

New potential of using millet-based yeast-fermented leaven for composite wheat bread preparation

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Summary

The many health benefits to be derived from millet and fermented food are well-documented. As a consequence of this, a novel method for the preparation of composite wheat-millet bread was designed on the basis of the use of millet-based yeast-fermented leaven. Bread was produced with 30% share of millet flour and evaluated in terms of the following physical parameters: bread mass and volume, textural properties of crumb, degree of crumb staling, and index of crumb texture homogeneity. The obtained results confirmed that it is possible to produce mixed bread from the millet-based yeast-fermented leaven. The results were dependent on flour properties, and from wheat flour of high gluten content and high falling number, bread of sufficient quality was obtained. Further studies could be proposed on rheological measurements of dough and estimation of biological activity of bread prepared from millet-based yeast-fermented leaven. Methods using yeast-fermented leaven prepared from millet flour with different origin and other types of flour should be tested for other composite wheat breads.

Keywords

millet; *Panicum miliaceum* L.; bread; leaven; dough

Recently, consumers started to request functional food products. The many health benefits to be derived from both fermented food and millets are well documented [1–6]. Millets are a group of highly variable grasses with many small seeds. Millet (*Panicum miliaceum*), and also pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*) and foxtail millet (*Setaria italica*) are the most important millets [7].

AWADALLA and SLUMP [8] reported that, in whole grain, millet (*Panicum milaceum*) had higher energy than wheat (21938.8 kJ·kg⁻¹; 1394.2 kJ·kg⁻¹), although millet had lower protein content than wheat (9.1%; 11.2%), the protein contained more essential amino acids per kilogram of total nitrogen, and about the same chemical score as wheat. Data presented in the report by KENT and EVERS [9] indicated that, compared to wheat in terms of amino acid content, millet contained by 82% more of leucine, by 29% more methionine, by 22% more valine, and by 48% more tyrosine. Millet, similarly to wheat [7], is an important source of B vitamins (thiamin, niacin) [10] and it contains three-fold more vitamin B₂ (riboflavin). Millets contain phenolic acids, which are

located in the pericarp, testa, aleurone layer and endosperm [11].

Millet bran is a component of the diet in the area of highest oesophageal cancer incidence in northern China, which is why O'NEILL et al. [1] suggested that silica particles from millet bran might be involved in the aetiology of oesophageal cancer. CHANDRASEKARA and SHAHIDI [2] demonstrated that phenolic extracts from millet may be effective in the prevention of cancer initiation and progression in vitro, and other studies [3] emphasized that millet, containing linoleic acid, might have anti-tumor activity. Millet health benefits include reducing cholesterol level and also controlling dysfunctional liver [4]. PARK et al. [5] suggested that millet extract is useful in the chemoprevention or treatment of chronic diseases such as obesity and obesity-related disorders. LEE et al. [6] demonstrated that millet may prevent cardiovascular disease by reducing plasma triglycerides in hyperlipidemia. The contents of serum total, high-density lipoprotein (HDL), and low-density lipoprotein (LDL)-cholesterol were significantly higher in the millet groups than in the sorghum group. CHANDRASEKARA and SHA-

HIDI [2] demonstrated that millet phenolics may serve as potential sources of natural antioxidants for inhibition of lipid peroxidation in LDL cholesterol and food systems. The content as well as the chemical nature of the phenolic constituents in the extract of millet grains may be responsible for the observed antioxidant effects. Millet grains may serve as a nutraceutical and functional food ingredient in health promotion and disease risk reduction [12]. Millet is a gluten-free cereal and is considered a suitable raw material for the production of foods and beverages for people suffering from celiac disease [13–18]. Wheat or mixed bread is distinguished by better organoleptic evaluation in comparison to gluten-free bread, therefore it is one of the most consumed products in the world. Daily consumption of this bread may have positive long-term effects on health. In the traditional diet, the consumption of millet can be increased by replacing wheat by millet to a required extent [19]. A mixture of millet flour and wheat flour was used for baking sponge cake [20], biscuits [21, 22], as well as bread [14, 19, 23, 24].

The results of sensory analysis showed that the acceptability of bread samples prepared from composite flours (millet and wheat) was almost equal to wheat bread [8, 19], however, specific volumes were lower than those for wheat bread [17, 24]. Studies conducted so far described the changes in the properties of bread, including bread volume, under the effect of a small addition of millet flour. GAVURNIKOVA et al. [23] and RÓŻYŁO and LASKOWSKI [24] made bread from millet flours added to wheat flour at a weight ratio of 5–30% or of 10–20%.

Some studies were focused on enhancing the effectiveness of the process of production of wheat bread enriched with millet flour. For multigrain bread, only ANGIOLONI and COLLAR [25] proposed a high hydrostatic pressure treatment of hydrated millet flours. SINGH et al. [19] used gluten addition as a natural improver, while ANGIOLONI and COLLAR [26], apart from gluten, proposed an addition of fat and Grindsted FiberLine (Danisco, Copenhagen, Denmark) with an enzymatic complex. AWADALA and SLUMP [8] proposed the use of artificial improvers, including $KBrO_3$ and calcium stearoyl lactylate. After the addition of the improvers, that author noted that replacing 20% part of wheat flour by millet impaired baking quality.

In previous studies, wheat bread with an addition of millet flour was produced primarily by the straight dough methods [19, 23, 24]. In some studies, the sponge dough process [26] and the sourdough process started with lactobacilli [14] were used. There is a lack of studies comparing

the quality of composite wheat-millet bread produced with various standard or modified methods.

Yeast-fermented leaven is a part of typical two-phase methods used mostly for wheat bread. This method consists of the prior preparation of leaven, its fermentation, and then formation of dough. Examples of the two-phase method include the firm yeast-fermented leaven (sponge dough) method [27], the liquid yeast-fermented leaven (poolish dough) method [28], or the lactic acid bacteria-fermented sourdough [29]. Previous studies showed that wheat bread produced by the two-phase method is characterized by better flavour and other sensory values [29], and by better quality parameters [29, 30] as compared to the straight-dough method.

Wheat bread with an increased content of millet wholegrain flour is a high-demand product for people requiring different diets. Moreover, the cultivation of millet is not as demanding as the cultivation of wheat. Therefore, in this study it was decided to enrich bread formulation with the most possible and accepted additive that is millet wholegrain flour. Previous studies as well as initial comparative tests of bread with 10%, 20%, 30%, 40% and 50% addition of flour demonstrated that the sufficiently accepted level of millet wholegrain flour was 30%. In this study, modification of the production process of this kind of bread was proposed based on preliminary fermentation of leaven utilizing millet flour. This modification, by a longer fermentation of millet flour, could increase health benefits from the mixed bread. Despite the use of millet-based yeast-fermented leaven, the results of batch were compared with straight-dough and two-phase methods, respectively.

MATERIALS AND METHODS

Experimental material

The raw material for making wheat bread included two types of bread wheat flour and one type of millet whole grain flour.

The wheat bread flour was obtained from two local milling industries in Poland. They are denoted with letters A and B, and are characterized by protein content (ISO 20483:2006) [31] and gluten content (ISO 21415-1:2006) [32]; the falling number (ISO 3093:2009, instrument for falling time determination type SWD, Sadkiewicz Instruments, Bydgoszcz, Poland) [33], the ash content (ISO 2171:2007, muffle furnace, Czyłok FCF, Jastrzębie Zdrój, Poland) [34] and the water absorption (ISO 5530-1:1997, Consistograph BZ,

Sadkiewicz Instruments) [35].

The millet whole grain flour was a commercial flour obtained from Bio Raj (Pokrzydowo, Poland) and was characterized by protein, ash and fat content.

The flour analyses were carried out in three replicates. Vital wheat gluten was obtained from the company Cargill (Warsaw, Poland), and the yeasts used were dried instant yeasts (Instaferm) obtained from Lallemand (Setúbal, Portugal). Salt and sugar were purchased from a local market in Poland.

Methods of bread making

Bread was baked in a laboratory oven equipped with a fermentation chamber (Sadkiewicz Instruments) following both the standard methods [36] as well as original modifications of the methods (Tab. 1). Dough was made from 100% wheat flour (control samples – C1, C2) and with the use of a 30% addition of millet flour.

The control samples were made by the straight dough method according to the Berlin Institute (C1) and the two-phase method (C2) [36].

Bread with a content of millet flour was made from dough prepared by the straight dough method with varied dough mixing times 5 min and 8 min (SM5; SM8), and with the addition of gluten at a level of 3% (SM5G; SM8G).

In the two-phase method, the wheat leaven (WLD, WLDG) or the mixed leaven (MLD, MLDG) was used. The leaven was prepared from the half of total flour weight. The mixed leaven was made from the whole amount of millet flour with the addition of wheat flour (millet flour : wheat flour, 3:2).

The dough proofing time (optimal dough development) was determined in preliminary tests analysing the loaf volume obtained after various times of dough development. In addition, the rule was applied that, if after a light depression (with a finger) of the dough, surface of the dough returned to its original position, it meant insufficient development of the dough, while if a slight indentation remained on its surface, it meant the optimal dough development [36].

The loaves were baked at 230 °C for 25 min in a laboratory oven (Sadkiewicz Instruments) with live steam being injected immediately after the loaves were placed in the oven. Baking tests were performed on six loaves (in triplicate on two loaves).

Evaluation of physical properties of bread

The weight and volume of the baked bread were determined after one day. Bread loaf volume

was measured using the millet seed displacement method [36] and the bread loaf volume and specific mass from 100 g of flour was calculated as describing previously [37].

Textural properties of the bread crumb were tested one and three days after baking. The measurements were made with the aid of a Zwick Z020/TN2S strength tester (Zwick Roell Group, Ulm, Germany). The loaves were sliced mechanically. The slices were cut from the middle part of the loaf and the tests were done on samples (30 mm × 30 mm × 20 mm).

In this study, the samples were compressed using a capital equipped with a 30 mm plug until a 50% depth at a crosshead speed of 1 mm·s⁻¹. The samples were compressed twice (curves 1 and 2) to give a two-bite texture profile analysis [38], from which textural parameters were obtained: hardness, elasticity, cohesiveness, chewiness (hardness × elasticity × cohesiveness). The texture tests were done in nine replicates.

To assess the changes of textural properties caused by storage, the percentage changes in hardness, elasticity, cohesiveness and chewiness were calculated as follows (Eq. 1):

$$x = \frac{x_{3d} - x_{1d}}{x_{1d}} \times 100 \quad (1)$$

where x_{3d} is textural property estimated after 3 days of storage, x_{1d} is textural property estimated after 1 day of storage.

The assessment of bread crumb texture heterogeneity [30] was done on the basis of variations in the values measured in the entire profile of a bread crumb slice. The evaluation of the heterogeneity of bread crumb texture complements the assessment of texture and shows which breads have, on slice cross-section, homogeneous or heterogeneous crumb. For example, heterogeneous crumb is characterized by a hard bottom of slice and much lower hardness of the top. This evaluation is important from the customer viewpoint. Bread crumb with a heterogeneity index value below 30% was classified as homogeneous, with values between 30% and 60% as medium homogeneous, and above 60% as heterogeneous.

Statistical analysis

Statistical analysis was done at a significance level of $\alpha = 0.05$ using software Statistica 7, PL (Statsoft, Cracow, Poland). Measurement scores were subjected to analysis of variance (ANOVA). When significant differences in ANOVA were detected, the means were compared using the Tukey range test.

RESULTS

The wheat bread flours A and B were characterized by protein contents of 10.9% (A) and 11.3% (B), and gluten contents of 26.5% (A) and 27.4% (B), the falling numbers of 230 s (A) and 405 s (B), the ash contents of the wheat flour was 0.8% (A) and 0.8% (B), and the water absorption was 56% (A) and 57% (B). The millet whole grain flour was characterized by protein content of 9.5%, ash content of 1.9%, and fat content of 3.4%.

Tab. 2 presents the dough proofing time, and the results concerning the bread loaf volume and specific mass are presented in Fig. 1, while the textural properties of the crumb are shown in Fig. 2.

The results of the measurements of dough proofing time indicate (Tab. 2) that, for the composite wheat-millet dough with a 30% content of millet flour, the parameter was shorter than the

Tab. 2. Proofing time of mixed dough (wheat-millet) produced by various methods.

Kind of dough making method	Proofing time [s]	
	Flour A	Flour B
SM5	75.3 ^a	88.0 ^d
SM8	70.0 ^b	80.3 ^e
SM5G	72.7 ^b	90.3 ^{df}
SM8G	68.3 ^c	85.0 ^d
WLD	74.7 ^{ab}	82.6 ^e
WLDG	69.3 ^c	80.3 ^e
MLD	70.3 ^c	70.7 ^c
MLDG	68.7 ^c	71.3 ^{bc}
C1	85.0 ^d	95.3 ^g
C2	82.3 ^{de}	85.6 ^d

Means with different superscript letters within the same row are significantly different ($\alpha < 0.05$).

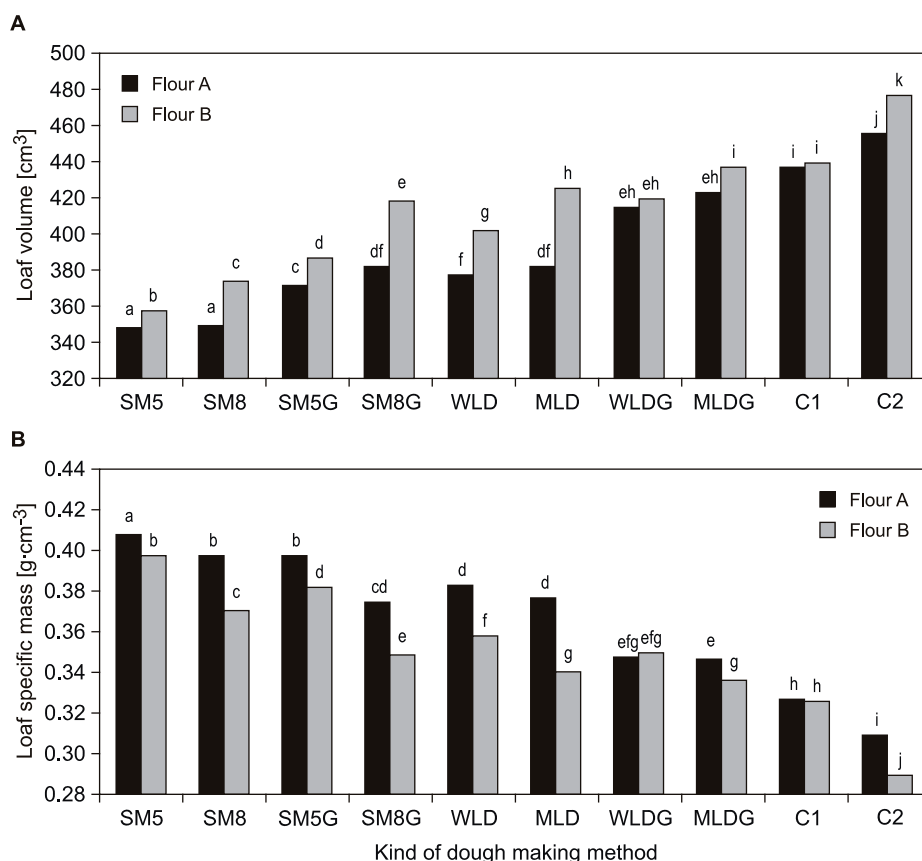


Fig. 1. Basic properties of wheat-millet bread made by different dough-making methods.

A – Bread loaf volume, B – Bread loaf specific mass.

Columns with different letters are significantly different ($\alpha < 0.05$).

SM5, SM8, SM5G, SM8G – wheat-millet bread made by standard straight dough method, WLD, WLDG – wheat-millet bread made by two-phase method using wheat leavened dough, MLD, MLDG – wheat-millet bread made by mixed (millet-wheat) leavened dough, C1 – wheat bread baked using standard straight dough method, C2 – wheat bread baked using leavened dough method.

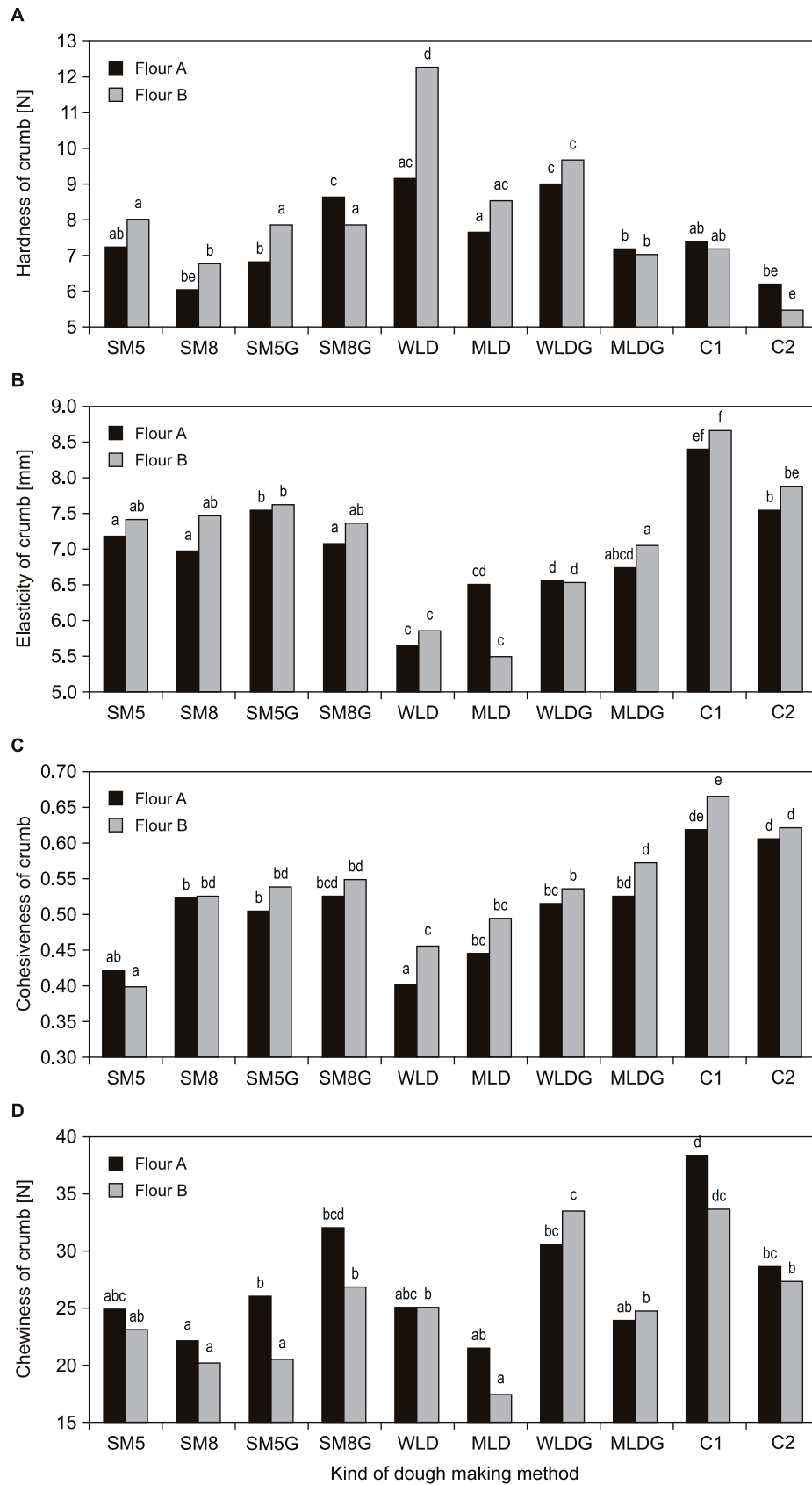


Fig. 2. Texture properties of composite wheat-millet bread crumb made by different dough-making methods.

A – Hardness of bread crumb, B – Elasticity of bread crumb, C – Cohesiveness of bread crumb, D – Chewiness of bread crumb. Columns with different letter are significantly different ($\alpha < 0.05$).

proofing time of wheat flour dough. In addition, it was noted that using the straight-dough method, the extension of mixing time resulted in shorter dough proofing times. Dough prepared from flour B, with higher falling number than that of flour A, was characterized by a longer proofing time. Dough production by the two-phase method resulted in shorter dough proofing times. Especially significantly shorter proofing times were characteristic for dough prepared from the millet-based leaven in the case of flour B. Dough from the millet-based leaven was also smoother and easier to form.

Significantly greater volume (Fig. 1A) and lower specific mass (Fig. 1B) was obtained for wheat bread from flours A and B with 30% content of millet flour, produced with a 3% addition of gluten, and those made from flour B by the two-phase method. In the case of flour A, characterized by low gluten content and low falling number, the use of the yeast-fermented leaven caused that the crumb was of insufficient consistency. Compared to the dough from the wheat leaven (WLDG), the

bread obtained from dough produced from the millet-based leaven (MLDG) was characterized by a comparable or even greater loaf volume and smaller specific mass. Loaf volume of bread produced by that method (MLDG) with the 30% addition of millet flour was comparable to the loaf volume of bread with 100% content of wheat flour, produced by the straight dough method (C1). In the case of bread with millet flour produced by the straight dough method, extension of mixing time caused an increase in bread loaf volume and a decrease in its specific mass, in particular in the case of flour B.

The textural properties characterizing the quality of bread crumb also varied (Fig. 2). Similar trends were observed in the case of flours A and B. The lowest hardness of bread crumb (Fig. 2A) and chewiness of bread crumb (Fig. 2D) were obtained for bread produced by the straight dough method (SM5, SM8) as well as for bread made from the millet-based leaven (MLD, MLDG). Comparable results of bread crumb hardness were obtained also in the case of wheat bread (C1, C2).

Tab. 3. Changes in crumb texture properties of composite wheat-millet bread made by different dough-making methods.

Kind of flour	Kind of dough-making method	Percentage changes in texture properties during 3 days of storage			
		Change of hardness [%]	Change of elasticity [%]	Change of cohesiveness [%]	Change of chewiness [%]
Flour A	SM5	260.4 ^a	−26.9 ^a	−47.7 ^a	117.2 ^a
	SM8	301.2 ^b	−23.6 ^b	−56.2 ^b	88.7 ^b
	SM5G	172.6 ^c	−23.4 ^{ab}	−54.0 ^{ab}	49.9 ^c
	SM8G	132.7 ^{cd}	−16.2 ^c	−46.7 ^a	41.6 ^{di}
	WLD	66.8 ^e	−21.2 ^d	−64.2 ^c	30.8 ^{de}
	WLDG	32.0 ^f	1.9 ^e	−55.1 ^b	13.2 ^f
	MLD	64.2 ^e	−26.3 ^{ab}	−63.9 ^c	22.7 ^e
	MLDG	29.1 ^f	−8.9 ^f	−58.7 ^b	11.0 ^f
	C1	114.4 ^d	−8.6 ^f	9.8 ^d	80.3 ^b
	C2	130.9 ^{icd}	3.6 ^g	−53.1 ^b	47.1 ^{cd}
Flour B	SM5	230.1 ^{ag}	−16.9 ^{cd}	−35.7 ^e	129.4 ^g
	SM8	289.5 ^g	−14.6 ^c	−36.4 ^{ae}	102.2 ^h
	SM5G	134.6 ^{cd}	−14.0 ^{ch}	−44.0 ^a	44.2 ^{cd}
	SM8G	129.7 ⁱ	−12.9 ^h	−57.3 ^b	37.5 ⁱ
	WLD	77.8 ^{eh}	−10.2 ^{fh}	−87.3 ^f	45.2 ^{cd}
	WLDG	48.8 ^{ef}	−5.7 ^{fg}	−79.1 ^g	11.3 ^f
	MLD	56.6 ^e	−19.3 ^{dc}	−48.9 ^{ae}	24.2 ^e
	MLDG	43.1 ^f	−10.9 ^{fh}	−39.8 ^e	9.8 ^f
	C1	129.4 ⁱ	−8.3 ^f	−5.4 ^h	75.3 ^b
	C2	132.8 ⁱ	−5.7 ^{fg}	−48.2 ^a	38.2 ⁱ

Means with different superscript letters within the same row are significantly different ($\alpha < 0.05$).

Tab. 4. Values of index of heterogeneity of composite wheat-millet bread crumb made by different dough-making methods.

Kind of flour	Kind of dough-making method	Index of heterogeneity [%]	Qualitative description of breadcrumb structure
Flour A	SM5	50.2 ^a	Medium homogeneous bread crumb
	SM8	59.4 ^b	Medium homogeneous bread crumb
	SM5G	51.2 ^a	Medium homogeneous bread crumb
	SM8G	17.5 ^c	Homogeneous bread crumb
	WLD	49.1 ^{ad}	Medium homogeneous bread crumb
	WLDG	42.6 ^d	Medium homogeneous bread crumb
	MLD	35.9 ^e	Medium homogeneous bread crumb
	MLDG	20.3 ^c	Homogeneous bread crumb
	C1	33.0 ^{ef}	Medium homogeneous bread crumb
	C2	29.3 ^{cf}	Homogeneous bread crumb
Flour B	SM5	39.1 ^{de}	Medium homogeneous bread crumb
	SM8	49.3 ^{ad}	Medium homogeneous bread crumb
	SM5G	42.2 ^d	Medium homogeneous bread crumb
	SM8G	31.0 ^f	Medium homogeneous bread crumb
	WLD	48.3 ^{ad}	Medium homogeneous bread crumb
	WLDG	45.9 ^{ad}	Medium homogeneous bread crumb
	MLD	29.4 ^f	Homogeneous bread crumb
	MLDG	23.5 ^{cf}	Homogeneous bread crumb
	C1	33.5 ^f	Medium homogeneous bread crumb
	C2	27.6 ^{cf}	Homogeneous bread crumb

Means with different superscript letters are significantly different ($\alpha < 0.05$).

Significantly higher values of crumb hardness were obtained using the wheat yeast-fermented leaven (WLD, WLDG). The best elasticity was observed for bread crumb produced by the straight dough method. No significant differences were noted between the elasticity of bread from the millet-based leaven with an addition of gluten (MLDG) and the elasticity of the bread produced by the straight dough method (SM5, SM8, SM5G, SM8G). Compared to the wheat bread (C1, C2), all breads with 30% content of millet flour had significantly lower elasticity. A similar relation was observed in the case of bread crumb cohesiveness (Fig. 2C). In addition, the bread with millet flour, produced by different methods, did not differ significantly regarding cohesiveness.

During the extension of bread storage time from 1 to 3 days (Tab. 3), there was an increase in bread crumb hardness and chewiness, and a decrease in its elasticity and cohesiveness. The greatest variability was identified for bread crumb hardness and, therefore, it can be adopted as an indicator of the degree of staling of the bread crumb. A lower degree of crumb staling was

characteristic for bread produced with a 3% addition of gluten, as well as those produced with the use of the two leavens under study. In the case of flour B, a significantly lower degree of staling was noted for the bread produced from the millet-based leaven (MLD, MLDG) compared to the other methods.

The index of heterogeneity of bread crumb texture (Tab. 4) determined on the basis of the index of variation in hardness differed for the methods studied. Better values of crumb texture homogeneity were obtained for bread produced with an addition of gluten, and for bread produced by the two-phase method as compared to the straight dough method, and also for bread from the millet-based leaven as compared to the wheat leaven. The crumb of bread from the millet-based leaven was characterized by a homogeneous texture.

DISCUSSION

The results of this study support the hypothesis that the application of various methods of dough

preparation leads to the production of bread with diversified physical parameters.

It was noted that the use of various methods caused a variation in the dough proofing time. The proofing time of the composite (wheat-millet) bread was shorter compared to that of the wheat bread. Composite bread produced by the two-phase method had shorter proofing times than bread produced by the straight dough method and, in addition, the application of the whole amount of millet whole grain flour in the leaven caused a shortening of the proofing time. The introduction of millet flour to the leaven could cause an increase in the amount of gases produced, due to the faster multiplication of yeast cells. BADI and HOSENEY [13] observed that bread produced with 10% addition of millet flour had greater loaf volume than wheat bread, which was due to the fact that the high α -amylase content of the millet flours improved the bread quality. It was also observed that dough produced from the millet-based leaven was smoother than dough from wheat leaven, which was due to the fact that coarse bran particles had more time to absorb water. In addition, fibre structures can be formed from gluten compounds or their network can be disrupted, therefore the rheological properties can be very different. In practice, in the case of baking bread with a higher rate of addition of the bran, it is recommended to apply earlier soaking of the bran, which will cause favourable changes to the properties of dough, and therefore the addition of millet whole grain flour may be the correct technological procedure.

In the present study, the addition of millet flour was 30% and bread loaf volume depended both on the quality of wheat flour and on the method of dough preparation. Moreover, the addition of gluten (3%) had a favourable effect on that parameter. There is a lack of comparative studies on varying methods of composite wheat-millet dough preparation. The few studies based on the straight dough method [19] demonstrated the value of gluten as a natural improver. Other studies determined the changes in properties of bread with varied levels of millet flour in the recipes. GAVURNIKOVA et al. [23] demonstrated that additions of 5% and 15% of millet flour significantly increased loaf volume, while additions of 20%, 25%, and 30% of millet significantly decreased this parameter. As it is known, the formation of the porous structure of wheat dough is possible primarily due to the presence of gluten [39]. Earlier research showed that, in the case of wheat bread, the loaf volume (at an optimal dough consistency) increases with the increase in the gluten

levels, both in the straight dough method [40] and in the two-phase method [41]. In addition, significantly different results of wheat bread loaf volume were obtained when the dough was produced by different methods [41].

Compared to the wheat bread, 30% addition of millet flour caused significant changes in the crumb texture parameters. An earlier study conducted by the straight dough method demonstrated that bread with a 5% addition of millet flour was characterized by significantly lower crumb hardness, and further increase in the rate of millet flour addition in the range of 10–20% caused an increase of that parameter [24]. The millet addition affected mainly the quality of crumb, which was dustier, crumbly, with lower elasticity [23]. In this study, significant differences were noted in the textural properties of wheat bread enriched with millet flour, produced by various methods; such comparisons are missing in the literature. Bread produced by the straight dough method was harder than bread produced by the two-phase method. Soft bread was obtained using a method in which yeast-fermented leaven was produced with millet flour. Such bread was additionally characterized by the smallest change in crumb hardness during storage. An increase in bread crumb hardness during storage was observed in all cases. The literature reports that the main process responsible for the staling of bread crumb is amylopectin retrogradation [42].

CONCLUSIONS

Obtained results confirm that it is possible to produce mixed bread from the millet-based yeast-fermented leaven. The results were dependent on flour properties, but from wheat flour of high gluten content and high falling number, bread of sufficient quality was obtained. More detailed chemical and physical analyses are necessary, including the comparison of results for different millet flours. Moreover, the evaluation of rheological properties of dough is essential. Further studies could be proposed to rheological measurements of dough and estimation of biological activity of bread prepared from millet-based yeast-fermented leaven. Because the health benefits of millet are highly dependent on the milling and separation processes as well as on the rate of decortication including millet flour of different origin, further studies are needed. In addition, the method using yeast-fermented leaven prepared from different flours should be tested for others composite wheat breads.

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