https://doi.org/10.5513/VOCF1218

Agriculturae Conspectus Scientificus, 2026, 91, e007

Original Research Article

CODEN: PJZSAZ e-ISSN: 1331-7776

Baking qualities of Bulgarian sorghum genotypes (*Sorghum bicolor* L. Moench)

Sonya Doneva[1*], Kalin Slanev[2]

[1] Agricultural Academy - Sofia, Dobrudzha Agricultural Institute - General Toshevo, Bulgaria

[2] Agricultural Academy - Sofia, Agricultural Institute - Shumen, Bulgaria

Correspondence: Sonya Doneva (sonya-doneva@abv.bg)

ARTICLE INFO

Received: 10 July 2025
Revised: 19 May 2026
Accepted: 28 May 2026
Available online: 10 June 2026

Academic Editor:
Assoc. Prof. Ante Galić, University of Zagreb Faculty of Agriculture, Croatia

Keywords:
Baking qualities
Dough
Flour
Sorghum

ABSTRACT

This study is part of an extensive scientific programme in Bulgaria focused on using sorghum as an ingredient in low-gluten flours for bread production. The baking qualities of new Bulgarian sorghum varieties and lines were evaluated. A remix method was used in laboratory conditions to bake bread from pure sorghum flour (100%) and composite blends containing 30%, 50%, and 70% sorghum. Pure flour from the Bulgarian common wheat variety, used in the hybrid flours, served as the control. Quantitative and qualitative assessments of the baked bread were carried out, including volume, weight, diameter, height, shape stability coefficient, crust surface and colour, and crumb quality. When considering the rheological properties, sorghum flour produced sticky dough unsuitable for machine processing. The resulting bread had low shape stability, a moist, non-elastic texture, and poor crumb porosity. The crust of the bread from the sorghum varieties and lines produced bread with a heavily cracked crust that were dark in colour. Sensory analysis indicated that sorghum bread had a specific smell, acidity, and astringency, in contrast to the pleasant aroma and taste of wheat bread. The best results were obtained when baking bread from composite flour containing 30% sorghum and 70% wheat. As the proportion of sorghum increased, the quality of the baked bread deteriorated, and the varietal characteristics became more pronounced. Based on the experimental results, conclusions were drawn about expanding the potential for incorporating sorghum products into the food industry for producing healthy and dietary foods.

How to Cite

Doneva S., Slanev K. (2026). Baking qualities of Bulgarian sorghum genotypes (*Sorghum bicolor* L. Moench). Agric Conspec Sci 91: e007.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. *Moench*) is one of the most widespread cultivated crops and ranks fifth in global grain production, after wheat, rice, corn, and barley (Chanapamokkhot and Thongngam, 2007; Trappey et al., 2014; Wang et al., 2016; Stoicea et al., 2025). It belongs to the Poaceae family and is characterised by significant genetic diversity of germplasm (Akin et al., 2022), high drought resistance, and low susceptibility to diseases and pests compared to other cereals (Singh et al., 2014; Rajani et al., 2018; Little and Perumal, 2019). These qualities have transformed sorghum from a "poor agriculture" crop into a promising alternative for grain production under modern climate change conditions, marked by prolonged droughts, heat stress, depletion of natural resources, and environmental pollution (Slanev, 2024).

The biochemical composition of sorghum is approximately similar to that of other cereals. In terms of protein content, it is comparable to corn and approaches wheat. Sorghum grains contain 73% of the fats found in corn and exceed those in wheat by 32%. There is a demonstrated similarity between sorghum and other cereals in terms of micro- and macroelement content, essential amino acids, and vitamins (Stefoska-Needham, 2024). Sorghum is rich in bioactive compounds (phenolic compounds) and tannins, which have antioxidant, anti-inflammatory, and antitumor effects, lower cholesterol levels, and are beneficial against obesity and diabetes (Anglani, 1998). Due to the absence of gluten, sorghum is increasingly used in gluten-free food products suitable for people with gluten intolerance celiac disease (gluten enteropathy). Harmful components such as phytic acid and trypsin inhibitors, which have adverse effects on the human body, are eliminated through various technological processing methods (sprouting, fermentation, soaking, etc.), making sorghum grains and their derivatives suitable for use as food supplements (Taylor et al., 2006; Duodu and Awika, 2019).

Sorghum is cultivated for various purposes. Due to its nutritional qualities similar to corn, it is included in different feed mixtures for livestock farming (Slanev et al., 2012; Enchev et al., 2016). Varieties richer in plant fibre are used in industries for biomethanisation, biomaterials, and biofuels (Hernandez and Capareda, 2019). In South Africa, China, and the USA, sorghum is used to produce distilled beverages and malt for beer. It is one of the main protein sources for millions of people living in semi-arid tropics since it is cheaper than other cereals and reduces food costs (Suresh et al., 1999; Hugo et al., 2000, 2003).

In the modern world, increasing attention is being paid to the quality of food products, as proper nutrition is a key factor for maintaining human health and prolonging life. This explains the growing interest in producing functional foods in the modern baking industry, where gluten-free sorghum flour is increasingly used for various types of bread (Pontieri and Guidice, 2016; Aguiar et al., 2026). According to Temnikova et al. (2020), baked bread containing sorghum can be classified as functional because each serving contains more than 15% of the recommended daily intake of magnesium, manganese, and silicon. The absence of the structural protein gluten in sorghum flour, which is necessary for forming dough with good viscoelastic properties (Hoseney, 1994), is overcome by combining it with flours from other cereals. Several studies and successful tests have shown that composite flours containing 30% to 50% sorghum can produce bread and other baked goods of high quality and taste characteristics, meeting the standards for safe and healthy foods (Hugo et al., 2003; Yetneberk et al., 2004; Taylor and Anyango, 2011; Pontieri and Guidice, 2016).

In Bulgaria, sorghum is primarily used as a feed component, but with the growing interest in healthy and dietary foods, this crop is increasingly entering the food industry.

In this regard, the main objective of this study is to investigate and assess the baking qualities of Bulgarian sorghum varieties and lines and the possibilities of incorporating them into hybrid flours with high-quality winter bread wheat in various quantitative ratios. By evaluating the rheological properties of the dough and the quality of the baked bread, the effect of added sorghum flour will be determined, and the most suitable genotypes for baking production will be identified.

MATERIAL AND METHODS

Sample selection

The study evaluated flours from two sorghum varieties and four lines: Maxibel, Maxired, MBA-5, MBA-11, MR-12, and MR-24. These samples were obtained from the Agricultural Institute - Shumen (Bulgaria), because they were adapted to Bulgaria's climatic conditions.

Chemical composition of the sorghum flour

The studied samples varied in grain colour, which determines both flour colour and chemical composition (Table 1).

The following methods were used to determine the chemical composition: Kjeldahl method (Nx6,25) for crude protein content; Soxhlet extraction apparatus for crude fat content; Weende method for crude fibre content; spectrophotometric method for mineral contents, and the oxalate method for calcium content.

Composite mixtures used for baking

The analysis of baking qualities was conducted in the laboratory for the technological qualities of cereal crops at the Dobrudzha Agricultural Institute – General Toshevo.

A test baking method was applied using 100% pure sorghum flour and hybrid flours containing 30%, 50%, and 70% sorghum from two sorghum varieties and four lines: Maxibel, Maxired, MBA-5, MBA-11, MR-12, and MR-24. As a control, the study used 100% pure flour from the winter bread wheat variety Pchelina (Bulgaria), which was also part of the composite mixtures.

To characterise the baking qualities of the sorghum varieties and lines, experimental flour was prepared by milling with a Buhler MLU 202 roller mill. The finest milled fraction with particle size of 80 μm was used for the analysis.

Flour moisture (%) was determined by an express method by drying 10 g flour for 60 min at 130°C according to BDS 754:1980/Amendment 4:2003.

Wet gluten content (WG) (%) was determined by washing dough from a refined (by moisture) amount of flour under a stream of running water (BDS 754:1980/Amendment 4:2003 and BDS EN ISO 21415-1:2007).

Farinographic properties, such as the water absorption capacity of the flour, dough development time, and dough stability, were measured using a Brabender farinograph (BDS ISO 5530 - 1:2004).

A single-phase dough mixing method was applied (Karadzhov, 2007; Lazova-Borisova, 2018), involving the mixing of flour (approximately 200 g, depending on the determined moisture content), water, yeast, salt, and sugar in a special kneading machine. After dividing and rounding, the dough pieces were left to proof in a chamber for 20 to 60 minutes at 32°C and 70% humidity. This was followed by shaping, placing in baking trays, final proofing for 30 to 40 minutes, and baking. The proofing and baking times varied depending on the composition of the pure flours and the composite mixtures.

Assessment of the dough and bread sample properties

The dough properties observed during handling were noted, using terms such as non-sticky and suitable for machine processing, or sticky and unsuitable for machine processing. Baked bread was evaluated for volume, crust colour and structure, shape, crumb texture, and crumb colour using the following scales: crust colour – 0 to 4.2 points; crumb colour – 0 to 4.3 points; texture and shape – 0 to 5 points (Haralampiev et al., 1970; Lazova-Borisova, 2018).

Organoleptic properties (aroma and taste) were identified through sensory analysis (Nasir et al., 2020; Nagy et al., 2023).

Table 1. Chemical composition and grain colour of sorghum varieties

Variants	Grain colour	Moisture %	Crude protein %	Crude fats %	Crude fibre %	Mineral substances %	Calcium %
Maxired	red	10.0	10.43	2.90	2.12	2.12	0.110
MR-24	red	10.0	9.33	3.59	2.06	1.90	0.170
MR-12	red	10.5	11.76	2.67	3.43	2.06	0.170
Maxibel	pink	9.5	10.08	2.24	2.99	1.03	0.170
MBA-5	grey	10.0	10.62	2.57	2.13	1.05	0.200
MBA-11	white	10.0	10.89	2.60	2.28	1.50	0.170

The sensory evaluation was performed by six participants, four women and two men of different ages and with different eating habits. The bread was tasted the day after baking in the following way: the bread was cut into small pieces on a plate and each variant was numbered. Between tasting the individual samples, each participant rinsed with water. After the tasting, each participant described the taste and aroma of all variants of the bread tasted. The bread volume was measured by the displacement method using small, uniform grains with a volumeter (cm^3) (BDS 3412:1979). The mass of the bread was measured by weighing on an electronic scale (g). The height, H (cm) and the diameter of the loaf, D (cm), which are necessary to calculate the dimensional stability coefficient (H/D), were measured with a ruler.

RESULTS AND DISCUSSION

Flour colour variation

During laboratory milling of sorghum varieties and lines using a small roller mill, the bran layers (pericarp and germ) were removed, thereby reducing tannin and phytic acid content. The milling method used was quick and resulted in high flour yield (up to 70%), but it could cause starch damage, negatively affecting the flour quality for bread preparation. The subsequent evaluation of the obtained flour samples revealed differences in colour. Compared to the wheat flour of the Pchelina variety, characterised by high whiteness, sorghum flour did not meet the whiteness requirements. On the one hand, the colour of sorghum flour is due to its higher ash content, while on the other hand, the sorghum grain pericarp can vary in colour from white to various shades of red, yellow, and black, depending on genetic factors and environmental conditions (Akin et al., 2022). Lines MBA-12 and MBA-24, classified as white-grained forms, produced flour with white to greyish colouring. Flour from the other varieties and lines ranged from pink (Maxibel variety) to red (Maxired variety and MR-12 and MR-24 lines) (Table 2).

Table 2. Colour of sorghum flour depending on ash content and genetic factors

Variants	Sorghum flour colour
MBA-12	white to greyish
MBA-24	white to greyish
Maxibel	pink
Maxired	red
MR-12	red
MR-24	red

Variations in dough properties

Wet gluten (WG) content was highest in composites with 30% sorghum (Table 3; Fig. 1 – column 2) and gradually decreased as the sorghum flour content increased to 50% (Table 3; Fig. 1 – column 3) and 70% (Table 3; Fig. 1 – column 4). Pure sorghum flour (100%) was gluten-free (Table 3).

The flour quality depends on its water absorption capacity, which is associated with the dough's rheological properties. Through farinographic analysis of hybrid flours, Dube et al. (2020), Sibanda et al. (2015) and Nagy et al. (2023) found a reduction in water absorption due to sorghum addition, a longer dough development time, and reduced dough stability due to the weakening of the gluten network configuration during kneading. The authors attributed this primarily to the low gluten content in sorghum-based flour mixtures.

In the present study, we found that water absorption in composites with 30%, 50%, and 70% sorghum was slightly higher than that of the control wheat flour and increased sharply in the 100% sorghum flour variant. The likely reason for the higher absorption capacity of the tested composites was the use of the finest-milled fraction of sorghum flour, which has a higher water absorption. This finding aligns with other reports, indicating that the degree of flour milling significantly affects water absorption (Torres et al., 1993). According to Akajiaku et al. (2017), the high-water absorption capacity of sorghum-based composites may also be due to the higher protein and carbohydrate content in pure sorghum flour compared to wheat flour.

Table 3. Average values of farinograph parameters of flour and dough from sorghum and sorghum-wheat composites for all analysed sorghum types - Maxibel, Maxired, MBA-5, MBA-11, MR-12, and MR-24 (WG – wet gluten; FU – farinographic units)

Variants	Flour moisture (%)	WG in 70% wheat (%)	Water absorption capacity of flour (cm^3)	Dough development (min)	Dough stability (min)	Degree of dough softening (FU)
100% wheat	10.8	30.5	45	1.5	8.7	13.0
100% sorghum	9.8 – 10.6	0.0	70 – 75	12.5 – 16.0	1.0	83.2
70% sorghum	10.2 – 10.5	1.5 – 2.8	60 – 67	8.3 – 12.0	1.2 – 1.4	60.1
50% sorghum	10.2 – 10.5	9.8 – 10.9	52 – 58	5.0 – 10.0	1.5 – 2.0	42.5
30% sorghum	10.2 – 10.7	17.4 – 19.1	47 – 50	3.6 – 4.8	1.8 – 2.4	27.6

This suggests that selecting a sorghum variety with high protein and carbohydrate content could improve the water absorption capacity of composite flours and enhance dough quality parameters.

As the sorghum content in hybrid flours increased, gluten content decreased, leading to longer dough development times and reduced stability (Table 3).

The properties of the dough in this experiment showed that pure sorghum flour and the 70% sorghum composite formed very sticky dough due to the absence or low gluten content, significantly hindering machine processing. The dough quality improved with decreasing sorghum content. In the variant with 30% sorghum flour and 70% wheat flour, the dough was non-sticky and easier to handle mechanically. Adding sorghum to standard white flour reduced the extensibility and elasticity of the composite dough, a finding also noted by Sibanda et al. (2015). The degree of softening of sorghum, particularly when used as a substitute in wheat dough, generally increases as the proportion of sorghum flour increases (from over 27.6 to 60.1 at 70% substitution) This indicates a weakening of the dough structure compared to pure wheat flour (Hinar and Azza, 2014; Omer et al., 2025).

Variations in baking quality

The baked bread was analysed based on several parameters: loaf volume, height, diameter, shape stability, surface, crust colour, crumb texture, and crumb colour (Table 4). Loaf volume decreased significantly as the sorghum content in the flour mixtures increased. The lowest loaf values for this indicator were measured for bread made from pure sorghum (Table 3). This was due to a correlation between the physicochemical composition of sorghum flours and loaf volume. The low gluten content in the composites reduced their water absorption capacity, diminishing their ability to retain gases and lowering the dough's viscoelastic properties, resulting in reduced loaf volume (Adzqia et al., 2023; Rumler et al., 2024). Bread made from pure wheat flour had a well-defined shape with a smooth, shiny, golden-brown crust (Fig. 2 – column 1). In the trials with 30% (Fig. 2, row D) and 50% sorghum flour (Fig. 2, row C) in the composites, the bread crust structure was closest to that of the control. The crust was smooth, with a colour ranging from darker to light brown. The formed bread had a slightly domed top crust and a regular shape. As the sorghum content in the flour mixture increased to 70%, the bread surface became rougher, and the crust colour darkened (Fig. 2, row B).

Figure 1. Washed pure gluten from flour. (A) 1. Control (100% wheat); 2. 30% MBA-5; 30% MBA-11; 3. 50% MBA-5; 50% MBA-11; 4. 70% MBA-5; 70% MBA-11; (B) 1. Control (100% wheat); 2. 30% MR-12; 30% MR-24; 3. 50% MR-12; 50% MR-24; 4. 70% MR-12; 70% MR-24; (C) 1. Control (100% wheat); 2. 30% Maxibel; 30% Maxired; 3. 50% Maxibel; 50% Maxired; 4. 70% Maxibel; 70% Maxired

https://doi.org/10.5513/VOCF1218

Table 4. Properties of baked bread from sorghum and sorghum-wheat composites (H – heigh; D – length)

Variants	Loaf volume (cm³)	H (cm)	D (cm)	Shape stability (H:D)	Surface/crust colour (0-4.2)	Crumb texture (0-5)	Bread shape (0-5)	Crumb colour (0-4.3)
100% Control	610	66	117	0.56	4.2	4.9	5.0	4.3
100% MBA-5	180	28	115	0.24	3.0	2.0	2.5	3.4
100% MBA-11	200	34	112	0.30	3.2	2.0	2.5	3.5
100% MR-12	165	26	128	0.20	2.6	2.0	2.5	3.0
100% MR-24	170	29	127	0.23	2.6	2.0	2.5	3.0
100% Maxibel	185	40	107	0.37	3.0	2.0	2.5	3.0
100% Maxired	175	35	108	0.32	2.6	2.0	2.5	2.8
70% MBA-5	190	37	118	0.31	3.2	2 – 2.5	2.5 – 3.0	3.4
70% MBA-11	205	36	111	0.32	3.4	2 – 2.5	2.5 – 3.0	3.4
70% MR-12	170	37	115	0.32	2.8	2 – 2.5	2.5 – 3.0	2.8
70% MR-24	175	36	111	0.32	2.8	2 – 2.5	2.5 – 3.0	2.8
70% Maxibel	190	32	115	0.28	3.2	2 – 2.5	2.5 – 3.0	3.0
70% Maxired	180	33	112	0.29	2.8	2 – 2.5	2.5 – 3.0	2.8
50% MBA-5	290	35	125	0.22	3.4	2.0 – 2.5	3.0 – 3.5	3.5
50% MBA-11	310	38	124	0.31	3.6	2.0 – 2.5	3.0 – 3.5	3.5
50% MR-12	285	40	125	0.32	3.0	2.0 – 2.5	3.0 – 3.5	3.0
50% MR-24	280	36	124	0.29	3.0	2.0 – 2.5	3.0 – 3.5	3.0
50% Maxibel	290	41	118	0.35	3.2	2.0 – 2.5	3 – 3.5	3.2
50% Maxired	285	37	129	0.29	3.0	2.0 – 2.5	3 – 3.5	2.8
30% MBA-5	320	51	106	0.48	4.0	2.5 – 2.8	4.0 – 4.2	3.7
30% MBA-11	330	50	107	0.47	4.0	2.5 – 2.8	4.0 – 4.2	3.9
30% MR-12	300	51	105	0.48	4.0	2.5 – 2.8	4.0 – 4.2	3.4

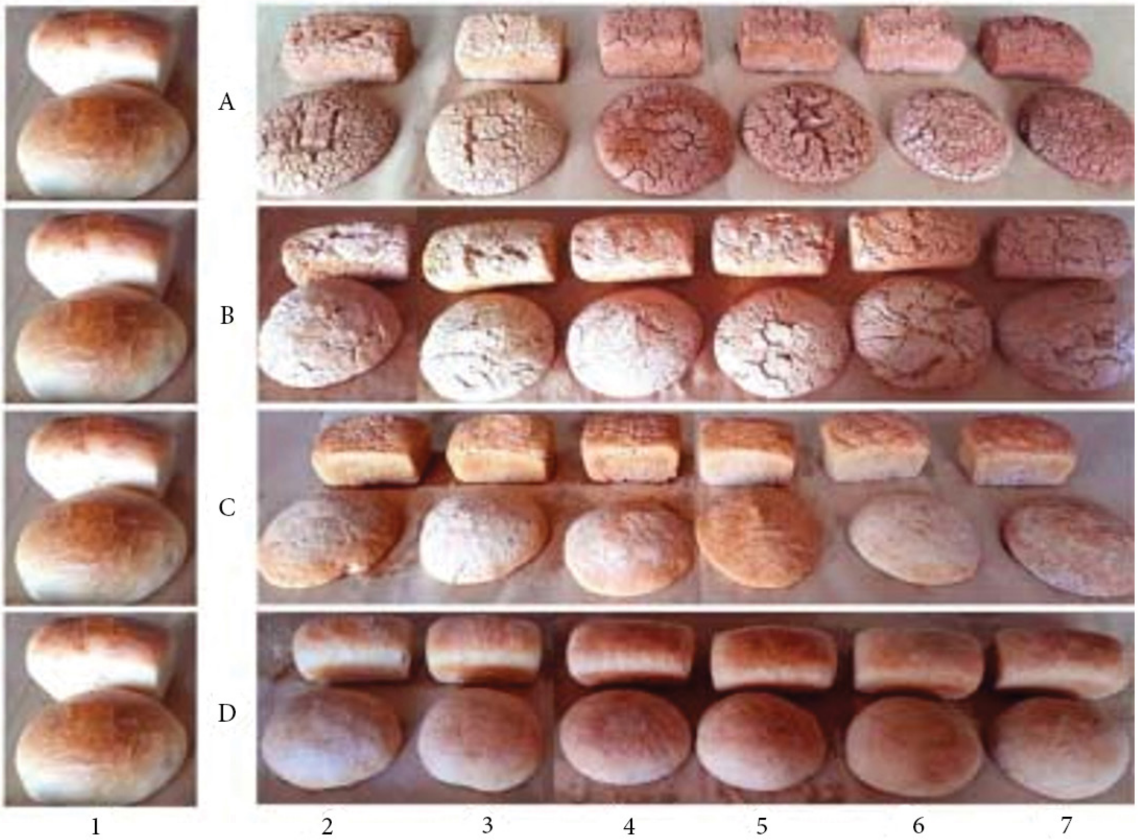

Figure 2. Bread shape, colour and structure of the crust. (A) 100% sorghum flour bread; (B) 70% sorghum flour bread; (C) 50% sorghum flour bread; (D) 30% sorghum flour bread: 1. Control (100% wheat); 2. MBA-5; 3. MBA-11; 4. MR-12; 5. MR-24; 6. Maxibel; 7. Maxired

Bread baked from 100% sorghum flour did not meet any of the requirements for shape, surface, or crust colour (Fig. 2, row A). The ratio between the height and diameter of the bread was used as an indicator of its shape stability. The highest values of this coefficient were recorded in the variant with 30% sorghum flour, with values decreasing with decreasing gluten content in the flour mixtures (Table 3).

The bread texture was evaluated using a five-point scale. Bread made from pure wheat flour exhibited high elasticity, with evenly distributed thin-walled pores and a white crumb, receiving a score of 4.9 points (Table 4; Fig. 3, column 1). Hybrid flours with varying sorghum content resulted in decreased elasticity and the appearance of uneven pores with a coarse and moist crumb. The colour also changed, transitioning from white to greyish or reddish-brown as the sorghum content increased to 70% (Table 4; Fig. 3, rows D, B, C). Bread made from 100% sorghum flour showed the poorest characteristics in terms of crumb porosity, receiving a score no higher than 2 points (Table 4; Fig. 3A). These results align with the findings of Hugo et al. (2003), Onyango et al. (2011), Cappa et al. (2016), and Adepehin et al. (2023), confirming that the best bread texture is achieved with composite flours containing up to 30% sorghum. This suggests that adding sorghum beyond this threshold significantly reduces bread-making quality, worsening the texture and decreasing the shape stability of the final bread. Therefore, if the sorghum content in flour mixtures is to be increased, additional methods for improving the texture and volume of the bread should be explored.

Sensory analysis indicated that sorghum bread had a specific smell, acidity, and astringency in contrast to the pleasant aroma and taste of wheat bread (Chaquilla-Quilca et al., 2024; Jebo and Urga, 2024). The main substances that influence the aroma and taste of bread are volatile aromatic compounds released during fermentation, and thermal reactions that occur during the baking process. Variants with 70% and 50% sorghum flour in the composites also showed deviations in taste due to an unpleasant aroma and a slightly bitter aftertaste. No significant differences in aroma and taste were observed in the bread containing 30% sorghum compared to the wheat control. Similar results have been reported by other authors, whose studies indicate that the aroma and taste of composite bread with 10% and 20% sorghum are closest to those of bread made from 100% wheat flour (Carson et al., 2000; Sibanda et al., 2015; Tuhanioglu et al., 2023).

Figure 3. Crumb texture and crumb colour. (A) 100% sorghum flour bread; (B) 70% sorghum flour bread; (C) 50% sorghum flour bread; (D) 30% sorghum flour bread: 1. Control (100% wheat); 2. MBA-5; 3. MBA-11; 4. MR-12; 5. MR-24; 6. Maxibel; 7. Maxired

CONCLUSIONS

The present study on the bread-making qualities of sorghum flour shows that, regardless of genotype, the best results were achieved with bread made from composite flour containing 30% sorghum and 70% wheat. As the proportion of sorghum increases, the quality of the baked bread deteriorates, and varietal characteristics become more pronounced. According to commercial and consumer standards for bread production, sorghum flours from the MVA-5 and MVA-11 lines, ranging from white to greyish in colour, are preferred because they produce bread with crust structure, crumb quality, and organoleptic properties similar to those of wheat products.

Our data on the chemical composition and bread-making characteristics suggest that sorghum-wheat composites can be used in the production of various food products—bread, breadsticks, rusks, crackers, and others. However, efforts should be made to improve the quality of hybrid flours containing sorghum by reducing gluten content through the addition of various ingredients and the application of traditional and innovative production technologies.

In Bulgaria, the consumption of low-gluten products containing sorghum is still not well established. In contrast, in other European countries (Italy, Spain, France), there is a trend towards expanding the production and consumption of foods containing hybrid flours with sorghum. In this regard, the present study is part of a large-scale, national scientific programme aimed at using sorghum not only as animal feed, but also for inclusion in low-gluten flours for bakery production. The goal of our scientific efforts is the wider adoption of sorghum-based products in the food industry and the satisfaction of the growing consumer interest in this future crop as a healthy and dietary food.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Sonya Doneva: Performed all laboratory experiments and research, analysed the data, and wrote the manuscript. **Kalin Slanev:** Developed the project and supervised the field work, verified the results, contributed to editing the manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICS APPROVAL

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Data will be made available on reasonable request from the corresponding author.

FUNDING STATEMENT

No funding was received to assist with the preparation of this paper.

AI USE STATEMENT

No AI-assisted technologies were employed in the preparation of this manuscript. All content was generated exclusively by the authors.

SAŽETAK

Pekarska kvaliteta bugarskih genotipova sirka (*Sorghum bicolor* L. Moench)

Ovo istraživanje dio je opsežnog znanstvenog programa u Bugarskoj usmjerenog na primjenu sirka kao sastojka brašna sa smanjenim udjelom glutena za proizvodnju kruha. Procijenjena su pekarska svojstva novih bugarskih sorti i linija sirka. U laboratorijskim uvjetima primijenjena je metoda remiksa za pečenje kruha od čistog sirkovog brašna (100 %) te kompozitnih smjesa koje su sadržavale 30 %, 50 % i 70 % sirka. Kao kontrola korišteno je čisto brašno bugarske sorte obične pšenice, koje je također bilo sastavni dio hibridnih smjesa.
Provedena je kvantitativna i kvalitativna procjena pečenog kruha, uključujući volumen, masu, promjer, visinu, koeficijent stabilnosti oblika, površinu i boju kore te kvalitetu sredine kruha. S reološkog aspekta, sirkovo brašno stvaralo je ljepljivo tijesto neprikladno za strojnu obradu. Dobiveni kruh imao je nisku stabilnost oblika, vlažnu i neelastičnu teksturu te slabu poroznost sredine. Kruh proizveden od sorti i linija sirka imao je izrazito ispucalu i tamno obojenu koru. Senzorska analiza pokazala je da kruh od sirka ima specifičan miris, kiselost i trpkost, za razliku od ugodne arome i okusa pšeničnog kruha. Najbolji rezultati postignuti su pri pečenju kruha od kompozitnog brašna koje je sadržavalo 30 % sirka i 70 % pšenice. Povećanjem udjela sirka kvaliteta kruha se smanjivala, a sortne karakteristike postajale su izraženije. Na temelju dobivenih rezultata zaključeno je da postoji mogućnost šire primjene proizvoda od sirka u prehrambenoj industriji za proizvodnju zdrave i dijetetske hrane.

Ključne riječi: pekarska kvaliteta, tijesto, brašno, sirak

REFERENCES

Adepehin J. O., Odeny D. A. Enujiugha, V. N. Badejo A. A., Young G. M. (2023). Original article physicochemical and sensory attributes of gluten-free sourdough breads produced from underutilised African cereal flours and flour blends. Int. J. Food Sci. Technol. 58(1): 493–501. https://doi.org/10.1111/ijfs.16094

Adzqia F., Suwonsichon S., Thongngam M. (2023). Effects of white sorghum flour levels on physicochemical and sensory characteristics of gluten-free bread. Foods 12(22): 4113. https://doi.org/10.3390/foods12224113

Aguiar E., Costa B., Santos F., Gonçalves E., Queiroz V., Capriles V., 2026. Sorghum-based gluten-free bread quality optimization – A mixture design approach. Future foods 13, 100958.

Akajiaku L. O., Nwosu J. N., Kabuo N. O., Odimegwu E.N., Umelo M. C., Unegbu V. C. (2017). Using sorghum flour as part substitute of wheat flour in noodles making. MOJ Food Proc. Technol. 5(2): 250-257. https://doi.org/10.15406/mojfpt.2017.05.00120

Akin P. A., Demirkesen I., Bean S. R., Aramouni F., Boyaci I. H. (2022). Sorghum flour Application in bread: Technological challenges and opportunities. Foods 11: 2466. https://doi.org/10.3390/foods11162466

Anglani C. (1998). Sorghum for human food – A review. Plant Foods Hum. Nutr. 52 (1): 85–95. https://doi.org/10.1023/A:1008065519820

BDS (Bulgarian State Standard) (1979). 3412:1979 Bread and Bread Products—Regulation for Taking Samples and Testing Methods; Bulgarian State Standard (BDS): Sofia, Bulgaria.

BDS (1980). BDS 754:1980/Amendment 4:2003. Milled Products—Rules for Sampling and Methods of Test; Bulgarian State Standard (BDS): Sofia, Bulgaria.

BDS EN ISO (2007). BDS EN ISO 21415- 1:2007. Wheat and Wheat Flour—Gluten Content—Part 1: Determination of Wet Gluten by a Manual Method; Bulgarian State Standard (BDS): Sofia, Bulgaria.

BDS ISO (2004). BDS ISO 5530 - 1:2004. Wheat Flour—Physical Characteristics of Doughs—Part 1: Determination of Water Absorption and Rheological Properties Using a Farinograph; Bulgarian State Standard (BDS): Sofia, Bulgaria.

Cappa C., Lucisano M., Raineri A., Fongaro L., Foschino R., Mariotti M. (2016). Gluten-free bread: Influence of sourdough and compressed yeast on proofing and baking properties. Foods 5(4): 69. https://doi.org/10.3390/foods5040069

Carson L., Setser C., Sun X. S. (2000). Sensory characteristics of sorghum composite bread. Int. J. Food Sci. Technol. 35(5): 465-471. https://doi.org/10.1046/j.1365-2621.2000.00399.x

Chanapamokkhot H., Thongngam M. (2007). The chemical and physico-chemical properties of sorghum starch and flour. Kasetsart J. (Nat. Sci.) 41: 343 – 349.

Chaquilla-Quilca G., Islas-Rubio A., Vásquez-Lara F., Salcedo-Sucasaca L., Silva-Paz R., Luna-Valdez J. (2024). Chemical, physical, and sensory properties of bread with popped amaranth Flour. Pol. J. Food Nutr. Sci., 74(2):137-146. https://doi.org/10.31883/pjfns/187799

Dube N. M., Xu F., Zhao R. (2020). The efficacy of sorghum flour addition on dough rheological properties and bread quality: A short review. Grain Oil Sci. Technol. 3(4): 164-171. https://doi.org/10.1016/j.gaost.2020.08.001

Duodu K. G., Awika J. M. (2019). Phytochemical-related health-promoting attributes of sorghum and millets, In: Sorghum and Millets: Chemistry, Technology, and Nutritional Attributes (Taylor J.R.N., Duodu K.G., eds), Woodhead Publishing Ltd, Duxford, UK, pp. 225-258.

Enchev S., Kikindonov Tz., Slanev K. (2016). Productive potential of varieties and elite populations sweet sorghum for silage production. J. Mt. Agric. Balk. 19(5): 124-134.

Haralampiev D., Cigshheva A., Minchev M., Velev G. (1970). Paper on Bread Production. Sofia, Technika, pp. 437. [*In Bulgarian*]

Hernandez J. R., Capareda S. C. (2019). Development of highly digestible grain sorghum lines suitable for efficient dry-grind ethanol production. J. Sustain. Bioenergy Syst. 9(3): 98-118. https://doi.org/10.4236/jsbs.2019.93008

Hinar A. S., Azza A. O. (2014). Evaluation quality of one layer flat bread supplemented with beans and sorghum baked on hot metal surface. Food Nutr. Sci. 5(22): 2246-2256. https://dx.doi.org/10.4236/fns.2014.522238

Hoseney R. C. (1994). Principles of Cereal Science and Technology. 2nd ed. American Association of Cereal Chemistry, St. Paul, Minnesota, USA.

Hugo L. F., Rooney L. W., Taylor J. R. N. (2000). Malted sorghum as a functional ingredient in composite bread. Cereal Chem. 77(4): 428-432. https://doi.org/10.1094/CCHEM.2000.77.4.428

Hugo L. F., Rooney L. W., Taylor J. R. (2003). Fermented sorghum as a functional ingredient in composite breads. Cereal Chem. 80(5): 495-499. https://dx.doi.org/10.1094/CCHEM.2003.80.5.495

Jebo K. K., Urga K. (2024). Sensory characteristics and nutritional value of wheat-sorghum based bread enhanced with orange fleshed sweet potato. Cogent Food Agric 10(1), 2438403. https://doi.org/10.1080/23311932.2024.2438403

Karadzhov, G., Vassileva R., Nikolova M. (2007). Bread, Bakery and Confectionery Technology. Sofia, Matcom Ltd, pp. 5 [*In Bulgarian*].

Lazova-Borisova I. (2018). Technology for obtaining of high-protein bread "diabetic" for specific health needs. J. Mt. Agric. Balk. 21(1): 251-260.

Little C. R., Perumal R. (2019). The biology and control of sorghum diseases. In: Sorgum: A State of the Art and Future Perspectives (Ciampitti, I.A., Vara Prasad, P.V., eds). Agronomy Monographs 58, pp. 297-346. https://doi.org/10.2134/agronmonogr58.c14

Nagy R., Neji C., Remenyik J., Sipos P. (2023). Evaluation of functional properties of physically treated sorghum flours and development of gluten-free sorghum. J. Microbiol. Biotech. Food Sci. 13(3): e9959. https://doi.org/10.55251/jmbfs.9959

Nasir S., Allai F. M., Gani M., Ganaie S., Gul K., Jabeen A., Majeed D. (2020). Physical, textural, rheological, and sensory characteristics of amaranth-based wheat flour bread. Int. J. Food. Sci. 27:8874872. https://doi.org/10.1155/2020/8874872

Omer S., Mohamed H., Zheng X. (2025). Effects of various sorghum flour particle sizes on the properties of sorghum-wheat composite dough sheets and noodles. Processes 13(12), 3840. https://doi.org/10.3390/pr13123840

Onyango C., Mutungi C., Unbehend G., Lindhauer M. G. (2011). Rheological and textural properties of sorghum-based formulations modified with variable amounts of native or pregelatinised cassava starch. Food Sci. Technol. 44(3): 687-693. https://doi.org/10.1016/j.lwt.2010.08.019.

Pontieri P., Guidice Del L. (2016). Sorghum: a novel and healthy food, In: Encyclopedia of Food and Health (Caballero B, Finglas P, Toldrá F., eds.). Academic Press, pp. 33-42. https://doi.org/10.1016/B978-0-12-384947-2.00637-1

Rajani V., Ramesh K., Anamika N. (2018). Drought resistance mechanism and adaptation to water stress in sorghum [*Sorghum bicolor* (L.) Moench]. Int. J. Bio-resour. Stress Manag. 9(1): 167-172. https://doi.org/10.23910/IJBSM/2018.9.1.3C0472

Rumler R., Bender D., Marti A., Biber S., Schoenlechner R. (2024). Investigating the impact of sorghum variety and type of flour on chemical, functional, rheological and baking properties. J. Cereal Sci. 116, 103881. doi 10:1016/j.jcs.2024.103881

Sibanda T., Ncube T., Ngoromani N. (2015). Rheological properties and bread making quality of white grain sorghum-wheat flour composites. Int. J. Food Sci. Nutr. Eng. 5(4): 176-182. https://doi.org/10.5923/j.food.20150504.03

Singh P., Nedumaran S., Traore P. C. S., Boote K. J., Rattunde H. F. W., Vara Prasad P. V., Singh N. P., Srinivas K., Bantilan M. C. S. (2014). Quantifying potential benefits of drought and heat tolerance in rainy season sorghum for adapting to climate change. Agric. For. Meteorol. 185: 37-48. https://doi.org/10.1016/j.agrformet.2013.10.012

Slanev K. (2024). Prospects for sorghum utilization as human food. Bulg. J. Crop Sci. 61(6): 46-51. https://doi.org/10.61308/GSLE3638

Slanev K., Enchev S., Kikindonov Tz. (2012). Breeding of sorghum x sudangrass hybrids for green productivity. Field Crops Stud. 8(2): 299-303. [*In Bulgarian*]

Stefoska-Needham A. (2024). Sorghum and health: An overview of potential protective health effects. J. Food Sci. 89(S1): A30-A41. https://doi.org/10.1111/1750-3841.16978.

Stoicea P., Iorga A. M., David L., Bucur C. G. (2025). Sorghum, the crop of the future under climate change conditions. Sci. Pap. Ser. Manag. Econ. Eng. Agric. Rural Dev. 25(2): 789-804.

Suresh K., Kiransree N., Venkateswar Rao L. (1999). Production of ethanol by raw starch hydrolysis and fermentation of damaged grains of wheat and sorghum. Bioprocess Eng. 21: 165-168. https://doi.org/10.1007/s004490050657

Taylor J.R.N., Schober T.J., Bean S.R. (2006). Novel food and non-food uses for sorghum and millets. J. Cereal Sci. 44: 252–271. doi: 10.1016/j.jcs.2006.06.009

Taylor J. R. N., Anyango J. O. (2011). Sorghum flour and flour products: Production, nutritional quality, and fortification. In: Flour and Breads and their Fortification in Health and Disease Prevention (Preedy, V.R., Watson, R.R., and Patel, V.B., eds), Academic Press, Elsevier, USA, pp. 127-139. https://doi.org/10.1016/B978-0-12-380886-8.10012-1

Temnikova O., Rudenko E., Mukovnina G., Ruzyanova A. (2020). Technology of functional bread using sorghum flour. BIO Web Conf. 17: 00196. https://doi.org/10.1051/bioconf/20201700196

Torres P. I., Ramirez-Wong B., Serna-Saldivar S. O., Rooney L. W. (1993). Effect of sorghum flour addition on the characteristics of wheat flour tortillas. Cereal Chem. 70: 8-13.

Trappey E., Khouryieh H., Aramouni F., Herald T. (2014). Effect of sorghum flour composition and particle size on quality properties of gluten-free bread. Food Sci. Technol. Int. 21(3): 188-202. https://doi.org/10.1177/1082013214523632

Tuhanioglu A., Lafontain S., Ubeyitogullari A. (2023). Enhancing the aroma of white whole sorghum flour using supercritical carbon dioxide. Future Foods 8: 100253, https://doi.org/10.1016/j.fufo.2023.100253

Wang H-Y., Upadhyaya H. D., Dweikat I. (2016). Sorghum. In: Genetic and Genomic Resources for Grain Cereals Improvement (Singh M. and Upadhyaya H. D., eds). Academic Press, Elsevier, USA, pp. 227-251.

Yetneberk S., de Kock H. L., Rooney L. W., Taylor J. R. N. (2004). Effects of sorghum cultivar on injera quality. Cereal Chem. 8(3): 314-321. https://doi.org/10.1094/CCHEM.2004.81.3.314