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Influence of defatted maize germ flour addition in wheat: maize bread formulations

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Abstract

Wheat bread is considered to be nutritionally poor and the supplementation of wheat flour with other flours is a powerful tool to improve the nutritional quality. Maize flour contains high levels of many important vitamins and minerals. On the other hand, defatted maize germ, a by-product of the corn oil industry, is rich in protein, dietary fiber and minerals. Addition of maize flour to wheat flour at levels of 30%, 40%, 50% and defatted maize germ flour to wheat: maize blends at levels of 5%,10%,15% was carried out to examine the effects on the baking and sensory characteristics of bread. The results of this study suggest that the incorporation of the maize flour at level up to 40% and defatted maize germ flour at level up to 15% produces bread without any negative effects in quality attributes and reasonable acceptance offering promising a nutritious and healthy alternative to consumers.

Keywords: maize flour, defatted maize germ flour, bread quality

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1. Introduction

Wheat bread is considered to be nutritionally poor and the supplementation of wheat flour with high-protein-content flours is a powerful tool to improve the nutritional quality of bakery products [1]. Protein-enriched food from plant sources are rich in lysine, a limiting amino acid in wheat flour. The use of composite flour in flour-based food preparations is a practice that has been used for decades but with variability in objectives. Wheat flour was composited with that of maize in order to investigate the expansion mechanism during extrusion cooking [2]. Flours from amaranth grain [3], plantain [4], rice/corn/soybean [1] and cassava [5] were respectively composited with that of wheat in the production of bread so as to determine the technical feasibility as well as to find a means to reduce the importation of wheat grains from the developed countries with associated benefit of minimizing wastage of scarce foreign exchange by the developed countries [6].

Maize ranks as the second most widely produced cereal crop worldwide. Because of the high productivity, corn is by far the most economical cereal to produce. By substituting part of the wheat flour with maize flour the lowering of the costs can be achieved [7]. On the other hand, maize flour contains high levels of many important vitamins and minerals, including potassium, phosphorus, zinc, calcium, iron, thiamine, niacin, vitamin B6, and folate [8] and maize flour could be composited with wheat flour.

Defatted maize germ (DMG) cake, a by-product of the corn oil industry, is rich in protein, dietary fiber and minerals [9]. The germ portion constitutes 5–14 g/100 g the weight of a maize kernel, depending on the hybrid or variety. In the maize milling process, the germ is separated from the kernel for oil production. In spite of the high nutritional quality of DMG, today it is being used mostly as animal feed. Only few research studies [10,11] reported DMG utilization for human consumption.

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The protein content in DMG flour is of superior nutritional quality, consisting mostly of albumin and globulin [12], with protein efficiency ratio value comparable to that of soy protein [13]. Lysine, a major limiting amino acid in wheat [14], represents about of 5–6% of the total proteins in DMG, which is more than twice than that in wheat flour. Blessin et al. (1973) [15], reported that defatted germ flour has possibilities of serving as protein and mineral supplement in a variety of foods as it is rich in minerals and protein with lysine content more than twice than that of normal wheat flour. He also reported that defatted corn germ contained 25% protein, 0.5% fat, 4% fiber, 10% ash. The utilization of DMG for human consumption is an additional nutritional source and is profitable [11].

In the north-western side of Romania, maize bread is a traditional food product obtained from a variety of ingredients that give special sensorial characteristics considered unique by consumers. The traditional maize bread is made with 30-50% maize flour mixed with wheat flour. The maize flour for breadmaking was traditionally obtained in stone wheel mills, moved by water, and nowadays frequently by electricity. The traditional recipes involve the addition of sieved maize flour, hot water, wheat flour, yeast and/or sourdough (leavened dough from late bread). After mixing and proofing the dough is baked in a wood-fire oven. Nowadays, even if the bread is prepared using traditional recipes, the utilisation of the commercial maize flour led to breads with the lowest nutritional value.

By this study we aimed to assess the influence of defatted germ maize flour addition on the quality of wheat: maize bread in order to obtain products with specific sensorial properties but with an improved nutritional value. For this purpose, firstly, the maize flour addition at levels of 30%, 40% and 50% was studied, than the maize flour level was kept constant at 40% and the defatted maize germ flour was added at different levels 5%, 10%, 15% .

2. Materials and Methods

2.1.Raw materials, formulations and processing. Commercial wheat flour and maize flour were purchased from a local mill. According to the producer, white wheat flour was type 550 (Romanian classification) and maize flour was obtained with 75% extraction rate and particle sizes about of 300-400 µm. Defatted maize germ was obtained from a local corn oil producer and was milled and sieved using laboratory equipment in order to achieve particles size about of 300µm. Common cooking salt, compressed yeast (Pakmaya) and sunflower oil were purchased from the local market.

The formulation for control bread was 300 g wheat flour, 9 g compressed yeast, 4.5 g salt, 50 ml sunflower oil and the optimum quantity of tap water in order to obtain a dough consistency up to 500 UB. The straight method for dough preparation was used. The process parameters were: mixing time 12 min, fermentation time 35 min, remixing time 25s. The dough was separated in samples of 100g which were round shaped by hand, placed in aluminum baking pans and proofed at 30°C/75% RH, 35min and finally baked at 240°C for 35min in a oven (Zanolli, Italy). Bread loaves were cooled at room temperature (23±1°C) and submitted to physico-chemical and sensorial analyses.

For experimental bread formulations, in the first part of the experiment, three trials of composite flours were performed in following ratios between wheat flour (WF): maize flour (MF) 60:40; 50:50; 40:60 (w/w on wet basis). In the second stage of the experiment, the MF was kept at a constant level of 40% and following ratios between WF:MF:DMGF (defatted maize germ flour) were used for composite flours: 55:40:5, 50:40:10 and 45:40:15 (w/w on wet basis).

2.2. Physico-chemical analyses. The functional parameters of the composite flours: humidity, ash, protein content, fat content, crude fiber content, wet gluten, acidity, water absorption capacity and deformation index were determined by methods described by [16].

The quality parameters of the bread samples: humidity, protein content, weight, porosity, elasticity, ratio between height and diameter were determined by methods described *by* [17] .

2.3 Sensory analysis. Sensory evaluation for crust color, crumb appearance, aroma, taste, overall acceptability was carried out as per score sheet by ten trained panelists on 9 point hedonic scale.

2.4 Statistical analysis. The results of three independent (n=3) assays performed with replicates each were expressed as mean ± SD. Data were compared by one-way analysis of variance (ANOVA) followed by Newman-Keuls test and

Dunnett's Multiple Comparison. The statistical evaluation was carried out using Graph Prism Version 5.0 (Graph Pad Software Inc., San Diego, CA, USA). Linear regression analysis between MF or DMGF level and some functional properties (deformation index, height/ diameter ratio) results were carried out using Microsoft Excel 2002.

3. Results and discussions

The chemical parameters for wheat, maize and defatted maize germ flours are presented in Table 1 and Table 2. By analyzing the chemical composition of the wheat flour (WF), maize flour (MF) and defatted maize flour (DMGF) it can be observed that the protein content of the DMGF is the highest. With a medium value of about 24.8 % (w/w), the protein content in DMGF was three times highest than the protein content in MF and two times higher than the WF protein content.

With respect to the DMGF chemical composition, Blessin et al. (1973) [15], reported that defatted germ flour has possibilities of serving as protein and mineral supplement in a variety of foods as it is rich in minerals and protein with lysine. Our findings are similar to those reported by [12,15,18].

As seen in Table 2, the commercial MF samples used in this study had the lowest protein content. Other studies reported [19] significant differences between maize varieties for protein content and also the extraction rate may be responsible for this low protein content. Blending different levels of MF and DMGF significantly ($p < 0.05$) affected the protein content of the wheat flour (table 3). The protein content decreased as the level of maize flour increased in blends obtained only from WF and MF. By increasing the DMGF content in the blends with a constant content of MF (40%), an increment of the protein content was recorded. The DMGF addition in the blend is a way to increase the protein content of the wheat: maize blends for baking, especially as the MF blending at levels up to 40% caused considerable reduction of the protein content.

Wheat flour blends showed a significant variation ($p<0.05$) in crude fiber content when DMGF was blended with WF and MF. The crude fiber content in blends containing WF:MF:DMGF varied from 1.21% to 2.93% (table 3). Both, MF and DMGF contributed to this increasing trend but the maximum value was recorded when DMGF was used in the blends. This high content in crude fiber is due to the DMGF addition and an increment was observed as increased level of DMGF was added. Our results are in correlation with [11,12] reporting that DMGF is a rich source crude fiber (Table 2).

The effect of blending MF and DMGF at varying levels with wheat flour on functional properties are given in Table 3. The water absorption decreased as the MF addition increased. This reduction in water absorption could be attributed to the ability of wheat starch to absorb water 2.47 times more than 2.40 in the case of corn starch, as was reported by [20]. Increase in water absorbed by flour blend during mixing was noticed at higher blending level of DMGF. Blends containing DMGF had higher water absorption than blends from WF and MF. High fiber and protein content in DMGF may be the contributing factor for high water absorption. Other studies [12,20] reported that wheat flour blended with different type of flour rich in protein and crude fiber revealed increased water absorption and consequently the dough stability increased.

Due to the presence of numerous components such as starch, proteins, lipids as flours constituents and added fat the water absorption capacity and distribution in dough require a complex study.

The effect of blending on the dough deformation index is presented in figure 1. As we expected the deformation index showed low baking power in blends obtained from WF and MF comparing with the control sample. The deformation index values were in correlation ($r2$ =0.92) with the increasing MF level in the blend. This behavior could be explained by the absence of gluten complex in corn protein that causing a reduction of gluten content in the blends so the viscoelastic properties were negatively affected by the MF blending level, as previous was reported by [21]. Also, among other causes of this behavior, Sabanis et al., 2009, [1], mentioned the presence of sulphyhydryl groups in corn, which causes the dough softening, the effective decrease in wheat gluten content and the competition between proteins of non-wheat and wheat flour for water hydration.

However, the blends containing DMGF showed a highest deformation index (fig.1) especially when the DMGF level increased to 15% in blends containing 40% MF, possibly due to the higher water absorption capacity of this flour.

Table 1. Wheat flour chemical parameters

	Humidity,%	Ash,%	Protein,%	Wet gluten,%	Crude fiber,%
Wheat flour (WF)	12.89±0.75	0.55±0.16	10.28±0.24	26.3±0.89	0.56±0.24

**Data represent means values± SD for three independent replications*

Table 2. Maize flour (MF) and defatted maize germ flour (DMGF) chemical parameters

	Humidity, %	Ash,%	Protein,%	Fat,%	Crude fiber,%
Maize flour(MF)	12±0.5	1.2±0.1	7.5±0.25	1±0.03	2.2±0.5
Defatted germ maize flour (DMGF)	6.03±0.1	8.42±1.3	24.8±1.98	0.9±0.15	12.75±1.45

**Data represent means values± SD for three independent replications*

Table 3. Effect of blending on functional parameters of composite flours obtained from wheat flour, maize flour and defatted maize germ flour (WF: MF and WF:MF:DMGF)

Composite flours	Humidity, %	Acidity, °	Water absorption capacity,%	Protein, %	Crude fiber,%
60:40	12.6±0.6	2.4±0.1	50.7±0.8	9.34±0.3	1.21±0.02
50:50	12.24±0.24	2.32±0.2	50.1±0.25	9.05±0.2	1.38±0.05
40:60	12.15±0.14	2.25±0.1	49.2±0.3	8.89±0.1	1.54±0.01
55:40:5	12.09±0.2	2.1±0.15	52.6±0.2	10.11±0.4	1.77±0.07
50:40:10	12.02±0.1	2.04±0.09	56.6±0.12	10.88±0.2	2.35±0.05
45:40:15	11.89±0.2	2.01±0.05	58.2±0.3	11.65±0.5	2.93±0.02

**Data represent means values± SD for three independent replications*

Table 4. Effect of MF and DMGF addition on the quality parameters of breads

Sample	Quality parameters					
	H/D	Porosity,%	Elasticity,%	Humidity,%	Protein,%	Weight, g
Control (100% WF)	0.72±0.01	70±1.2	88±1.5	40.5±0.95	9.88±1.13	700±2.5
60:40	0.65±0.01	61±1.5	63.02±1.2	37.17±1.12	8.99±1.35	728±2.9
50:50	0.58±0.01	59.5±1.25	61.15±1.8	36.06±1.23	8.65±0.88	731±1.5
40:60	0.49±0.015	57±0.9	59.34±1.35	34.57±1.9	8.47±0.56	734±2.7
55:40:5	0.57±0.02	60.4±1.12	61.88±1.23	39.62±1.45	9.81±0.23	732±2.5
50:40:10	0.51±0.01	58±0.89	60.31±1.8	41.98±0.75	10.48±0.12	736±3.1
45:40:15	0.48±0.01	56±1.05	58.98±0.98	43.18±0.56	11.23±0.45	740±2.5

**Data represent means values± SD for three independent replications*

The bread quality parameters are given in table 4. Bread volume is regarded as the most important bread parameters since it provides a quantitative measurement of baking performance. Moreover, this parameter is also extremely important to consumers because they desire breads that appear to be light and not so dense [22].

By calculating the ratio between the height and the diameter (H/D) of the breads, a significant decrease ($p<0.05$) was recorded as the MF and DMGF levels increased.

It was an expected effect as the amount of gluten, which imparts higher volume in bread, was decreased as a result of partial replacement of the wheat flour with non- glutinous flour. Linear regression analysis showed that the level of DMGF addition was positively and significantly correlated with H/D ratios ($r2$ = 0.9899); also a good correlation was recorded between the deformation index and the H/D ratio in the case of samples obtained using WF:MF: DMGF ($r2$ = 0.9582).

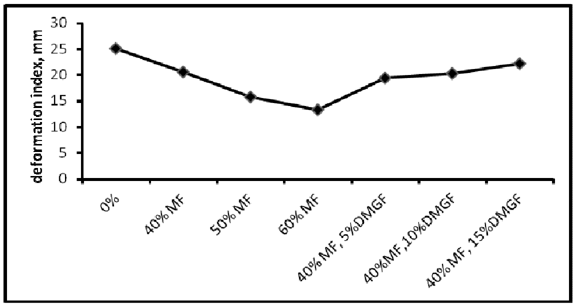

Figure 1. Effect of maize flour (MF) and defatted maize germ flour (DMGF) blending on the deformation index expressed in mm

Figure 2. Breads obtained using wheat flour (WF), maize flour (MF) and defatted maize germ flour (DMGF) at different levels of blending

A similar pattern was recorded for the porosity and elasticity of the breads obtained from composite flours containing WF, MG and DMGF. A lower ability of the gluten network to enclose the carbon dioxide produced during fermentation is the explanation for this pattern. Similar findings regarding the loaf volume depression effect of composite flours were reported by several researchers [23-26].

Bread weight was found to be increased by the addition of MF and DMGF. Maximum bread weight was obtained in the case of the highest level of DMGF, respectively 15%. The increment was about of 5.72% compared with the control sample and about of 1.65% compared with the bread obtained using the blend WF:MF 60:40.

The MF addition negatively affected the protein content, as seen in table 4. By increasing the MF added level in bread a decrement of the protein content was recorded. However, the addition of DMGF at levels of 5,10,15% in bread with 40% MF significantly ($p<0.05$) affected the protein content. A higher protein content was recorded as the level of DMGF increased in this breads and a good linear correlation (r^2=0.88) was found between DMGF level and the protein content.

Results of all sensory attributes evaluated are shown in figure 3. Generally, no significant differences (ns) were observed for the sensory attributes of crust color, crumb appearance, texture, flavor and overall acceptability in breads with up to 40% MF and 15 % DMGF. The DMGF addition at levels of 5, 10, 15% in bread formulation don't affect negatively the consumers acceptability.

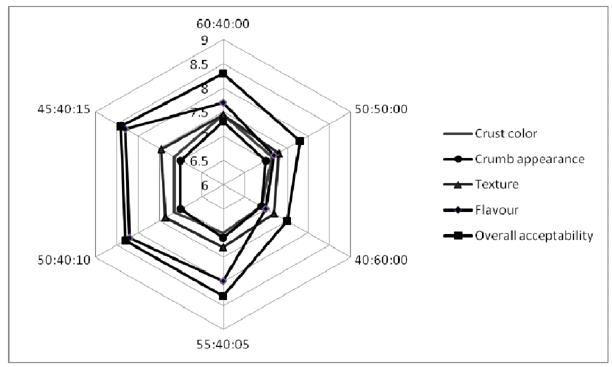

Figure 3. Sensory mean scores of the control bread and breads obtained by blending wheat flour (WF) with maize flour (MF) and defatted maize germ flour (DMGF)

4. Conclusion

In this study, by two steps experiments, the influence of the defatted maize germ flour (DMGF) addition on maize: wheat bread quality was assessed. For this purpose, firstly, the maize flour addition at levels of 30%, 40% and 50% was studied, than the maize flour level was kept constant at 40% and the defatted maize germ flour was added at different levels 5%, 10%, 15%. The chemical and functional properties of all flours and blends used in the study are determined as well as the quality parameters of breads. The commercial maize flour used in this study had the lowest protein content and consequently the bread samples obtained using wheat: maize blends recorded lowest protein content. The addition of DMGF in wheat: maize bread formulations significantly increased the bread protein content. By the other hand enhanced crude fiber content was recorded by blending all flours. Both MF and DMGF contributed to this increasing trend but the maximum value was recorded when DMGF was used. The bread quality and sensorial attributes were not negatively affected by blending MF and DMGF.

The results of this study suggest that the incorporation of the maize flour at level up to 40% and defatted maize germ flour at level up to 15% produces bread without any negative effect in quality attributes and reasonable acceptance offering promising nutritious and a healthy alternative to consumers.

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

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