

## The effects of malt flours obtained from different cereals on flour and bread quality

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**Abstract:** In this study, firstly, enzyme-active malt flours were obtained from different germinated grains including wheat, barley, rye, triticale, millet, maize, rice, and oat. Next, these enzyme-active malt flours and commercial enzyme were added to bread wheat flour in a level that provides the same amylolytic activity and their effects on bread quality were investigated. The germination process significantly increased the amylolytic enzyme activity in grains but also caused a significant change in  $L^*$ ,  $a^*$ , and  $b^*$  color values. Among flours containing different malt flours, the lowest delayed Zeleny sedimentation value was determined in flour containing paddy malt, while the highest value was measured in flours containing commercial enzyme. The highest average value for gluten index was achieved in flour containing triticale malt, while the lowest value was obtained in flour containing wheat malt. The addition of malt flours obtained from different grains was effective in decreasing the L color value in bread crumb, compared to the control samples. The highest specific volume of 4,78 cm<sup>3</sup>/g was obtained from bread produced using flour with paddy malt, while the lowest specific volume value of 4,17 cm<sup>3</sup>/g was obtained from bread made using wheat malt. In conclusion, better bread quality characteristics of specific volume and texture were achieved using flours containing corn, rye, oats, barley, and paddy malt compared to control samples.

**Key words:** Germinated cereal, malted flour, amylolytic enzyme, bread-making properties

### 1. Introduction

Controlled cereal germination has been used for centuries to increase nutrient content and availability (Jan et al., 2017), to reduce the antinutritional effects, and to improve the activity of enzymes in grains (Pachari Vera et al., 2019; Wang et al., 2020). In bread-making industry, amylolytic activity,  $\alpha$ -amylase enzyme in particular, is of great importance because it breaks down the starch into simple sugars and allows them to be fermented by yeast in the production of yeast-based bakery products (Kostyuchenko et al., 2021). Achieving an optimum fermentation increases the gas-forming ability of the dough, resulting in an increase in the quality characteristics of the final product such as volume, texture and color, and shelf life (Ait Kaki El-Hadef El-Okki et al., 2017; Movahedpour et al., 2021). Amylolytic enzyme activity that is too low or high adversely affects product quality. If the amylolytic activity of the flour is low, the sugar used by the yeast cells in the dough semifinished product will not be enough. The fermentation process will occur with low intensity, the product will turn out to be of poor quality, with an insufficiently porous, fluffy crumb (Simakova et al., 2018; Pekmez, 2019). When the enzyme activity is too high,

starch breakdown occurs faster in bread and the pore structure in the bread is disrupted resulting in lower than desired bread volume and sticky bread crumb (Aljabi and Pawelzik, 2021). Enzyme activity is determined by falling number analysis and this method is also used to obtain the ideal mixture from flours with different amylase activity or to determine the addition level of enzyme (Koç, 2015). The amylolytic enzyme activity, which catalyzes the degradation of starch polymers, is generally low in wheat grown in Turkey (Kara et al., 2020). Therefore, amylases are routinely added to wheat flours to optimize the amylolytic enzyme activity, as well as antistaling agents to retard crumb hardening caused by retrogradation in starch gels and changes in water distribution (Mäkinen and Arendt, 2012). Enzyme active malt flour is natural and widely used in place of commercial  $\alpha$ -amylase and assists to regulate the amylolytic activity, contributes to increase the quality of bread and enriches its aroma (Baranwal, 2017; Durmuş, 2022).

The  $\alpha$ -amylases are widely distributed in nature and can be obtained from various sources, such as bacteria (Bacillus), mold species (Aspergillus), and germinated cereal grains. The use of enzyme active malt flours obtained

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from grains such as wheat, barley, and rye for the regulation of the amylolytic activity of bread flours has many advantages. Enzyme-active cereal malt flours can be more preferred than other enzyme sources due to their natural structures, suitable thermostability for bread-making processes, and lower production costs (Dura and Rosell, 2017; Tebben et al., 2018; Aladejana et al., 2020; Savkina et al., 2020).

In bread-making, enzyme-active malt flours are used as dough conditioners at very low levels (1%–3%) depending on flour quality (Abd-Elsattar, 2018; Belcar et al., 2022). Some studies reported that the use of malt flours (containing active enzymes) in controlled conditions improves loaf volume and crumb texture (Honcu et al., 2015; Abd-Elsattar, 2018; Belcar et al., 2022; Tapsoba et al., 2022). These positive effects were attributed to the natural enzymes formed during germination. It has been reported that the maximum level of amylase activity by germination is observed after 7 days in barley (Farzaneh et al., 2017), 5 days in wheat (Baranzelli et al., 2018), and 3 days in corn (Zhan et al., 2017). Üstün and Çelik (2011) reported that maximum phytase activity was obtained after 5-days of germination, and addition of 3% the malted flour to the bread dough significantly affected the bread hardness and the color. Tian et al. (2010) stated that a rapid increase in total amylase activity was observed after 24 h in the germination process of oat grains and the absolute activity of beta amylase was always higher than alpha amylase.

According to the Turkish food codex, it is forbidden to add additives except vitamin C and enzyme to whole wheat bread, bread with whole wheat flour, wholemeal bread, sour dough bread, and bread which are placed on the market without packaging. In general, bacterial and mold originated amylolytic enzymes are used in the manufacturing of yeast-based bakery products in industrial production. Since the production process is straightforward and at low cost, it will be advantageous to use malt flour obtained from germinated cereal grains as an enzyme source, if its natural structure is also taken into consideration. Therefore, wheat, barley, rye, triticale, millet, corn, rice, and oats were germinated under standard conditions and enzyme-active cereal malt flour was obtained by milling in this research. Later, using these malt flours, amylolytic enzyme activities of bread flours were adjusted to the desired level and their effects on bread quality were investigated. The novelty of this study is to obtain enzyme-active malt flour by using all of the currently used cereals, and to compare the effects of these malt flours on flour and bread properties by adding them to wheat bread flour at the same time. In the studies carried out so far, the changes that occur in grains with germination in general have been examined, and such a variety of malt flour has not been used as an enzymatic additive at the same time.

## 2. Materials and methods

### 2.1. Materials

In the study, wheat (Doğu 88), barley (Olgun), rye (Aslım-95), triticale (Ümran Hanım), millet (white millet), corn (Ada-313), paddy (Osmancık-97), and oat (Ankara-76) grains obtained from Bayburt, Erzurum, and Çorum region (Turkey) were used as material to produce malt flour. Commercial enzyme derived from *Bacillus subtilis* was used as an enzymatic additive. Wheat flour (Birsan flour, Turkey) with low diastatic activity (Falling Number 539 s), fresh yeast (Pakmaya Yeast Co.) and salt were procured from the local markets of Erzurum, Turkey.

### 2.2. Malting procedure

Malt flours were produced according to Boz and Karaoğlu (2013) with some modifications. The cleaned grains were washed and kept in water at 20 °C for 24 h, and after removing the excess water, they were allowed to germinate in the container at room temperature (20 °C), 70% relative humidity, and darkness conditions. Samples were hydrated every 8–10 h and scrambled to prevent them from getting lumpy. The germination process was continued until the sprouts of the grains reached 1 cm (i.e. 7 days in rice and oat grains, 4 days in corn grains, and 3 days in other grains). Germinated cereals were dried at room temperature down to 14% moisture content followed by cleaning the shoots and roots. Next, dried grains were milled in the combined mill (Yücebaş Machine Analytical Equipment Industry, İzmir) to obtain malt flour. The obtained enzyme-active malt flours were added to bread flour at levels that would ensure a falling number of  $275 \pm 5$  s to increase the enzyme activity of the flour.

### 2.3. Flour analyses

Flour moisture content was determined using the air-oven method (AACC Approved Method 44-01.01) (AACC, 2010). Falling number (FN) values were determined with a model 1800 Falling Number apparatus according to the AACC method 56-81.04 (AACC, 2010). Flour Zeleny and delayed retarded Zeleny sedimentation values were calculated using the AACC approved method 56-61.02 (AACC, 2010). Wet and dry gluten values of the samples were determined according to Approved Method 38-12.02 (AACC, 2010).

Color measurements were carried out using a calibrated colorimeter CR 200 (Konica Minolta Co. LTD, Osaka, Japan).  $L^*$  (0 black and 100 white),  $a^*$  (greenness and redness), and  $b^*$  (blueness and yellowness) color values were determined as defined by CIE (International Commission on Illumination). Total color change ( $\Delta E$ ) was calculated as follows:

$$\Delta E = [(L_0 - L_1)^2 + (a_0 - a_1)^2 + (b_0 - b_1)^2]^{1/2},$$

where  $L_0$ ,  $a_0$ ,  $b_0$  are  $L^*$ ,  $a^*$ , and  $b^*$  color values of the

flour obtained from ungerminated grain,  $L_1$ ,  $a_1$ ,  $b_1$  are  $L^*$ ,  $a^*$ , and  $b^*$  color values of the flour obtained from germinated grains, respectively.

Dough mixing properties and water absorption capacity of flour were determined according to AACC approved methods 54-21.02 (AACC, 2010) by using Farinograph with 300 g mixing bowl (Yücebaş Machine).

#### 2.4. Bread-making and technological evaluation of bread

In the preparation of bread samples, basic straight dough process was used AACC 10-09.01 (AACC, 2010). Basic dough recipe with 3% yeast, 1.5% salt based on 100 g flour weight and amount of water up to optimum consistency of 500 BU were used. Enzyme-active malt flours and commercial amylolytic enzyme were added to bread flour at levels that would ensure an FN of  $275 \pm 5$  s to increase the enzyme activity of the flour. Additional levels were determined as 0.880%, 0.570%, 1.067%, 0.5985, 1.455%, 1.356%, 1.902%, 1.705%, 0.011% for wheat, barley, rye, triticale, millet, corn, oats, paddy malt and commercial enzyme (amylolytic), respectively. All ingredients were mixed in a mixer (Stephan-UM5, Stephan, Erlangen, Germany), at high speed for 2 min. After mixing, the dough was divided into 160 g portions and molded. After 60 min of fermentation at 30 °C and 80% relative humidity, the dough was sheeted and rolled, put into baking pans, proofed in a fermentation cabinet at 30 °C and 85% relative humidity for 40 min, followed by baking at 230 °C for 25 min. Control bread was prepared exactly as described above, without malt flour and commercial enzyme. Bread samples were allowed to cool for a minimum of 60 min before packaging and further testing.

Breads were weighed within 1 h after baking, volumes of breads were determined with rapeseed displacement method according to official method (AACC 10-05.01, 2010) and specific volumes were calculated by dividing the volume by the mass of the loaf.

Color values of  $L^*$ ,  $a^*$ , and  $b^*$  of bread samples were determined as stated in the flour samples by using the Minolta CR-200. Using these color values, the total color change ( $\Delta E$ ) was calculated with the following equation.  $\Delta E = [(L_0 - L_1)^2 + (a_0 - a_1)^2 + (b_0 - b_1)^2]^{1/2}$  where  $L_0$ ,  $a_0$ ,  $b_0$  are  $L^*$ ,  $a^*$ , and  $b^*$  color values of control bread sample;  $L_1$ ,  $a_1$ ,  $b_1$  are  $L^*$ ,  $a^*$ , and  $b^*$  color values of bread samples with malt flour and enzyme.

The textural characteristics of the bread were measured with a Texture Analyzer TA.XT2i (Stable Microsystems, Godalming, U.K.) equipped with an aluminum 35 mm diameter cylindrical probe and 5 kg load cell. Samples (cut by an electronic knife) of 2.5 mm thickness  $\times$  2.5 mm length  $\times$  2.5 mm wide obtained from the bread center part were assessed applying 'texture profile analysis (TPA)' double compression test. The settings used were a 40% strain, 10 g trigger force, test speed of 1 mm/s with 5 s

delay between the 1st and 2nd compression and posttest speed 5 mm/s. Four primary TPA parameters (hardness, cohesiveness, springiness, adhesiveness) and one derived parameter (chewiness) were calculated. TPA of bread crumb was measured at days 1 and 3 to assess the potential shelf life of the breads.

#### 2.5. Statistical analysis

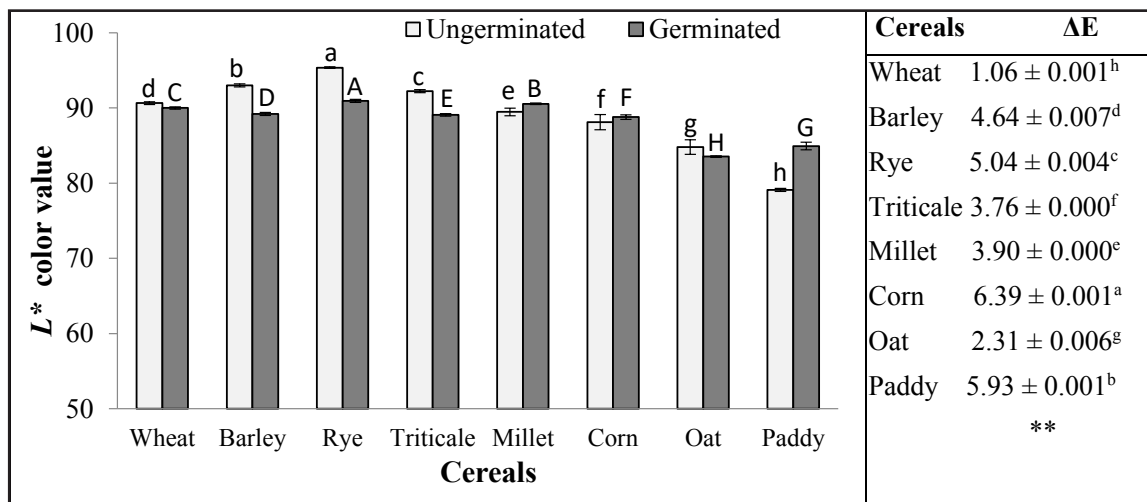
All the experiments were carried out in triplicate and in two different trials. SPSS 10.0 software for Windows (SPSS for Windows Release 10.01, Chicago, IL, USA, SPSS Inc.) was used to perform statistical analyses. Differences in properties of flour and bread because of addition of malt flour were tested for significance using analysis of variance (ANOVA) techniques. Duncan's new multiple range test was used when the ANOVA indicated significant difference in mean values. A level of significance of  $p < 0.05$  was used throughout the analysis.

### 3. Results

#### 3.1. Flour Properties

$L^*$  color values of the germinated and ungerminated grain flour samples and color change ( $\Delta E$ ) values caused by germination in cereal flour are given in Figure 1. The germination process performed to increase the amylolytic enzyme activity in cereals also caused color change in the flour obtained from these cereals. The color values of the grains are naturally different from each other and these differences are subsequently reflected in the flours and breads. The important point here is that the germination process affected the colors of the grains differently. Although germination decreased the  $L^*$  color values denoting the lightness of barley, rye, wheat, oats and triticale; it increased millet, corn, and paddy  $L^*$  color values. In addition, the total color change ( $\Delta E$ ) calculated before and after germination using the brightness ( $L^*$ ), redness ( $a^*$ ), and yellowness ( $b^*$ ) color values were high in corn, paddy, and rye. However, low total color change in wheat and oat was observed. The change in  $L^*$ ,  $a^*$ , and  $b^*$  color values with the germination process was found similar to the results of the study conducted by Üstün and Çelik (2011).

The germination process significantly increases the diastatic enzyme activity in cereals. The most basic and simple method of measuring diastatic enzyme activity is the FN test. The optimal FN value for wheat flour is between 230 and 270 s. The  $\alpha$ -amylase in flour breaks down starch to fermentable sugars and the amount of  $\alpha$ -amylase present in the flour have a crucial effect on the bread quality to be produced. When the activity of  $\alpha$ -amylase is at the optimal level, the resulting bread will be firm harboring high volume and soft texture. However, excessive activity of  $\alpha$ -amylase might result in a bread with low volume and sticky crumb. Moreover, very low



**Figure 1.**  $L^*$  color values of germinated and ungerminated cereal flours and total color change ( $\Delta E$ ) caused by germination in cereal flours (\*\* $p < 0.01$ ) (mean  $\pm$  standard error).

activity of alpha-amylase yields a bread with small volume and dry crumb (Pekmez, 2019; Iorga et al., 2002; Dahal, 2012). FN values obtained in this study are shown in Table 1. To determine the increase in diastatic activity occurring in grains by germination process, the FN values before and after germination were compared. However, a very high enzymatic activity in germinated grain flours prevented the determination of enzymatic activity in the FN test. Therefore, germinated cereal flours were added to their ungerminated form at 1% and the measurements were compared. FN is inversely related to the  $\alpha$ -amylase activity of the flour. As seen in Table 1, the germination process decreased the FN values in all grains. This suggests that the germination process results in an increase in the alpha amylase activity as falling number is inversely correlated to the alpha amylase activity (Leghari et al., 2020). FN values decreased by 34%, 75%, 30%, 53%, 71%, 71%, 10%, and 84% for wheat, barley, rye, triticale, millet, corn, oat, and paddy, respectively. If the addition of germinated grain flour is considered to be at a low level (i.e. 1%), it would be better recognized how drastic this increase is.

Enzyme active malt flours obtained from different germinated grains (wheat, barley, rye, triticale, millet, maize, rice, oat) and commercial enzyme were added to wheat flour in a level that provide the same FN (274 s). Zeleny sedimentation, delayed Zeleny sedimentation, wet and dry gluten, gluten index values of wheat flour and containing different malt flour and enzyme are given in Table 2. The addition of enzyme and malt flour had a significant ( $p < 0.05$ ) effect on the gluten index value of the flour and a very significant ( $p < 0.01$ ) effect on delayed Zeleny sedimentation value. However, Zeleny

sedimentation and wet and dry gluten contents were not statistically influenced by malt and commercial enzyme addition.

The principle of the Zeleny sedimentation test is based on swelling of gliadin and glutenin proteins within an ethanol-lactate-solution. As seen in Table 2, although statistically insignificant, Zeleny sedimentation value was found higher in flour containing triticale, millet, and corn malt, compared to flour containing paddy and rye malt. The highest delayed Zeleny sedimentation value (46 cm<sup>3</sup>) was determined in flour containing commercial enzyme, while the lowest (36.5 cm<sup>3</sup>) was found in flour containing paddy malt, compared to control flour. The reason behind low delayed Zeleny sedimentation value of flour containing paddy malt might be due to the increase in protease activity with germination process (Likittrakulwong et al., 2021). However, there was no significant difference ( $p > 0.05$ ) observed among delayed Zeleny sedimentation values of flours containing barley, rye, millet, and oat malt. The Zeleny and delayed Zeleny sedimentation tests are rapid means of estimating the baking quality of wheat flour. The test involves the rate of sedimentation of the solid phase following suspension of the flour in an aqueous lactic acid solution and relies on the relationship between flour baking strength and gluten hydration capacity, which is, in turn, a function of gluten quantity and quality (Abbasi et al., 2012). In wheat flour containing high gluten content and quality, the particles are more densely packed and less precipitated in the solution. Thus, Zeleny sedimentation values of high quality wheat flours were higher. Zeleny sedimentation value of <15 corresponds to very weak flour; that of between 16 and 24 is attributed to weak

**Table 1.** Falling number values of ungerminated cereal flours and flours containing 1% of malt flours obtained by germination of these grains.

		Cereal flours							
		Wheat	Barley	Rye	Triticale	Millet	Corn	Oat	Paddy
FN (s)	Ungerminated	390	1489	285	366	2303	2095	310	3639
	Added with 1% germinated	255	366	199	171	665	590	276	580

FN: Falling number

**Table 2.** Zeleny sedimentation, delayed Zeleny sedimentation, wet and dry gluten, gluten index values flour samples containing different malt flour and enzyme.

Flour samples	Zeleny sedimentation (cm <sup>3</sup> )	Delayed Zeleny sedimentation (cm <sup>3</sup> )	Wet gluten (%)	Dry gluten (%)	Gluten index (%)
Control (wheat) flour	33.50 ± 0.50 <sup>a</sup>	37.50 ± 1.50 <sup>cd</sup>	32.99 ± 0.17 <sup>a</sup>	11.01 ± 0.23 <sup>a</sup>	89.73 ± 2.11 <sup>bc</sup>
Wheat	33.00 ± 0.00 <sup>a</sup>	40.50 ± 0.50 <sup>b</sup>	32.95 ± 0.35 <sup>a</sup>	10.81 ± 0.08 <sup>a</sup>	84.80 ± 0.89 <sup>c</sup>
Barley	33.00 ± 0.00 <sup>a</sup>	39.00 ± 0.00 <sup>bcd</sup>	33.27 ± 0.69 <sup>a</sup>	11.11 ± 0.02 <sup>a</sup>	88.59 ± 0.78 <sup>bc</sup>
Rye	32.50 ± 0.50 <sup>a</sup>	38.50 ± 0.50 <sup>bcd</sup>	32.58 ± 0.30 <sup>a</sup>	10.62 ± 0.10 <sup>a</sup>	90.76 ± 0.02 <sup>ab</sup>
Triticale	34.25 ± 0.25 <sup>a</sup>	40.00 ± 0.00 <sup>bc</sup>	30.12 ± 2.63 <sup>a</sup>	10.75 ± 0.15 <sup>a</sup>	95.45 ± 2.42 <sup>a</sup>
Millet	34.25 ± 0.75 <sup>a</sup>	39.00 ± 0.00 <sup>bcd</sup>	32.73 ± 0.24 <sup>a</sup>	10.57 ± 0.08 <sup>a</sup>	86.48 ± 0.26 <sup>bc</sup>
Corn	34.00 ± 1.00 <sup>a</sup>	39.50 ± 0.50 <sup>bc</sup>	33.37 ± 0.04 <sup>a</sup>	11.20 ± 0.04 <sup>a</sup>	90.14 ± 3.02 <sup>abc</sup>
Oat	33.50 ± 0.50 <sup>a</sup>	38.75 ± 0.25 <sup>bcd</sup>	33.31 ± 0.47 <sup>a</sup>	11.17 ± 0.13 <sup>a</sup>	91.11 ± 1.69 <sup>ab</sup>
Paddy	32.75 ± 0.25 <sup>a</sup>	36.50 ± 0.50 <sup>d</sup>	33.83 ± 0.11 <sup>a</sup>	11.12 ± 0.14 <sup>a</sup>	87.08 ± 1.82 <sup>bc</sup>
Enzyme (α-amylase)	33.00 ± 2.00 <sup>a</sup>	46.00 ± 2.00 <sup>a</sup>	34.35 ± 2.71 <sup>a</sup>	10.80 ± 0.65 <sup>a</sup>	86.35 ± 0.46 <sup>bc</sup>
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Different letters in the same column are significantly different (\*p < 0.05; \*\*p < 0.01) (mean ± standard error).

flour; that of 25–36 is considered good flour; >36 is considered very good (Elgün et al., 2011). The delayed Zeleny sedimentation test is based on the principle of reduction in the precipitate formed by the flour particles. This is achieved by hydrolysis of gluten proteins that are kept in a weak acid solution for a certain period of time. If the delayed Zeleny sedimentation value is lower than the normal Zeleny sedimentation value, it means that the protease activity in the flours is high enough to reduce the quality of the flour (Arslan, 2018). Therefore, the delayed sedimentation value is desired to be higher or similar to the normal sedimentation value (Özbay, 2014). Delayed sedimentation value was higher in flour containing malt flour and enzyme than in normal sedimentation. Although the main goal is to increase amylolytic enzyme activity, it is reported that the germination process to obtain malt flour increases amylase, phytase, and some protease activity (Bilgiçli and Türker, 2004). When the results in Table 2 are

analyzed, it is seen that the protease activity in malt flour is not at a level to negatively affect the quality of the flour.

Wet gluten content and gluten index are important for evaluating the processing quality of wheat, since they are measurements of both gluten quality and content (Zhang et al., 2016). The use of commercial enzyme and malt flour did not show a statistically significant effect on the wet and dry gluten values of flour samples (p > 0.05). Since the enzyme-active malt flour addition level was very low, there was no significant change in the wet gluten content of the flours. However, due to enzymes in malt flour, gluten index values were affected differently by added malt flours. The highest gluten index values were found in triticale malt-added flour, while the lowest values were determined in wheat-malt-added flour. The gluten index values were statistically the same in control flour (without enzyme) and flour samples containing commercial enzyme, barley malt, millet malt, and paddy malt.



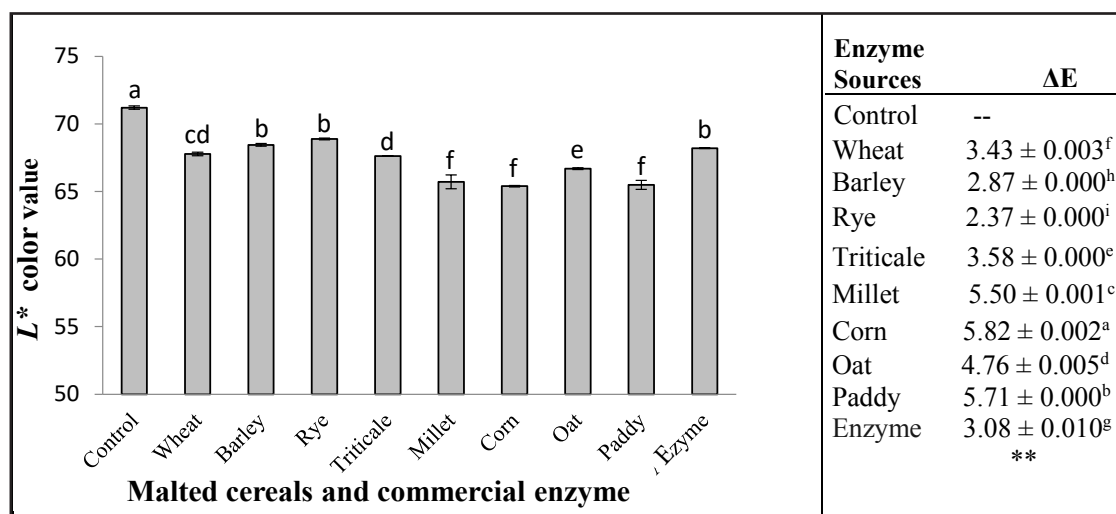
### 3.2. Bread properties

In calculation of total color changes, the control bread was taken as reference and the color change caused by the addition of different malt flours and commercial enzymes to bread was calculated. According to the values given in Figure 2, it is seen that the highest color change occurred in bread with corn malt, while the lowest change occurred in rye malt. It is desirable that the addition of malt flour to bread flour increases the amylolytic enzyme activity and should not affect the color. Therefore, given the total color change values, the best results were obtained by rye, barley malt, commercial enzyme, wheat and triticale malt, respectively, while breads containing corn, paddy, millet, and oat malt had more color change compared to control bread. Breads produced with flour containing enzyme-active malt flour showed a significantly ( $p < 0.01$ ) lower value of the  $L^*$  color parameter compared to the control samples. The addition of enzyme active malt flour darkened the bread crumb. This could be attributed to the fact that malt flours are darker in color than bread wheat flour (Belcar et al., 2022). The decrease in L color value of bread crumb was especially greater in breads containing millet, maize, oat, and paddy malt flour. As seen in Figure 2, the total color change values in breads containing millet, corn, oat, and paddy malt flours were higher than the other breads.

Specific volume is one of the most important quality parameters of bread (Mudgil et al., 2016). The highest specific volume of  $4.784 \text{ cm}^3/\text{g}$  was obtained in bread with paddy malt. However, the lowest specific volume of  $4.174 \text{ cm}^3/\text{g}$  was obtained in bread with wheat malt (Figure 3). Wheat, barley and millet malt containing bread samples were found statistically similar to the control sample with

regards to specific volume. The specific volume values of the breads produced from flours containing commercial enzyme, corn and rye malt did not differ statistically and these values were higher than the control group breads. Mäkinen and Arendt evaluated the effect of addition of 0.5%, 1.0%, 2.5% and 5.0% oats, barley and wheat malt to bread flour on bread and dough properties (Mäkinen and Arendt, 2012). They reported that specific volume of bread increased with the increase of addition rate of malt, and the addition of 2.5% wheat and barley malt increased the specific volume from  $3.04 \text{ cm}^3/\text{g}$  to 3.36 and  $3.44 \text{ cm}^3/\text{g}$ , respectively. As seen from Figure 3, bread with paddy malt had higher specific volume compared to others. Veluppillai et al. (2010) reported that the paddy malt obtained by germinating for 3 days was effective in increasing the bread volume.

Textural properties are an important quality criterion in bakery products with a soft internal structure such as bread. Bread crumb firmness is defined as the maximum force measured during the first compression in the TPA test. The low maximum force indicates soft bread crumb texture, which is desired by consumers. As shown in Figure 4, the highest bread firmness value was determined in the control group bread, while the lowest value was found in commercial-enzyme-added bread. A decrease in the firmness value was observed in all the bread containing malt flour and enzyme, compared to the control bread without malt flour and enzyme. In terms of hardness values on the first day, no statistically significant difference was observed among the hardness values of the breads containing wheat, triticale, and millet malt. Bread firmness increases with storage mainly due to structural changes (such as retrogradation) in starch and the



**Figure 2.** Influence of malt flour and enzyme on  $L^*$  color value and total color change ( $\Delta E$ ) of bread crumb (\*\* $p < 0.01$ ) (mean  $\pm$  standard error).

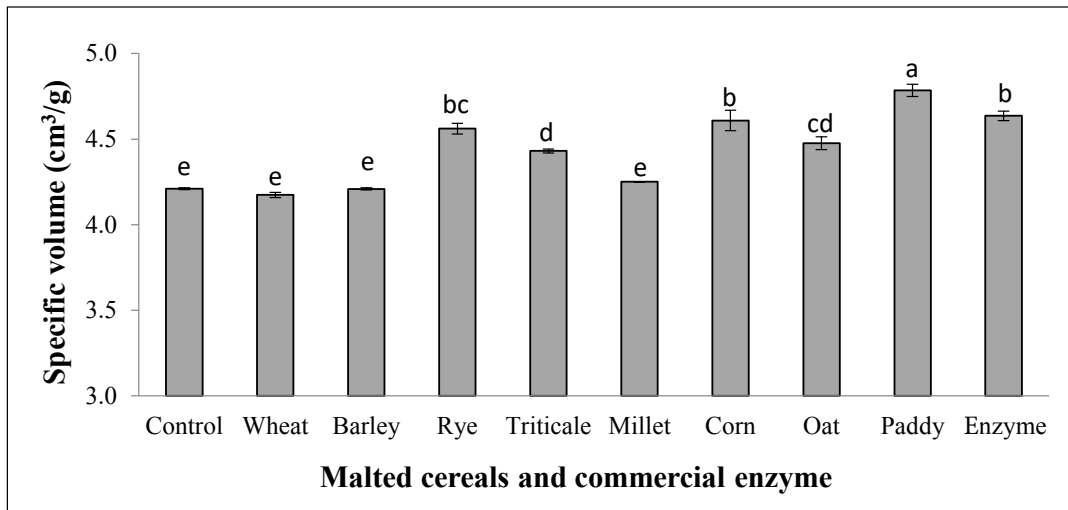


Figure 3. Influence of malt flour and enzyme on specific volume of bread

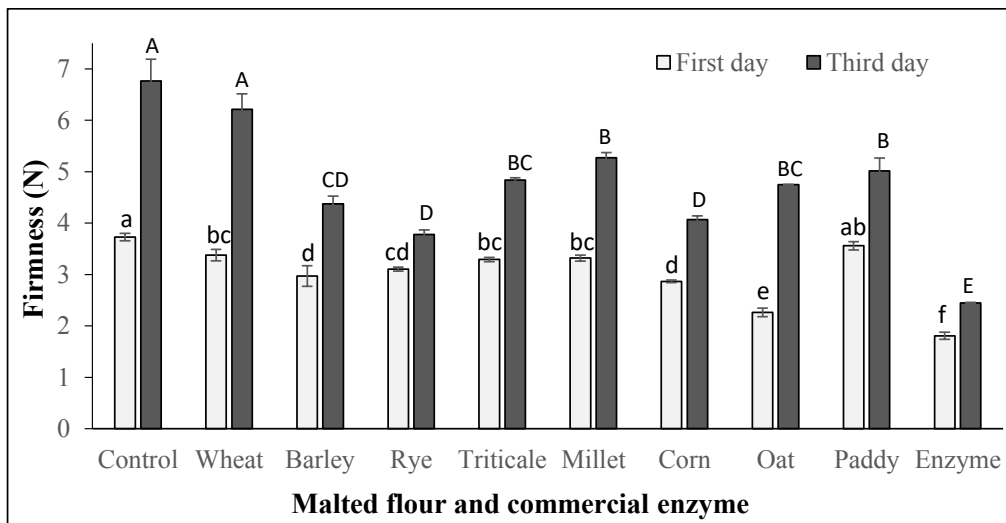


Figure 4. Influence of malt flour and enzyme on firmness of bread crumb.

formation of cross-links between partially dissolved starch and gluten proteins. All undesirable changes that occur upon storage are called staling (Tamani et al., 2013). As starch retrogradation occurring during storage caused the increased rigidity in the crumb matrix (Arslan, 2018), the increase in storage time caused a significant increase in the bread firmness values. With the increase of storage time, the highest increase (110%) in firmness was observed in oat malt-added bread, while the lowest increase (21%) was seen in rye-malt-added bread. The freshness of bakery products, especially for bread, is generally demanded by consumers. The most important parameter determining the perception of freshness is the softness of the bakery product and it is generally considered that the softer the

bakery product is, the fresher it is. However, in bakery products with a soft internal structure such as bread, it is desired that this softness should be maintained or firmness should not increase too much with storage (Karaoğlu and Kotancilar, 2005). In this study, when the hardness values of both the 1st and 3rd days were taken into consideration, it was seen that the use of barley, rye, corn, oat malt, and the commercial enzyme provide better results compared to the control group bread sample.

Cohesiveness, the ratio of the second positive area to the first positive area in the TPA graph (Uslu et al., 2010), is a measure of the degree of difficulty in breaking down the flesh internal structure (Yang et al., 2007). Breads with low cohesiveness are more susceptible to fracture

and crumble. Therefore, breads with high cohesiveness value are more preferred (Demirkesen et al., 2014). Breads with high cohesiveness values allow a bolus to be formed during mastication instead of breaking up (Martínez et al., 2013). In breads produced with the addition of malt flours obtained from different grains, the highest cohesiveness value was determined in rye-malt-supplemented recipe, while the lowest values were achieved when paddy malt and commercial enzyme were supplemented (Figure 5). Apart from wheat, barley, rye, and oat malt, all other enzymatic additives were effective in decreasing the cohesiveness value, compared to the control bread. When storage time increased from day 1 to day 3, the cohesiveness value increased in triticale malt and commercial enzyme added-bread, while it decreased in other bread samples. The cohesiveness of bread is influenced by the gluten amount and quality of flour, as well as the gelatinization and hydrolysis properties of starch molecule (Hayıt and Gül, 2017). Gluten index is an indicator of gluten strength, as well as a parameter which simultaneously defines its quantity and quality. In general, bread samples obtained from flours with high gluten index (Table 2) exhibited high cohesiveness values.

While the highest springiness values were determined in breads with rye, wheat, oat, triticale malt, and control bread, this value was lowest in bread made using commercial enzyme (Figure 6). An increase in the storage time caused a small increase in springiness of bread containing barley malt, while it had a decreasing effect on all other bread samples. In this study,  $\alpha$ -amylase of bacterial origin (*Bacillus subtilis*) was used as commercial

enzyme. The thermal stability of bacterial amylolytic enzymes is higher than those of cereal malt flour. These enzymes retain their activity better during the baking of the bread and after the bread is baked, it breaks down the gelatinized starch in the bread, which softens the bread crumb and reduces its elasticity (Elgün and Ertugay, 2002). Therefore, the springiness value of commercial enzyme added-bread was found to be quite low, compared to other enzyme sources. As seen in Figure 4, the fact that the crumb firmness values of breads containing commercial enzymes are quite low also supports this effect. Springiness is an important quality parameter of the bread which reflects the softness, and its ability to get back to its original condition when subjected to different handling conditions (Paul et al., 2019). From this point of view, it is important that the bread firmness should be evaluated together with elasticity, and the bread firmness value is low and the elasticity value is as high as possible. However, the factors that generally reduce the firmness of bread crumb, which makes the bread crumb too soft, also reduce the elasticity of the crumb. Therefore, it is more desirable to have a balance between crumb firmness and springiness. As in commercial enzyme-added bread, the low firmness and springiness values of the bread crumb show that the bread crumb has a more doughy structure since it is softer but not elastic.

Chewiness is the energy required to chew a solid food product to a state where it is ready for swallowing, and it is calculated as the product of hardness, cohesiveness, and springiness (Peng et al., 2017). Therefore, changes in crumb chewiness generally reflected the changes in

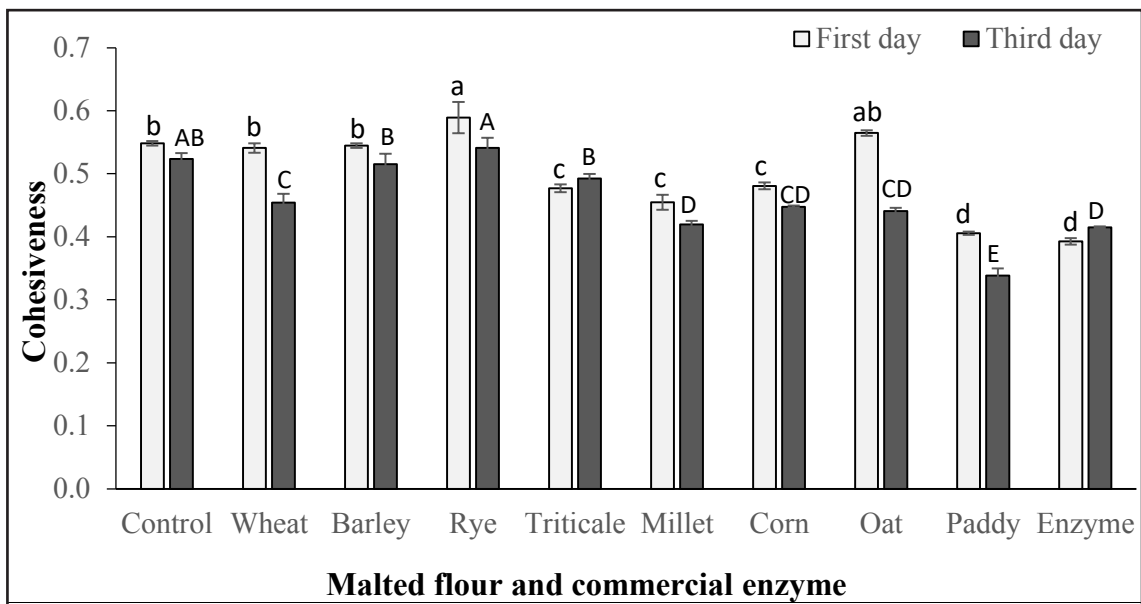


Figure 5. Influence of malt flour and enzyme on cohesiveness of bread crumb.



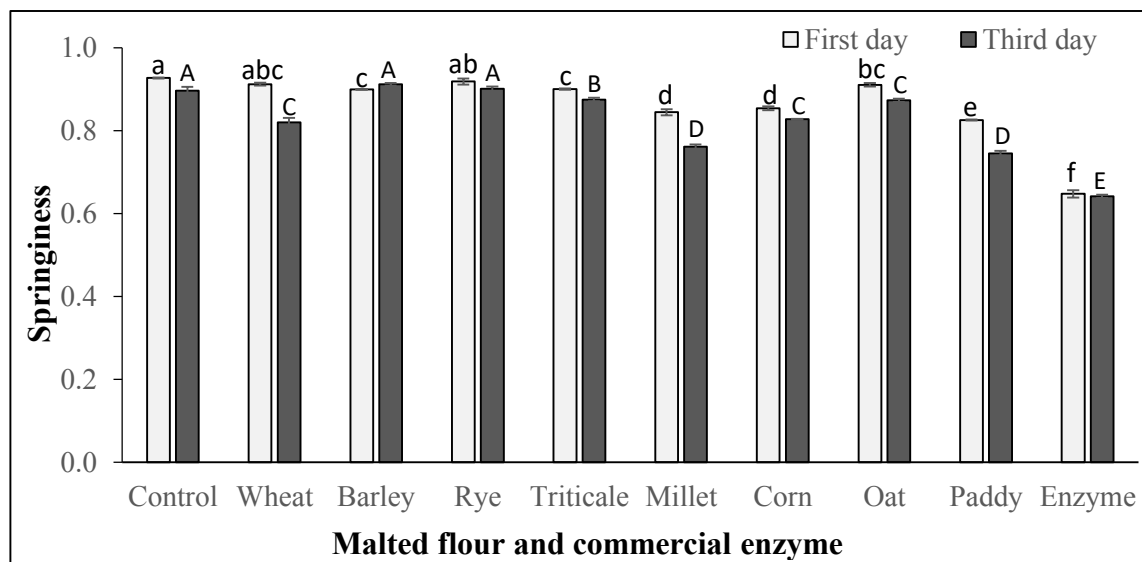


Figure 6. Influence of malt flour and enzyme on springiness of bread crumb.

firmness, cohesiveness, and springiness (Onyango et al., 2010). As with the springiness and firmness values, the highest chewiness value was determined in control bread, though the lowest value was determined in commercial enzyme added-bread (Figure 7). The increase in storage time increased the chewiness values in all bread samples and this increase was higher in control samples, compared to others. In both first and third days of storage, adding of enzyme active malt flour and commercial enzyme to flour was effective in reducing the chewiness value of bread. Chewiness and firmness are negatively correlated with pan bread quality (Ning et al., 2017). Compared to the control, there was a significant decrease in the chewiness and firmness values of the breads with malt flour. Therefore, it is possible to say that the addition of enzyme-active malt flour has a positive effect on the quality of breads. We hypothesized that firmness and chewiness decreased with the addition of malt flour because amylolytic hydrolysis of gelatinized starch destroyed the three-dimensional polymer network in the crumb.

As seen in Figure 8, the adhesiveness value was quite high in commercial-enzyme-added bread, compared to others. While the increase in storage time was effective in decreasing the adhesiveness values of bread crumb containing wheat, triticale, corn, oat, and paddy malt additives, it was effective in increasing in other bread samples. Adhesiveness, work required to overcome the attractive forces between the surface of the food and the surface of the material responsible for the deformation, is an indicator of the degree of adhesion to the teeth during food chewing (Carocho et al., 2020). It was reported that the adhesiveness values of bread crumb decreases with

increasing storage time (Demiray et al., 2015; Paciulli et al., 2016; Rinaldi et al., 2017; Barışık and Tavman, 2018) and increases with increasing amylolytic enzyme activity (Onyango et al., 2010). In the present study, the adhesiveness values (data not given) measured after 5 days of storage decreased in all bread samples, except for bread to which commercial enzyme was added. However, the adhesiveness values in bread samples made using commercial enzymes continued to increase after 5 days of storage, unlike other breads. Since the commercial enzyme ( $\alpha$ -amylase) used in this study is of a spore forming bacterial origin, its thermostability is expected to be higher. Upon baking the bread, this perhaps results in showing residual activity during the storage period and increases the adhesiveness of the bread crumb. As expected, in agreement with the increase in crumb adhesiveness and softness of bread; the firmness, cohesiveness, springiness, and chewiness values were found to be lowest in commercial enzyme added-breads.

#### 4. Conclusion

The germination process to increase the enzyme activity in cereal grains caused color changes in the flour obtained from these grains, and those changes were also reflected in the color values of bread crumb. The germination process significantly increased diastatic activity in all grains, especially in barley, millet, corn and paddy. Malt flours obtained from different grains were added to the bread flour to provide 274 seconds of FN (the ideal level of enzymatic activity in bread flours). Addition levels of malt flours varied between 0.57% (barley malt) and 1.90% (oat malt), were depended on the type of grain. The addition

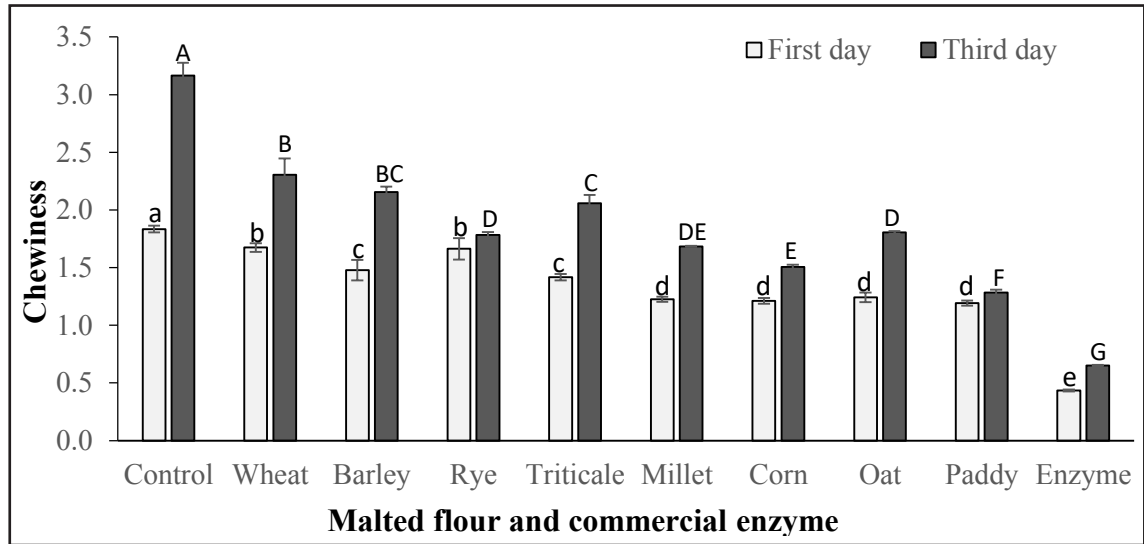


Figure 7. Influence of malt flour and enzyme on chewiness of bread crumb.

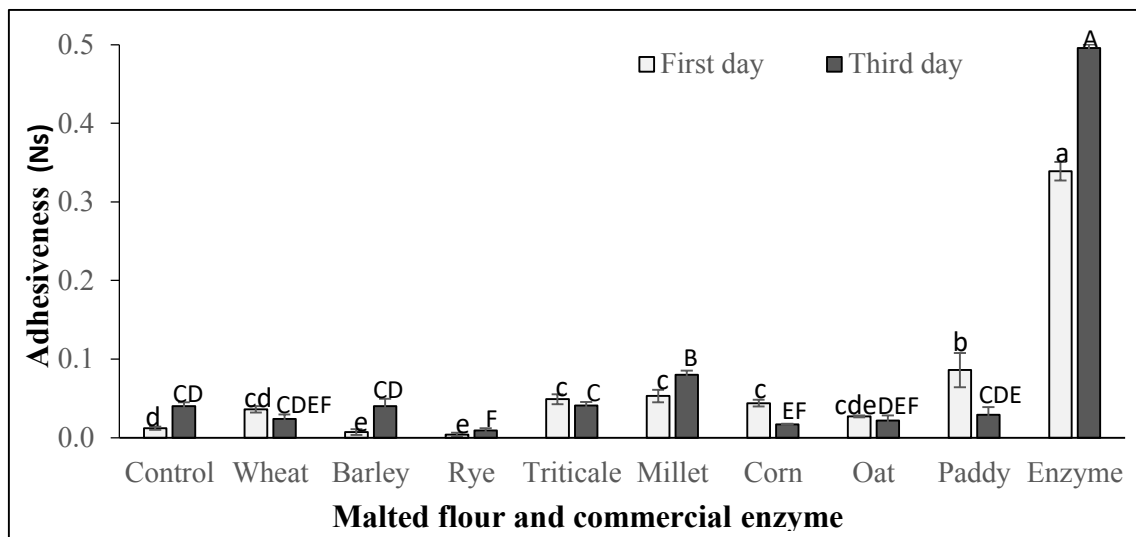


Figure 8. Influence of malt flour and enzyme on adhesiveness of bread crumb.

of different malt flours and commercial enzyme did not have a significant effect on the wet gluten, dry gluten and Zeleny sedimentation values of bread flour, while they exerted a significant effect on the gluten index and Zeleny sedimentation values. Considering the gluten index and the kept Zeleny sedimentation values, it is possible to say that the malt flour added to increase the diastatic activity of the flour does not adversely affect the protein quality of the flour. Addition of rye, triticale, corn, oats, paddy malt and commercial enzyme had a positive effect on the specific volume values of bread samples. In terms of

firmness, which was an important quality parameter of bread, it was seen that the use of enzyme active malt flour and commercial enzymes gave better results compared to the control sample. However, it is possible to say that the commercial enzyme addition does not give better results, compared to malt flours, as it reduces the springiness value of the bread and increases the adhesiveness value too much. Considering all the bread quality characteristics, it was concluded that enzyme active rye, oats, corn, barley and paddy malts can be used to increase diastatic activity in bread flours without disturbing other quality parameters.

**Conflict of interest**

The article authors declare that there is no conflict of interest between them.

**References**

- AACC (2010). AACC International Approved Methods of Analysis, AACC International, St. Paul, MN, USA, 11th edition.
- Abbasi H, Ardabili SMS, Emam-Djomehi Z, Mohammadifar MA, Zekri M et al. (2012). Prediction of extensograph properties of wheat-flourdough: artificial neural networks and a geneticalgorithm approach. *Journal of Texture Studies* 43: 326-337.
- Abd-Elstatar HH (2018). Influence of ultrasonic treatment on barley grains germination as well as pan bread quality. *Egyptian Journal of Agricultural Research* 96 (3): 1057-1067. <https://doi.org/10.21608/ejar.2018.140381>
- Ait Kaki El-Hadef El-Okki A, Gagaoua M, Bourekoua H, Hafid K, Bennamoun L et al. (2017). from *Rhizopus oryzae* FSIS4. *Foods* 6: 1. <https://doi.org/10.3390/foods6010001>
- Aladejana OM, Oyedeji O, Omoboye OO, Bakare MK (2020). Production, purification and characterization of thermostable alpha amylase from *Bacillus subtilis* Y25 isolated from decaying yam (*Dioscorea rotundata*) tuber. *Notulae Scientia Biologicae* 12(1): 154-171. <https://doi.org/10.15835/nsb12110521>
- Aljabi HR, Pawelzik E (2021). Impact of cultivar and growing conditions on alpha-amylase properties in wheat. *Starch* 73 (3-4). <https://doi.org/10.1002/star.202000032>
- Arslan EZ (2018). Prediction of quality parameters of flour by using near and mid infrared spectroscopy. MSc, Hacettepe University Graduate School of Natural and Applied Sciences, Department of Food Engineering, Ankara, Turkey.
- Baranwal D (2017). Malting: An indigenous technology used for improving the nutritional quality of grains: A review. *Asian Journal of Dairy and Food Research* 36: 179-183. <https://doi.org/10.18805/ajdfr.v36i03.8960>
- Baranzelli J, Kringel DH, Colussi R, Paiva FF, Aranha BC et al. (2018). Changes in enzymatic activity, technological quality and gamma-aminobutyric acid (GABA) content of wheat flour as affected by germination. *LWT - Food Science and Technology* 90: 483-490. <https://doi.org/10.1016/j.lwt.2017.12.070>
- Barişık D, Tavman Ş (2018). Using chickpea flour in gluten free bread formulation to effect of bread quality. *Academic Food Journal* 16 (1): 33-41 (in Turkish with an abstract in English). <https://doi.org/10.24323/akademik-gida.415652>
- Belcar J, Kaszuba J, Gorzelany J (2022). Effect of wheat and barley malt addition on the quality of the baking blend and wheat bread. *Polish Journal of Food and Nutrition Sciences* 72(2): 129-139. <https://doi.org/10.31883/pjfn/147796>
- Bilgiçli N, Türker S (2004). The effects of yeast, malt flour and phytase additions on digestible protein and ash content of tarhana. *Selçuk Journal of Agriculture and Food Sciences* 18 (33): 90-97 (in Turkish). <https://doi.org/10.10007/s13197-014-1598-x>

**Author contributions**

The authors declare that they have contributed equally to the article.

- Boz H, Karaoğlu MM (2013). Improving the quality of whole wheat bread by using various plant origin materials. *Czech Journal of Food Sciences* 31 (5): 457-466. <https://doi.org/10.17221/410/2012-CJFS>
- Carocho M, Morales P, Ciudad-Mulero M, Fernández-Ruiz V, Ferreira E et al. (2020). Comparison of different bread types: Chemical and physical parameters. *Food Chemistry* 310: e125954. <https://doi.org/10.1016/j.foodchem.2019.125954>
- Dahal KP (2012). Assessment of pre-harvest sprouting resistance in spring wheat in Norway. MSc, Norwegian University of Life Sciences, Department of plant and environmental sciences, Norway.
- Demiray E, Çelik İ, Nogay O, Tülek Y (2015). Color and textural properties of Denizli Karahöyük (Turkey) bread *Zıgır. Academic Food Journal* 13: 223-228 (in Turkish with an abstract in English).
- Demirkesen İ, Kelkar S, Campanella OH, Sumnu G, Sahin S, Okos M (2014). Characterization of structure of gluten-free breads by using X-ray microtomography. *Food Hydrocolloids* 36: 37-44. <https://doi.org/10.1016/j.foodhyd.2013.09.002>
- Dura A, Rosell CM (2017). Enzymes in Baking. In: Ray RC, Rosell CM (editors). *Microbial Enzyme Technology in Food Applications*. Broken Sound Parkway NW, Boca Raton, FL, CRC Press Taylor & Francis Group, pp. 295-314.
- Durmuş E (2022). The quality properties of malt flours made from some cereals and effects on the bioactive and physicochemical properties of bread. MSc, Kastamonu University Graduate School of Natural and Applied Sciences, Department of Food Engineering, Kastamonu, Turkey
- Elgün A, Ertugay Z (2002). *Tahıl İşleme Teknolojisi*. Erzurum, Turkey: Atatürk Üniversitesi Ziraat Fakültesi Yayınları (in Turkish).
- Elgün A, Ertugay Z, Certel M, Kotancılar HG (2011). *Tahıl ve Ürünlerinde Analitik Kalite Kontrolü ve Laboratuvar Uygulama Kılavuzu*. Erzurum, Turkey: Atatürk Üniversitesi Ziraat Fakültesi Yayınları (in Turkish).
- Farzaneh V, Ghodsvali A, Bakhshabadi H, Zare Z, Carvalho IS (2017). The impact of germination time on the some selected parameters through malting process. *International Journal of Biological Macromolecules* 94: 663-668. <https://doi.org/10.1016/j.ijbiomac.2016.10.052>
- Hayit F, Gül H (2017). Effect of the buckwheat flour and transglutaminase addition on physical and textural properties of partially-baked frozen sourdough bread. *Mediterranean Agricultural Sciences* 30 (2): 113-119 (in Turkish with an abstract in English).
- Honcu I, Krejcirova L, Prihoda J, Slukova M (2015). The effect of addition of malt flour on the dough, volume and sensory properties of bread. *Paripex - Indian Journal of Research* 4 (9): 152-155.

- Iorga E, Belc N, Stancov A, Campeanu GH (2002). Improvement of falling number on Romanian wheat flours. *Roumanian Biotechnological Letter* 7 (2): 635-646.
- Jan R, Saxena, DC, Singh S (2017). Effect of germination on nutritional, functional, pasting, and microstructural properties of *Chenopodium* (*Chenopodium album*) flour. *Journal of Food Processing and Preservation* 41 (3): e12959. <https://doi.org/10.1111/jfpp.12959>
- Kara B, Acun S, Gül H (2020). Effect of grain size on some flour quality characteristics of bread wheat (*Triticum Aestivum* L.) cultivars. *Black Sea Journal of Agriculture* 3 (4): 246-252 (in Turkish with an abstract in English).
- Karaoğlu MM, Kotancılar HG (2005). Effect of part-baking method and storage on softness of bread crumb. *The Journal of Food* 30 (2): 117-122 (in Turkish with an abstract in English).
- Koç Ö (2015). Production, purification and characterization of extracellular  $\alpha$ -amylase from *Aspergillus fumigatus* HBF125. PhD, Adnan Menderes Graduate School of Natural and Applied Sciences, Department of Biology, Aydın, Turkey.
- Kostyuchenko M, Martirosyan V, Nosova M, Dremucheva G, Nevskaya E et al. (2021). Effects of  $\alpha$ -amylase, endo-xylanase and exoprotease combination on dough properties and bread quality. *Agronomy Research* 19 (S3): 1234-1248. <https://doi.org/10.15159/AR.21.067>
- Leghari AA, Afraz MT, Arslan M, Ghani SM, Basit M et al. (2020). Quality Assessment of cereal based foods through its rheological, proximate and mineral analysis. *The International Journal of Global Sciences* 3 (1): 44-52
- Likittrakulwong W, Poolprasert P, Srikaeo K (2021). Effects of extraction methods on protein properties obtained from paddy rice and germinated paddy rice. *Peer Journal* 9: e11365. <https://doi.org/10.7717/peerj.11365>
- Mäkinen QE, Arendt EK (2012). Oat malt as a baking ingredient a comparative study of the impact of oat, barley and wheat malts on bread and dough properties. *Journal of Cereal Science* 56: 747-753. <https://doi.org/10.1016/j.jcs.2012.08.009>
- Martínez MM, Marcos P, Góme M (2013). Texture development in gluten-free breads: Effect of different enzymes and extruded flour. *Journal of Texture Studies* 44: 480-489. <https://doi.org/10.1111/jtxs.12037>
- Movahedpour A, Asadi M, Khatami SH, Taheri-Anganeh M, Adelipour M et al. (2021). A brief overview on the application and sources of  $\alpha$ -amylase and expression hosts properties in order to production of recombinant  $\alpha$ -amylase. *Biotechnology and Applied Biochemistry* 2021: 1-10. doi: 10.1002/bab.2140.
- Mudgil D, Barak S, Khatkar BS (2016). Optimization of bread firmness, specific loaf volume and sensory acceptability of bread with soluble fiber and different water levels. *Journal of Cereal Science* 70: 186-191. <https://doi.org/10.1016/j.jcs.2016.06.009>
- Ning J, Hou GG, Sun J, Wan X, Dubat A (2017). Effect of green tea powder on the quality attributes and antioxidant activity of whole-wheat flour pan bread. *LWT - Food Science and Technology* 79: 342-348. <https://doi.org/10.1016/j.lwt.2017.01.052>
- Onyango C, Mutungi C, Unbehend, G Lindhauer MG (2010). Batter rheology and bread texture of sorghum-based gluten-free formulations modified with native or pregelatinised cassava starch and  $\alpha$ -amylase. *International Journal of Food Science and Technology* 45: 1228-1235. <https://doi.org/10.1111/j.1365-2621.2010.02265.x>
- Özbay B (2014). Determination of the impact on the yield and quality of sunn pest and genetic differences in different phonological. MSc, Namik Kemal University Graduate School of Natural and Applied Sciences Department of Food Engineering, Tekirdağ, Turkey.
- Pachari Vera E, Alca JJ, Rondón Saravia G, Callejas Campioni N, Jachmanían Alpuy I (2019). Comparison of the lipid profile and tocopherol content of four Peruvian quinoa (*Chenopodium quinoa* Willd.) cultivars ('Amarilla de Marangani', 'Blanca de Juli', INIA 415 'Roja Pasankalla', INIA 420 'Negra Collana') during germination. *Journal of Cereal Science* 88: 132-137. <https://doi.org/10.1016/j.jcs.2019.05.015>
- Paciulli M, Rinaldi M, Cirlini M, Scazzina F, Chiavaro F (2016). Chestnut flour addition in commercial gluten-free bread. A shelf-life study. *Food Science and Technology* 70: 88-95. <https://doi.org/10.1016/j.lwt.2016.02.034>
- Paul S, Kulkarni S, Rao KJ (2019). Utilization of concentrated whey in the production of multigrain bread: optimization of solid levels in concentrated whey and temperatures of baking. *International Food Research Journal* 26 (2): 599-606.
- Pekmez H (2019). Properties of flour used in flat bread (Gaziantep pita) production. *Turkish Journal of Agriculture - Food Science and Technology* 7 (2): 209-213. <https://doi.org/10.24925/turjaf.v7i2.209-213.2195>
- Peng B, Youqian L, Shiyong D, Yang J (2017). Characterization of textural, rheological, thermal, microstructural, and water mobility in wheat flour dough and bread affected by trehalose. *Food Chemistry* 233: 369-377. <https://doi.org/10.1016/j.foodchem.2017.04.108>
- Rinaldi M, Paciulli M, Caligiani A, Scazzina F, Chiavaro E (2017). Sourdough fermentation and chestnut flour in gluten-free bread: A shelf life evaluation. *Food Chemistry* 224: 144-152. <https://doi.org/10.1016/j.foodchem.2016.12.055>
- Savkina O, Kuznetsova L, Burykina M, Kostyuchenko M, Parakhina O (2020). The influence of the flour amyolytic enzymes activity, dosage of ingredients and bread making method on the sugar content and the bread quality. *Agronomy Research* 18 (S3): 1873-1887. <https://doi.org/10.15159/ar.20.047>
- Simakova O, Korenets Y, Yudina T, Nazarenko I, Goriainova I (2018). Examining a possibility of using purple amaranth in the technology for products made of yeast dough. *Eastern-European Journal of Enterprise Technologies* 92: 57-64. <https://doi.org/10.15587/1729-4061.2018.127173>
- Tamani J, GOH KKT, Brennan CS (2013). Physico-chemical properties of sourdough bread production using selected lactobacilli starter cultures. *Journal of Food Quality* 36: 245-252. <https://doi.org/10.1111/jfq.12037>

- Tapsoba FW, Douamba Z, Bationo F, Compaore-Sereme D, Ndig-Yenouba Tj et al. (2022). Effects of cereal malts used as improver on physico-chemical, nutritional and sensory characteristics of wheat and red sorghum composites breads. *American Journal of Food Science and Technology* 10 (3): 119-129. <https://doi.org/10.12691/ajfst-10-3-4>
- Tebben L, Shen Y, Li Y (2018). Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality. *Trends Food Science and Technology* 81:10-24. <https://doi.org/10.1016/j.tifs.2018.08.015>
- Tian B, Xie B, Shi J, Wu J, Vai Y et al. (2010). Physicochemical changes of oat seeds during germination. *Food Chemistry* 119: 1195-1200. <https://doi.org/10.1016/j.foodchem.2009.08.035>
- Uslu MK, Erbaş M, Turhan İ, Tetik N (2010). Effects of starch ratios and soapwort extract addition on some properties of Turkish delight. *The Journal of Food* 35 (5): 331-337 (in Turkish with an abstract in English).
- Üstün Ö, Çelik İ (2011). Phytase activity of wheat, barley and corn grains during germination and effect of germinated grain flour addition on bread quality. *Academic Food Journal* 9 (6): 6-12.
- Veluppillai S, Nithyanantharajah K, Vasantharubai S, Balakumar S, Arasaratnam V (2010). Optimization of bread preparation from wheat flour and malted rice flour. *Rice Science* 17: 51-59. [https://doi.org/10.1016/S1672-6308\(08\)60104-3](https://doi.org/10.1016/S1672-6308(08)60104-3)
- Wang H, Hu F, Wang C, Ramaswamy HS, Yu Y et al. (2020). Effect of germination and high pressure treatments on brown rice flour rheological, pasting, textural and structural properties. *Journal of Food Processing and Preservation* 44 (6): e14474. <https://doi.org/10.1111/jfpp.14474>
- Yang Z, Zheng Y, Cao S, Tang S, Li N (2007). Effects of storage temperature on textural properties of Chinese Bayberry *Fruitzhenfeng*. *Journal of Texture Studies* 38:166-177.
- Zhan L, Jungui X, Yue G, Chun W, Genyuan G et al. (2017). The synergistic priming effect of exogenous salicylic acid and H<sub>2</sub>O<sub>2</sub> on chilling tolerance enhancement during maize (*Zea mays* L.) seed germination. *Frontiers in Plant Science* Jul 5; 8:1153 eCollection. <https://doi.org/10.3389/fpls.2017.01153>.
- Zhang J, Zhang J, Mengqin LI (2016). The study on the appropriate ranges of important flour traits for making high-quality staple food Man-tou. *Jornal of Food Science* 37: 30-36.