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Application of shiitake and maitake extracts to wheat flour and their effect on technological and baking properties

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Abstract

Shiitake and maitake extracts were added to composite flours in the amounts of 5%, 7.5%, and 10%, which subsequently changed the basic technological properties of the composite flours. Compared to control flour, wet gluten content decreased only slightly, but gluten swelling and gluten extensibility decreased significantly. Falling number, Zeleny sedimentation volume, and crude protein also decreased. The experimental loaves were baked from composite flours and evaluated by Volscan. The weight of the experimental loaves decreased in proportion to the amount of addition of medicinal mushroom extract. The volume and specific volume of the experimental loaf decreased with the addition of maitake extract in proportion to its amount. The addition of shiitake extracts in the amount of 5% increased the volume and specific volume of the experimental loaf; however, higher additions (7.5%, 10%) reduced the evaluated parameters in the case of shiitake extract. Nevertheless, all additions were technologically acceptable, and the differences in technological quality of experimental loaves compared to control loaves were not significant. These types of designed foods with nutritional benefits have potential for producers and are desirable to consumers.

Keywords: Composite flours, Mushroom extracts, Gluten, Falling number, Zeleny index, Baking test, Quality evaluation, Volscan.

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Contents

Contribution of this paper to the literature

The research provides information on the changes caused by the addition of non-baking ingredients to wheat flours intended to produce bread. The presented additives are exceptional in their nutritional benefits, and the results obtained are original regarding the possibilities of their application to make bakery products more attractive.

1. Introduction

Cereals are key plant resources that have provided human nutrition for thousands of years. Wheat and rye, as the basic cereals of Europe, are irreplaceable from the point of view of the production of bread and pastries as basic foods. Despite the fact that the consumption of bread and pastries in Slovakia has been decreasing for more than 30 years, in 2022 it was at the level of 62 kg per person per year [1], which is definitely not low. Such consumption is significant enough to call attention to the nutritional benefits of consuming these basic foods.

The main raw material used worldwide for bread production is wheat flour, which is characterized mainly by a high proportion of starch and a low proportion of proteins that are deficient in some essential amino acids, but with an exceptional ability to capture fermentation gases formed during the fermentation process, thanks to gluten [2, 3]. Efforts to improve the nutritional quality of bread are made by partially replacing wheat with non-bakery raw materials, which are valued for their content of biologically active ingredients that traditional breads do not contain. This produces a variety of products with beneficial health effects [4-9].

However, in composite flours prepared by combining wheat flour and flours from non-bakery raw materials, or directly by specific valuable ingredients, a lower proportion of gluten causes problems related to the technological properties of the flour, dough, and finished product. The gluten-free addition causes the wheat dough to be diluted and subsequently weakened; however, the effect of the addition can be very specific [10-13]. A balance must be struck between nutritional benefits and technological requirements.

The group of non-bakery raw materials in which nutritional benefits can be assumed includes medicinal mushrooms, which exhibit a wide range of pharmacological activities, including antiallergic, antibacterial, antifungal, anti-inflammatory, antioxidant, antiviral, cytotoxic, immunomodulatory, antidepressant, antihyperlipidemic, antidiabetic, digestive, hepatoprotective, neuroprotective, nephroprotective, and osteoprotective [14]. The authors summarized known findings and compared clinical studies aimed at confirming the positive effects of the consumption of medicinal mushrooms.

In Shiitake (Lentinula edodes), an important compound with immunomodulatory effects is lentinan, β-1,3-D-glucan. Polyphenol-rich mushroom extract also shows high free radical scavenging [15-18]. The antioxidant effect of shiitake is caused by ergothioneine (2-mercaptohistidine trimethylbetaine), whose significant increase in blood within two hours after mushroom consumption was demonstrated by Weigand-Heller et al. [19]. As a potential raw material, shiitake is interesting because of its content in therapeutic compounds that have antitumor, antifungal, antibacterial, anti-inflammatory, hypocholesterolemic, antihypertensive, hypoglycemic, and antioxidant effects [18].

The potential positive effects of Maitake extract (Grifola frondosa) on the human body can be summarized in the benefits related to its antioxidant mechanisms [20], which are conditioned by the content of valuable bioactive components [21]. Moreover, the content of polysaccharides, especially β-glucans and heteroglycans, as well as other bioactive macromolecules, is potentially useful in terms of antitumor and immunomodulatory effects [22, 23], prebiotic effects [24], or effects on visceral leishmaniasis [25].

The aim of the study was to verify the possibilities of adding extracts from medicinal mushrooms, Shiitake and Maitake, to wheat flour, and subsequently to evaluate the basic technological properties of composite flours and the resulting experimental breads.

2. Materials and Methods

2.1. Materials

For the preparation of composite flours, commercial wheat flour (Mlyn Grznár, Veľké Hoste, Slovakia) was used, the quality of which is defined by the following parameters: energy value (1464 kJ), carbohydrate content (71 g/100 g) including sugars (1.59 g/100 g), fiber content (3.3 g/100 g), protein content (11 g/100 g), fat content (1.3 g/100 g) including saturated fat (0.3 g/100 g), salt (0.01 g/100 g), and ash content (0.65 %).

As part of the presented research, two types of non-bakery additives were added to wheat flour: maitake extract and shiitake extract. The extracts were obtained from Natural Field (Xi'an Natural Field Bio-Technique Co., Ltd., Xi'an, China), from the source One Pharma s.r.o, Janka Kráľa 5, 974 01 Banská Bystrica, Slovakia.

Formulations using the evaluated composite flour (experimental design) are listed in Table 1.

Table 1. Experimental design.

Wheat flour T650	Shiitake extract	Maitake extract	Identification of the samples	
100 %	0 %	0 %	WF	
95 %	5 %	5 %	Sh_5	Ma_5
92.5 %	7.5 %	7.5 %	Sh_7.5	Ma_7.5
80 %	10 %	10 %	Sh_10	Ma_10

2.2. Methods

As part of the evaluation of the technological quality of composite flours, the following parameters were determined: moisture by gravimetric method in % (ICC standard 110/1, 1976), gluten content G_{30} (ISO 21415-1:2006), plus the swelling of gluten T_{30} (cm), and the extensibility of gluten Q_{30} (mL), sedimentation index by Zeleny in mL (STN ISO 5529), Falling number in seconds (ICC 107/1, Falling Number 1500, fa Perten Instruments, AB), Crude protein (Kjeldahl, N x 5,7), Starch content by Ewers (ISO 10520:1997), conversion factor 1.898, Ash content in % (ICC Standard 104/1) and titration acidity of flour (mmol/kg).

Experimental breads were baked from composite flours (Table 1) by the processing procedure described by Bojňanská et al. [26] and analysed using a Volscan Profiler volume analyser (Stable Mycrosystems, Surrey, UK). The following parameters were evaluated: weight of the bread (g), bread volume (mL), specific volume (mL/g), volume yield (mL/100 g flour), and aspect ratio of a middle slice.

2.3. Statistical Analysis

All analyses were performed in triplicate, and average values were calculated. XLSTAT 2020.5.1 [27] together with Microsoft Excel 365 [28] was used as the statistical and data analysis software (ANOVA and a Duncan's multiple range test).

3. Results and Discussion

The addition of non-bakery raw materials generally worsens the technological parameters of composite flours, which has also been confirmed in the case of the addition of maitake and shiitake extracts. The amount of wet gluten, its ductility, and swelling decreased in proportion to the amount of extracts added (Figure 1). These findings are not surprising, as the change in protein-protein fraction ratios in composite flours affects the rheological properties of the dough [8, 26, 29]. The main problem in applying non-wheat flour to dough is the disturbance of the starch–gluten matrix and the dilution of gluten, which reduces its ability to retain gases produced during dough leavening [30-32]. In addition to the decrease in wet gluten content, which is understandable, the extensibility of gluten decreased significantly. Nevertheless, the values observed in Table 1 can be characterized as adequate, indicating the usability of such composite flours.

Other parameters evaluating the technological quality of flours were also influenced by the addition of extracts. Compared to control wheat flour, flours with added extracts had demonstrably higher enzymatic activity and lower sedimentation index (ZI) values.

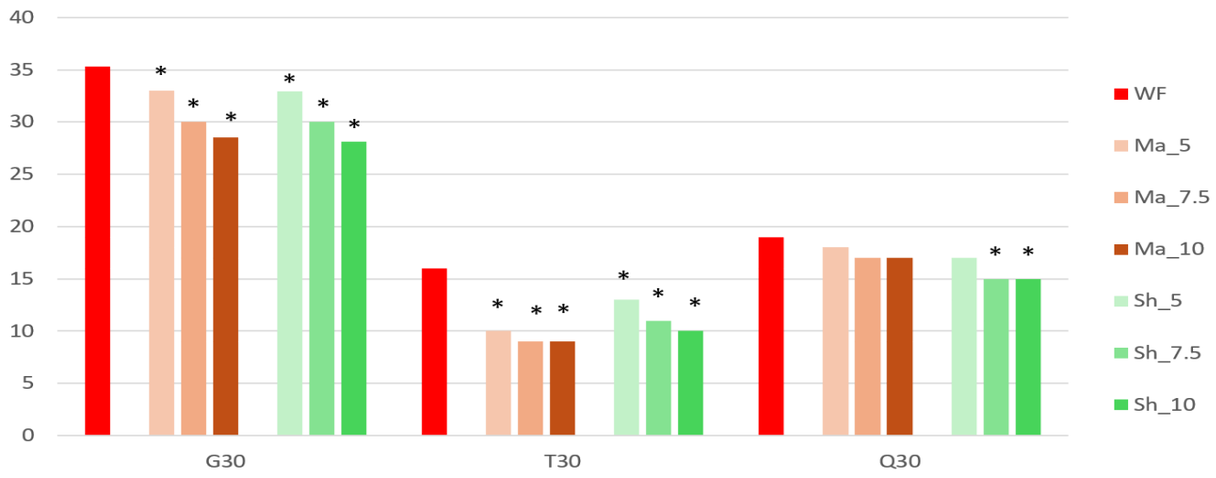

Figure 1. Gluten content and its properties in composite flours.

Note: Legend: G_{30} wet gluten content after 30 minutes of resting (%); T_{30} the swelling of gluten (cm); Q_{30} the extensibility of gluten (mL). * Means significantly different samples compared to control ($P \leq 0.05$).

Starch content did not change significantly, but crude protein content was lower. The addition of shiitake extract reduced the ash content. Interestingly, the addition of maitake significantly increased the acidity of the composite flour, up to 23% with just a 5% addition compared to control flour. This finding does not have to be negative, as the higher acidity of the flour can positively influence the sensory evaluation of the final products. In bread and pastries, it is the cause of a fuller and better perceived taste [33-36]. Figure 2 shows comparisons expressed as a percentage, representing 100% of the value of a given property in control wheat flour (WF).

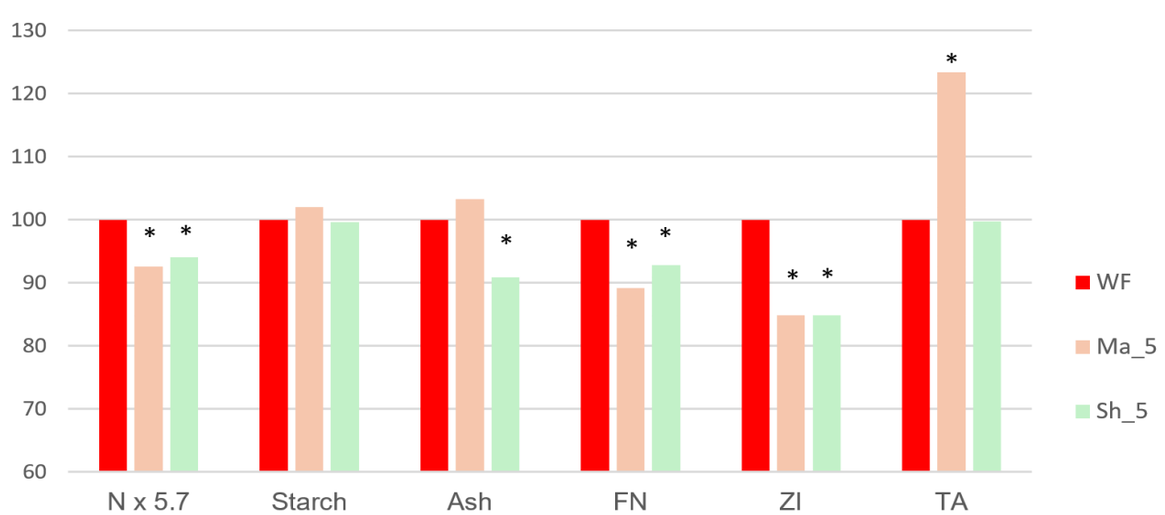

Figure 2. Technological quality of composite flours with the addition of 5 % of extracts.

Note: Legend: N x 5,7 - crude protein content compared with control (100 %); Starch - starch content compared with control (100 %); Ash - ash content compared with control (100 %); FN – falling number compared with control (100 %); ZI – sedimentation test compared with control (100 %); TA - titration acidity compared with control (100 %).
*means significantly different samples compared to control ($P \leq 0.05$).

The indirect indicators of bakery quality evaluated indicated a potentially negative impact of the additions of medicinal mushroom extracts, although most of the evaluated indicators did not show changes at a level that would predict that it is unsuitable to use the composite flours under consideration. On the contrary, in the case of an addition of 5%, we can expect good results from baking experiments.

More interesting, more informative, and more convincing in terms of quality, usable results in practice were found within the baking experiment, which is considered a direct method of determining bakery quality. When preparing the dough, it is important to add a suitable amount of water, which will ensure the formation of dough with optimal consistency and affect the total weight of the dough being processed. The final weight of the bread is subsequently affected by baking losses. In the case of the evaluated experimental bread, their weight decreased in proportion to the amount of additions. Figure 3 shows comparisons of important bread quality parameters, expressed as a percentage, representing 100% of the value of a given property in control wheat flour (WF).

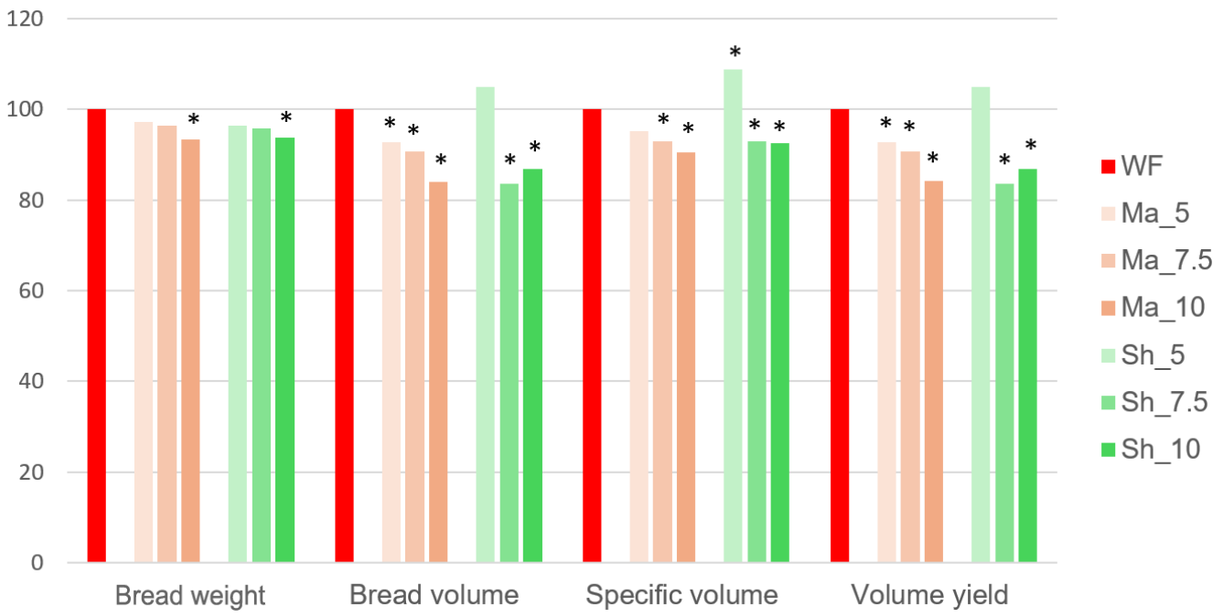

Figure 3. Qualitative parameters of experimental breads.

Note: *Means significantly different samples compared to control ($P \leq 0.05$).

The bread volume can clearly be considered the most important quality parameter. It was very interesting to find that the addition of shiitake extract in the amount of 5% had a positive effect on the bread volume, and in the experimental bread, the bread volume was higher than in the control breads. Higher additions of shiitake extract already reduced the bread volume in comparison with the control. In the case of all additions (5%, 7.5%, and 10%) of maitake extract, the properties of the experimental breads were worse than in the control breads (Figure 3). This is also documented by the scans obtained by Volscan (Figure 4a) and the photo documentation of the experimental bread compared to the control (Figure 4b), on which the differences in the volume, shape, and porosity of the breads are very clearly visible.

The volume and other characteristics of experimental loaves are key in evaluating their quality, but trade-offs must be sought in the case of value-added foods where the expected nutritional benefits of non-bakery additives are pursued. We believe that bread's slightly reduced level of technological quality is significantly outweighed by its nutritional benefits. Sensory evaluation is also considered an important part of a comprehensive assessment of innovative products, as it ultimately determines whether a product will be suitable for consumption.

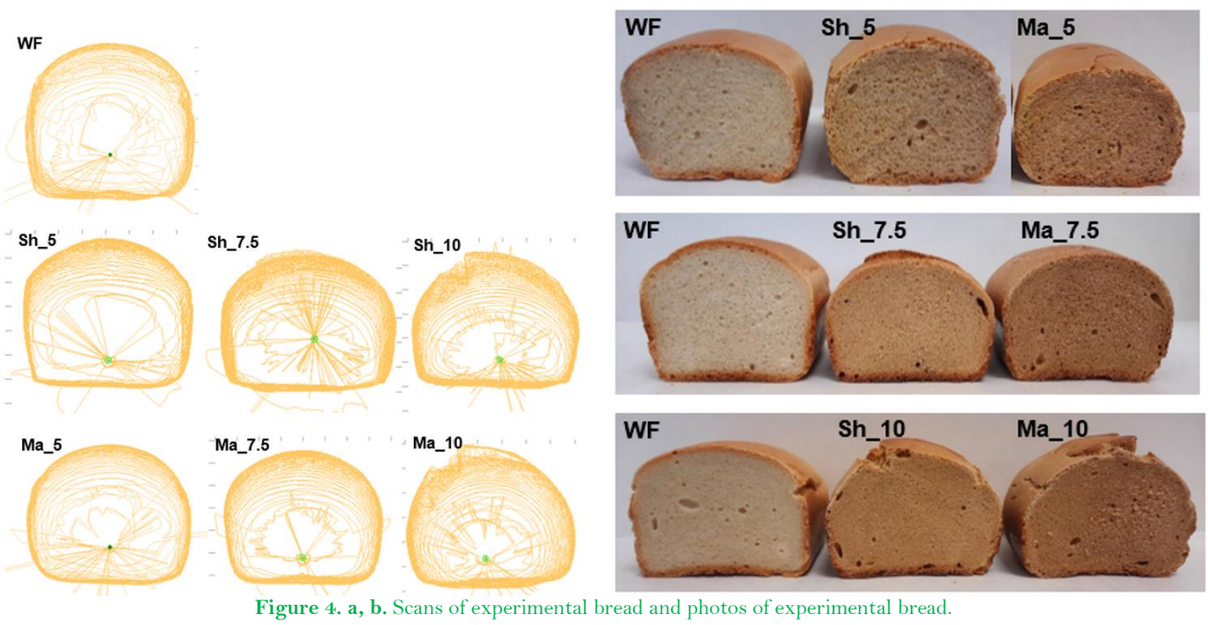

Figure 4. a, b. Scans of experimental bread and photos of experimental bread.

In general, value-added foods are rated worse than standard ones, especially in relation to the additives used and their amounts [26, 36-39]. When applying dried shiitake powder at levels of 5% and 10%, the results found by Van Toan and Thu [36] were comparable to or slightly better than the evaluators' overall preference compared to control pastries. Pastries with the addition of 15% were no longer acceptable to evaluators. Other authors [33] found significantly lower bread preferences, in which wheat flour was replaced by shiitake powder as early as 5%. In most cases, non-bakery ingredients worsen the technological parameters of bread, which is also associated with impaired perception by consumers [40-42].

In the case of composite flours and experimental bread evaluated by us, it can be stated that the additions of maitake and shiitake extracts influenced the technological properties of both composite flours and breads; however, the found values can be considered acceptable and balanced with the expected nutritional benefits. The method of adapting and targeted design of staple foods to the intended nutritional benefits leads to healthier foods and potential improvements in consumer health.

4. Conclusion

Due to the addition of extracts of medicinal mushrooms Shiitake and Maitake, the basic technological properties of composite flours have changed. In proportion to the amount of the addition, wet gluten content decreased, and its swelling and extensibility decreased. The value of the Falling Number also decreased, so composite flours have higher enzymatic activity, but all values complied with legislative requirements. The value of the Zeleny index, crude protein content, and, in the case of composite flour with added Shiitake, ash content also fell. Its acidity did not change, unlike composite flour with the addition of Maitake, in which the acidity increased significantly compared to both control flour and composite flours with the addition of Shiitake.

In relation to the results of the bakery experiment, it was found that the weight of the loaves decreased in proportion to the amount of addition of medicinal mushroom extracts. The volume and specific volume of the loaves decreased with the addition of maitake extract in proportion to its height. The addition of shiitake extracts in the amount of 5% resulted in an increase in the volume and specific volume of the experimental loaf (by 4.7% and 8.5% respectively), so that with such an addition, apart from the nutritional benefits, there was also an improvement in the technological quality of the bread. Higher additions of extracts reduced the evaluated parameters. Nevertheless, all additions were technologically acceptable. Verified composite flours and breads with nutritional benefits have potential for manufacturers and are desirable for consumers.

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