; 12,75; 21,25; 25,5.

For the **spiced breads** (except parsley), I used the following quantities of spices: 0, 2, 4, 6, 8, 10, 12 g.

The **spiced breads containing the specified amount of spices** contained 10 g spices.

The **coloured breads** were made with purple cabbage, beetroot, baby spinach and carrot juice by replacing the amount of water (100 ml) with whole or partial substitutions (0, 25, 50, 75 and 100 ml).

The **spices and coloured** products contained specific amounts of substances. These were wheat and rye flour, spiced with basil, dill, oregano and chives, and made with 50 ml of spinach juice and 75 ml of beetroot juice.

2.1. Analytical methods

2.1.1. Determination of dry matter content

Dry matter content was determined from the samples in all cases except for herbs. For the analysis, I used an oven (Memmert UF 75 Universal Oven, Memmert GmbH+Co. KG, Schwabach, Germany). For the breads, I used the standards MSZ 20501-1 (2007), while for vegetable juices, I used MSZ EN 12145 (1998).

2.1.2. Determination of Total Polyphenol Content (TPC)

For the determination of total polyphenol content, I used the method of Singleton et al., (1999), in which the key reagent was Folin-Ciocalteu (VWR International S.A.S., France). After the preparation of the samples, their absorbance was measured with a spectrophotometer (Evolution 300 LC, Thermo Electron Corporation, England) at 760 nm. The concentration corresponding to the values obtained was read off from a calibration curve prepared from gallic acid (Alfa Aesar GmbH&Co. KG, Karlsruhe, Germany). The results were expressed in mg GAE (gallic acid equivalent)/100 g sample.

2.1.3. Determination of flavonoid content

To determine the flavonoid content, I used the method of Kim et al. (2003). Measurements were carried out with a spectrophotometer (Evolution 300 LC, Thermo Electron Corporation, England) at 510 nm. The concentration corresponding to the values obtained was read from a calibration curve prepared from catechin (Cayman Chemical Company, USA). Results were expressed in mg CE (catechol equivalent)/100 g sample.

2.1.4. Determination of element content

Sample preparation was performed according to the method of Kovács et al. (1996). This process was carried out by using nitric acid (69% v/v, VWR International Ltd., Radnor, USA) and hydrogen peroxide (30% v/v, VWR International Ltd., Radnor, USA) chemicals and different temperatures (60 ºC, 30 min; 120 ºC, 90 min). The element content of the fragments was measured using an inductively coupled plasma optical emission spectrometer (ICP-OES; Thermo Scientific iCAP 6300, Cambridge, UK) at the following wavelengths: Al (396.1), B

(249.7), Ba (455.4), Ca (315.8), Cu (324.7), Fe (259. 9), K (769.8), Mg (280.2), Mn (259.3), Mo (202.0), Na (818.3), P (185.9), S (180.7), Sr (421.5), Zn (213.8).

2.1.5. Determination of crude protein content

The crude protein content was determined from the bread samples. It was based on the Kjeldalh method. The nitrogen content of the samples was determined by digestion, distillation and titration of the samples, and the nitrogen content measured was multiplied by the Kjeldahl conversion factor (6,25) to obtain the crude protein content of the samples. For the determination of this parameter of the breads, I used the standard MSZ 20501-1 (2007).

2.1.6. Determination of crude fat content

The crude fat content of bread was measured according to the standard MSZ 20501-1 (2007). Accordingly, the samples were digested with sulphuric acid (98% v/v, VWR International Ltd., Leuven, Belgium) and ethanol (96%, VWR International Ltd., Radnor, USA), and the fat was extracted with light petroleum ether (40-60ºC, VWR International Ltd., Radnor, USA). The crude fat content was determined by a formula from the weight of the fat recovered, the amount of petroleum ether added, the weight of the sample and its dry matter content.

2.1.7. Determination of carbohydrate content

Carbohydrate content was determined from samples (BL0-BL7) containing 10 g of spices and from coloured spiced breads (1-20) according to the phenol sulphuric acid method (Lásztity and Törley, 1987). The principle of the method is to hydrolyse the samples with sulphuric acid and then remove the proteins with Carrez I and Carrez II solutions. To the prepared solution, concentrated sulphuric acid (98% v/v, VWR International Ltd., Leuven, Belgium) and phenol solution (≥99% VWR International Ltd, Solon, USA) are added and after half an hour, the absorbance of the samples is measured at 490 nm against a blank solution containing distilled water instead of the sample. For the determination of the carbohydrate content of the samples, a calibration solution of sucrose (a.r., VWR International Ltd., Leuven, Belgium) was also prepared, so that the result was obtained in g/100 g (%) of sucrose.

2.1.8. Determination of total dietary fibre (TDF) content

The total dietary fibre content was determined, similarly to the carbohydrate content, from samples containing 10 g of spices (BL0-BL7) and from coloured spiced breads (1-20) according to Annex 2 of the Hungarian Food Guide 3-2-2008/1. During the measurement, different enzymes and chemicals were added to the samples and the samples were subjected to different

heat treatments, followed by protein and ash determinations in order to obtain the total dietary fibre content.

2.1.9. Determination of nutritional value and energy content

The energy and nutritional information on food labels must be indicated in tabular form, since 2016. The energy and nutritional content of the end products was calculated using the conversion coefficients and parameters found in Regulation (EU) No 1169/2011, based on the values of the coloured spiced breads and 2-2 control samples (wheat flour and rye flour, n=20) per 100 g of product (crude fat, carbohydrate, crude protein, fibre and salt content).

2.1.10. Daily intake contribution values of products (nutritional reference value)

The labels of some foods may contain information on the contribution of the consumption of a certain amount of the product to the nutritional reference value (NRV), which is in Annex XIII to Regulation (EU) No 1169/2011. These nutritional contribution values have been determined for 100 g of products from the values of coloured spiced breads and 2-2 control samples (wheat flour and rye flour, n=20) in terms of macronutrient content.

2.1.11. Statistical analysis

The results, except for the nutritional and energy content and the daily intake contribution values of the products, were analysed using a statistical software (SPSS 13.0). This was used to determine the mean, standard deviation, minimum and maximum of the samples' results. To determine statistically verifiable differences, I used one-way ANOVA (Tukey's and Dunett's T3 tests were chosen based on the results of the homogeneity test) for the spiced breads. When the p value was below 0.05, the difference was considered statistically justified.

2.1.12. Sensory analysis

The tasting was carried out on the samples containing 10 g of spices and the samples coloured by spinach and beetroot (with higher vegetable juice content). 17 people tasted the spiced breads (B10, K10, O10, F10, M10, R10 és Fo10) and 18 tasted the samples enriched with vegetable juices (C2, C3, C4, Sp2, Sp3, Sp4), and scored them on a scale of 1 to 5 based on the following criteria: aroma, texture, colour, taste.

3. Results

3.1. Spices

To enrich the breads, I examined different spices, among which I would highlight basil. It contained high concentrations of antioxidant compounds and had the highest calcium, potassium and magnesium content of all the herbs tested. Dill should also be mentioned, as it had similar polyphenol and flavonoid content to basil, and the highest sodium and sulphur content. I also found high concentrations of antioxidant compounds in oregano and rosemary, but these spices had the lowest levels of potassium, phosphorus and sulphur. Chives, although was less rich in polyphenols and flavonoids, showed high levels of calcium, potassium and sulphur. In terms of microelements, basil was also outstanding, with the highest concentrations of barium, strontium and zinc, but also rich in copper, iron, manganese and molybdenum. In this case, in addition to basil, dill should also be mentioned, which also showed a high microelement content. It should be noted, however, that these two herbs also had the highest aluminium concentrations, which can probably be explained by the contamination of the soil used for cultivation. I used all the spices except parsley in the following experiment to prepare the breads.

3.2. Basil test breads

To determine the amount of spices to add to the bread dough, I chose basil because I found it to be the best spice in terms of its flavour. In my opinion, products with the highest spice levels would have been inappropriate for consumers, although the measurement results were very convincing compared to the parameters measured in the control products, as I observed an increase in all the parameters tested, except for sodium content. On this basis, I concluded that the addition of spices could significantly increase the values of the parameters I was testing, but on the basis of the results obtained, I considered it necessary to change the amount of spices added, and so I set the maximum amount of spices at 12 grams.

3.3. Spiced breads

I baked 42 types of flavoured breads with the selected spices in 6 different enrichments, as well as the corresponding control breads, and found that the concentrations of macroelements and antioxidant compounds increased mostly proportionally with the increasing the amount of spices.

Based on the results obtained, I found that the addition of spices to bread dough had no effect on the dry matter, crude protein and crude fat content of the breads, i.e. on the basic nutritional parameters of the bread.

For the total polyphenol content, the results showed that the enrichment with my selected spices increased the polyphenol content measured in the final products. The greatest increase was obtained by the addition of rosemary and oregano, with increases of 48% and 90% for oregano and 69% and 127% for rosemary at 6 g and 12 g of addition, respectively. This was around 50% and 100% for basil and dill.

Even with the addition of caraway and chives, the increase was only 25% and 43% for the 12 g spice amount.

My results demonstrated that the fact that a spice has a high flavonoid content does not guarantee that a proportional increase in flavonoid content can be obtained by fortifying a product with an increase in the amount of flavonoids, especially since it was already found in the basil test batch that the heat treatment resulted in a greater reduction in flavonoids. Significant increases were observed for three spices, which were 50% and 83% for basil, 27% and 45% for dill and 60% and 115% for rosemary breads at 6 g and 12 g enrichment, respectively. Other spice enrichments showed little or no increase in the flavonoid content.

In many cases, the macro-nutrient content of spiced breads and the spices used showed a similar trend. My results showed that basil fortification increased mostly the calcium, potassium and magnesium content of the breads, while spice fortification increased the phosphorus and sulphur content. It is an important observation that in many cases, higher spice content did not cause an increase in the concentration of macroelements, and in fact, for several elements I observed a decrease after adding higher amounts of spices. Adding higher amounts of oregano, caraway, chives and garlic granules to bread dough resulted in a decrease in sodium content, and fortification with garlic granules also reduced the calcium and magnesium content in the final product. On the basis of the results obtained, I decided to add 10 g of spices to the bread dough for further testing.

3.4. Spiced breads containing the specified amount of spices

With the above-mentioned amount of spices, I prepared the breads again, and in addition to the parameters already mentioned, I also determined the carbohydrate and dietary fibre contents. In this case, the addition of spices did not change the dry matter content of the final products; minor differences in crude fat and crude protein content were observed, but overall it can be stated that the addition of spices to bread dough had no verifiable effect on any of these

parameters. This confirmed the results obtained in the previous experiment. The carbohydrate content was also not significantly affected by the enrichment, with statistically verifiable differences only between the lowest and highest values, i.e. between oregano and basil breads. In case of fibre content, differences were verifiable. The enrichment with chives and basil had the highest increase in the fibre content of the final product, while the enrichment with garlic granules and dill had the lowest effect.

In case of microelements, the molybdenum and zinc contents did not change with the addition of different spices. For copper, iron, manganese and strontium, it is clear from the results that the spices with the highest elemental content increased the concentrations most. The most significant increases compared to the concentrations measured in the control breads were for boron and strontium, the only exception was the product fortified with garlic granules. The addition of dill, oregano and rosemary increased the boron content in the final product by a factor of eight. In case of strontium, the spices doubled the concentration on average, but basil was the main ingredient, which resulted in an almost eightfold increase in strontium content in the enriched bread. Copper and manganese did not show such a significant increase, while fortification with oregano resulted in 50% higher concentrations, compared to 40% and 20% for basil and dill respectively. Manganese content was 30-35% higher in the final product after fortification with dill, basil and chives. The results for iron were very different, due to the spices used for fortification.

For this element, it was also observed that the iron content in the final products decreased in the order of the concentrations measured in the spices. This suggests that two products should be highlighted in which the concentration of iron increased more significantly, namely dill bread, in which the concentration was three and a half times higher, and basil bread, in which the concentration was almost three times higher than in the control bread. The concentrations of the elements that our body needs were also increased after enrichment with spices; the results show that in this case, too, the order of the concentrations measured in the breads was the same as in the spices used. In the case of aluminium, the addition of dill, basil and oregano to the bread dough resulted in the highest concentrations, with a tenfold increase for dill, sevenfold for basil and fourfold for rosemary. The addition of basil and herbs caused the highest barium content in the final products, which was about one and a half times higher than the concentrations in the control breads.

The results obtained show that fortification with dill and basil is the best way to increase the iron, manganese and strontium content in breads, while dill, oregano and rosemary are the best substances to increase the boron content, while fortification with oregano and basil has the best

results for the copper content. It should be noted, however, that as micronutrient content can be influenced by numerous factors, spices sourced from different areas may result in different micronutrient content.

3.5. Coloured breads

The aim was to produce functional breads with a higher concentration of antioxidant compounds and macro and micro elements essential for the human body. I investigated whether the partial or total replacement of the drinking water used for bread dough with vegetable juices would lead to an additional increase in these parameters, in addition to the enrichment with spices. Outstanding concentrations of the colouring agents used were measured, which can be considered as a useful basis for further research. In the case of compounds with antioxidant activity, the purple cabbage juice should be highlighted, as it contained several times higher concentrations of these compounds than the other vegetable juices, but I also determined high polyphenol content in red and green pepper juices. In terms of flavonoid content, beetroot juice and spinach juice also had significant concentrations, in addition to purple cabbage juice.

I measured high concentrations of calcium, potassium, magnesium and phosphorus in spinach juice, but sodium and sulphur contents were also high in these vegetable juices. I also found high levels of calcium, potassium, magnesium, phosphorus and sulphur in the juice of the purple cabbage. Based on the results obtained and the amount of juice that could be extracted from the vegetables, I selected the juice of purple cabbage, spinach, beetroot and carrot for colouring breads, which I added to the bread dough in 25, 50, 75 and 100 ml volumes. Based on the results, I continued my experiments with spinach juice and beetroot juice. When fortified with these, I observed changes in concentration that were worth further experimentation.

3.6. Products enriched with juices and spices

I prepared the following breads based on the results of the previous tests. The flours I chose were wheat flour and rye flour, which are readily available to consumers and are the most widely known and consumed. As for the spices, I selected basil, dill and oregano, which had the best taste and texture parameters, and I also included chives in the tests, as the tasters considered chive bread to be the best in terms of taste and texture. The colouring agents chosen were spinach juice and beetroot juice, also in terms of their nutritional parameters.

In the case of the spiced-coloured wheat and rye breads, the dry matter content of the products was higher in the wheat flour samples than in the rye flour breads.

Rye flour samples had significantly lower crude protein content compared to wheat flour products. This was also observed when testing the raw materials and the loaves made from them, as both the wheat flour and the rye flour loaves had higher crude protein contents.

As with the crude protein content, the wheat flour products also had a higher crude fat content than the rye flour samples.

The carbohydrate content of the flours was around 70%, according to the information on the packaging. I tested the carbohydrate content in two experiments. Products with a given amount of spices had a carbohydrate content of 39-42%, while spiced-coloured breads had a carbohydrate content between 41-47%. The measured results showed that the addition of basil increased the carbohydrate content in both spinach juice and beetroot juice coloured products, but the other spices caused a decrease in this parameter compared to the control breads.

Rye flour had a higher dietary fibre content than wheat flour. This is confirmed by the results of the control breads and the spiced-coloured breads, since in all cases the rye flour breads had a higher fibre content than the wheat flour products. I measured twice as high fibre content in the control rye breads than in the wheat flour control products, which had a significant effect on the fibre content of the fortified products. The results suggest that the addition of colouring agents had no effect on fibre content, but spices did. In my opinion, the addition of vegetables in pureed form to bread dough would also have increased the fibre content.

In case of the total polyphenol content, products made from rye flour had a higher polyphenol content, which also affected the polyphenol content of the enriched breads. The addition of spices further increased the total phenolic content, with the most significant increase in all cases being due to fortification with oregano and basil. In addition to the spices, the addition of colouring agents also had a positive effect on the polyphenol content of the breads, with beetroot juice having the most significant effect, despite the higher polyphenol content in spinach juice.

In every case, the addition of spices increased the flavonoid content of the final products, but there were differences between breads made from different flours. While in wheat flour products the addition of basil had the greatest effect in increasing the flavonoid content, followed by dill, oregano and chives, in rye flour breads the greatest effect was found in case of the addition of oregano, followed by basil, dill and chives. When looking at the colouring agents, products containing beetroot juice showed a higher flavonoid content in wheat flour breads, while products coloured with spinach juice showed a higher flavonoid content in rye flour breads.

The addition of spices and colouring agents to bread dough clearly increased the calcium, potassium, magnesium and sulphur content of the products. In case of phosphorus, the

concentration increased in wheat flour and rye flour breads made with spinach juice, but only the addition of basil and dill in wheat flour products coloured with beetroot juice resulted in a minimal increase in the concentration, while in rye flour breads only the addition of basil increased the concentration of this element, also minimally. For sodium, only wheat and rye flour products flavoured with dill in spinach juice and basil in beetroot juice, and wheat flour breads flavoured with dill and beetroot juice increased in concentration compared to the control bread.

For wheat flour breads, basil and dill flavouring increased calcium, potassium and magnesium content the most in both spinach juice and beetroot juice coloured products; however, dill and chives flavouring increased sulphur content more. Colouring with spinach juice resulted in higher concentrations of calcium when the added spice was dill, oregano or chives, but in the case of basil, the beetroot juice product showed higher concentrations. For potassium and magnesium, colouring with spinach juice increased the concentration more, while for sulphur there were no significant differences between the concentrations measured in the coloured products from which any conclusions could be drawn. Since I measured higher macroelement contents in spinach juice, the results obtained were in line with my expectations.

In the rye flour breads, flavouring with basil and oregano was the most effective in increasing calcium content, while dill and basil increased potassium and magnesium content in both spinach juice and beetroot juice coloured products; however, the higher sulphur content was also due to flavouring with dill and chives. The sodium content increased in only two cases, fortification with spinach juice and dill and fortification with beetroot juice and basil. As with wheat flour products, there was no significant difference in phosphorus content. For calcium, the concentrations were similar to wheat flour products, with higher concentrations in breads coloured with spinach and flavoured with dill, oregano and chives. For potassium and magnesium, also for this type of flour, the colouring with spinach juice resulted in higher concentrations.

In case of micronutrients important for our body, I found that in most cases, the coloured spiced breads contained higher concentrations of these elements than the control breads. For boron, the concentration was increased by the fortification, except for the products with basil in spinach, dill in beetroot juice and chives in beetroot juice. The enriched breads had higher copper contents than the control samples, but chive products also worth mentioning, which had similar or lower concentrations than the control bread. The iron content clearly increased as a result of colouring and seasoning, with the highest levels of iron among the micronutrients tested. Basil increased the iron content nearly threefold in the final wheat flour bread and nearly

twice as much in the rye flour bread. There was also an increase in manganese content, but only in wheat flour breads. The concentration of this element was increased mostly by oregano, which resulted in a manganese content about twice as high as measured in the control bread. The molybdenum content was also increased in the fortified products, but the extent was also not significant.

I found a higher increase in the strontium content, where the biggest effect was due to the basil fortification, as I measured very high concentrations in these products compared to the control sample. In the wheat flour products, the concentration was 8-9 as higher, while in the rye flour breads it was 5-6 times higher. This can clearly be explained by the high strontium content of basil. There was no significant increase in zinc content compared to the control sample.

The effect of colouring agents was only clearly detectable for one element, boron, where colouring with spinach juice resulted in higher boron content in wheat flour bread than in beetroot soup products, but the difference was not as significant for rye flour products.

Based on the results, it can be concluded that vegetable juices did not have as significant effect on micronutrient content as antioxidant compounds or macroelements, with the only exception of iron content, which significantly increased by colouring. Overall, however, it can be concluded that in the case of micronutrients, spices have a much greater influence on the micronutrient content of the final product than colouring agents.

The aluminium content increased more significantly compared to the concentration in the control breads, mainly due to the aluminium content of the spices, but vegetable juices also had an effect on this parameter. The highest increase was observed in breads flavoured with basil, which contained ten times higher concentrations of this element in wheat flour breads and five times higher concentrations in rye flour products compared to the control samples. There was no such significant increase in barium content.

Taking into account all the results of the experiments, it can be said that fortified products contribute more to the daily intake of antioxidant compounds and macronutrients than control products, and breads containing only spices or vegetable juices. It is important to note that fortification of breads with the spices and vegetable juices that I used does not cause a difference in the dry matter, crude protein or crude fat content of the final product, but it does increase the fibre content, which has a positive effect on our digestion. In addition, carbohydrate content can also be affected by fortification, where I have seen a reduction - except for basil coloured products - which is also a positive result.

4. New scientific results of the dissertation

1. The addition of spices to breads significantly increases the amount of antioxidant compounds in the end product, in spite of the high temperatures applied during baking. The highest increase in polyphenol content is obtained with the addition of basil, dill, oregano and rosemary. Adding 6 g of the first three spices to the dough can increase the polyphenol content by 50%, while adding 12 g of spices can double the polyphenol content. In the case of rosemary, this is an increase of 70% and 130% respectively. The flavonoid content is increased mostly by rosemary and basil, with increases of 60% and 50% for 6 g of spices and 115% and 80% in case of 12 g of spices.

   Out of the herbs tested, basil and dill were found to increase potassium, calcium, magnesium and phosphorus levels to the highest extent, thus increasing the contribution to the recommended daily intake of macronutrients. With 12 g of spices, the potassium content can be increased by 30% and the phosphorus content by 6-9% in breads. For calcium, basil more than doubles the measured concentration and rosemary increases it by 70%. For magnesium, basil increases the magnesium content by 70% and dill by 30%.
2. Chives and basil play a significant role in increasing the dietary fibre content of breads, which aids digestion. Compared to control bread, the fibre content can be increased by 45-50% by using 10 g of spices.
3. Among the vegetable juices added to breads, purple cabbage and beetroot juices have the potential to increase the total phenolic compounds in the products, but the flavonoid content is not increased to a verifiable extent by vegetable juices. When water is fully replaced by vegetable juice, the increase in polyphenol content is 50% for purple cabbage juice and 34% for beetroot juice.
4. Vegetable juices contribute much less to the macronutrient content of breads than spices. The combination of spices and vegetable juices can increase the amount of antioxidant compounds, calcium, potassium, magnesium, sodium and dietary fibre of breads. The type of flour used has a significant effect on these parameters, but the rate of increase in concentrations is similar for both wheat and rye flour products.
5. In terms of microelements, fortification with spices and vegetable juices does not cause a significant increase in their concentrations, with the exception of iron, which is significantly increased by the above-mentioned additives. Breads enriched with spinach juice and spices show a higher increase than spiced breads containing beetroot juice, so the use of spinach juice results in a higher iron content. Besides vegetable juices, basil

has the greatest effect on the concentration of this element, resulting in almost three times higher iron content in wheat breads and almost twice higher in rye breads.

6. Spices and vegetable juices have no effect on the crude protein, crude fat and carbohydrate content of breads. Breads made from rye flour and enriched with spices and vegetable juices have a lower energy content than rye breads made without additives. Enrichment of wheat flour breads with vegetable juices and dill or oregano also results in a lower energy content than that calculated for unenriched wheat breads, but the addition of basil and chives increases the energy content of wheat breads. The increases are 7.5% and 1% for wheat bread with spinach-basil and spinach-chives, and 11% and 4% for wheat bread with beetroot-basil and beetroot-chives.

5. Practical results

1. The consumption of breads enriched with herbs contributes significantly to the intake of antioxidant compounds and macronutrients that are important for our body. Increasing the amount of herbs can increase the concentration of these parameters in the product, but adding too much herbs can reduce the enjoyment of the final product, so determining the right amount can also have a significant impact on consumer perception. Based on my results, for most spices, 10 g is sufficient to achieve a significant increase in these parameters and create a product that is suitable for consumers.
2. The garlic granulate did not increase the value of most of the parameters I tested in the final product, but its use is recommended for bread enrichment, as it scored very high in terms of aroma, texture, colour and taste, so although the flavour of the product is not improved, the enjoyment value of the bread can be increased by using this spice.
3. Out of the vegetable juices examined, juices pressed from peppers also had a significant total phenolic content, so their use as a substitute for water in breads may have a significant effect on the polyphenol content of the final product.
4. If the vegetables are added to the bread dough as a puree rather than as a juice, an additional increase in dietary fibre content can be achieved, which can also reduce waste.
5. The amount of antioxidant compounds and the concentration of macro elements and iron will be higher in the final product if we do not add only spices or vegetable juice (vegetable puree) to the dough, but use both of those together. The greatest increase in polyphenol content in both spinach and beetroot bread is achieved by adding oregano, while the concentration of calcium and magnesium is increased to a higher extent by adding basil and potassium by adding dill. Iron content is significantly increased by the addition of basil.
6. The use of spinach juice and beetroot juice had an overall positive effect on the measured parameters, but not to the same extent as the spices. The results do not allow a clear distinction to be made between the two different vegetable juices, so it is worth taking consumer judgement into account when considering which vegetable juice to use when preparing bread dough. On this basis, I would clearly recommend the use of beetroot juice as it scored higher than the spinach juice breads in terms of smell, texture, colour and taste.

7. As to the quantity of vegetable juices added to bread dough, I do not recommend replacing the water entirely with vegetable juice, as there is no effect on the parameters tested to justify this, and the reviewers also preferred breads with only partial application of vegetable juice. On this basis, I recommend replacing 50-75% of the water with vegetable juice.

6. References

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7. Publications

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Registry number: DEENK/110/2023.PL
Subject: PhD Publication List

Candidate: Andrea Kántor
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10065424

List of publications related to the dissertation

Hungarian scientific articles in Hungarian journals (3)

1. **Kántor, A.**, Alexa, L., Topa, E., Kovács, B., Czipa, N.: Különböző fűszerekkel dúsított kenyerek makroelem tartalmának meghatározása és hozzájárulásuk a táplálkozási referencia értékhez. *Elelmiszervizsgalati Kozlemen. 68* (3), 4036-4046, 2022. ISSN: 2676-8704. DOI: http://dx.doi.org/10.52091/EVIK-2022/3-5-HUN
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3. **Kántor, A.**, Fischinger, L. Á., Alexa, L., Topa, E., Kovács, B., Czipa, N.: Funkcionális kenyér, avagy a fokhagyma és készítményei hatása a kenyér egyes paramétereire = Functional bread, or the effects of garlic and its products on certain parameters of bread. *Elelmiszervizsgalati Kozlemen. 65* (4), 2704-2714, 2019. ISSN: 2676-8704.

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7. Fischinger, L. Á., Czipa, N., Alexa, L., Kovács, B., **Kántor, A.**: Beltartalmi paraméterek vizsgálata kereskedelmi forgalomban kapható fokhagymákban és fokhagymakrémekben.
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