GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research / Araştırma
GIDA (2022) 47 (6) 980-991
doi: 10.15237/gida.GD22055

DETERMINATION OF PHYSICOCHEMICAL, ANTIOXIDANT, TEXTURAL AND SENSORY FEATURES OF PASTIRMA CEMEN PASTE PRODUCED BY USING DIFFERENT CONCENTRATIONS OF BLACK GARLIC

Emre TURAN, Atilla ŞİMŞEK*
[1] Ordu University, Faculty of Agriculture, Department of Food Engineering, Ordu, Türkiye

Received /Geliş: 27.05.2022; *Accepted* /Kabul: 17.10.2022; *Published online* /Online baskı: 04.11.2022

Turan, E., Şimşek, A. (2022). Determination of physicochemical, antioxidant, textural and sensory features of pastirma cemen paste produced by using different concentrations of black garlic. GIDA (2022) 47 (6) 980-991 doi: 10.15237/gida.GD22055

Turan, E., Şimşek, A. (2022). Farklı konsantrasyonlarda siyah sarımsak kullanılarak üretilen pastırma çemen macununun fizikokimyasal, antioksidan, tekstürel ve duyusal özelliklerinin belirlenmesi. *GIDA* (2022) 47 (6) 980-991 doi: 10.15237/gida.GD22055

ABSTRACT
This study aims were to evaluate the effects of using different concentrations (10%, 15%, 20%) of black garlic (BG) as an alternative to fresh garlic on the physicochemical, antioxidant, textural and sensory properties of pastırma cemen paste (CP), and to determine the most appropriate amount of BG in terms of consumer acceptance and bioactive properties. The addition of BG at increasing concentration decreased the moisture, pH, colour (L*, a*, and b*), firmness and stickiness values of the CP compared to the control with fresh garlic. While the total phenolics and antioxidant activity of CP increased with the addition of BG, the highest values were in having 20% BG-added group. On the other hand, considering the parameters of odour, taste, spreadability and general appreciation, the 15% BG-added group was the most appreciated. As a result, 15% BG can be used as an alternative to fresh garlic to increase CP's sensory acceptability and bioactive properties.
Keywords: Pastırma cemen paste, black garlic, antioxidant, texture, sensory acceptance

FARKLI KONSANTRASYONLARDA SİYAH SARIMSAK KULLANILARAK ÜRETİLEN PASTIRMA ÇEMEN MACUNUNUN FİZİKOKİMYASAL, ANTİOKSİDAN, TEKSTÜREL VE DUYUSAL ÖZELLİKLERİNİN BELİRLENMESİ

ÖZ
Bu çalışmanın amacı, taze sarımsağa alternatif olarak farklı konsantrasyonlarda (%10, %15, %20) siyah sarımsağın (SS) kullanımının pastırma çemen macunun (ÇM) fizikokimyasal, antioksidan, tektürel ve duyusal özellikleri üzerine etkilerini değerlendirmek ve tüketici kabulü ve biyoaktif özellikler açısından en uygun SS miktarını belirlemektir. Artan konsantrasyonda SS ilavesi, taze sarımsaklı kontrole göre ÇM'nun nem, pH, renk (L*, a* ve b*), sertlik ve yapışkanlık değerlerini azaltmıştır. SS ilavesi ile ÇM'nun toplam fenolikleri ve antioksidan aktivitesi artarken, en yüksek değerler %20 SS ilaveli grupta belirlenmiştir. Öte yandan koku, lezzet, sürülebilirlik ve genel beğeni

* *Corresponding author* / Yazışmalardan sorumlu yazar:
✉: atillasimsek62@yahoo.com ✆: (+90) 452 226 5200 🖷: (+90) 452 226 5220
Emre Turan; ORCID no: 0000-0002-4289-0107
Atilla Şimşek; ORCID no: 0000-0003-2092-1803

parametreleri göz önüne alındığında, %15 SS eklenen grup en beğenilen grup olmuştur. Sonuç olarak, ÇM'nun duyusal kabul edilebilirliğini ve biyoaktif özelliklerini artırmak için taze sarımsağa alternatif olarak %15 SS kullanılabilir.
Anahtar kelimeler: Pastırma çemen macunu, siyah sarımsak, antioksidan, tekstür, duyusal kabul

INTRODUCTION

Pastırma is a traditional dry-cured meat product produced from certain muscles of beef and buffalo carcasses. Dry curing, progressive drying, intermittent pressing, and covering with cemen (a spreadable paste) are the main processes of pastırma production, but the absence of heat and smoking processes differentiate it from other similar products (Cakici et al., 2015; Aksu et al., 2020a). Covering the outer surface of pastırma with cemen paste is an important process that affects the quality of pastırma. This edible coating material is prepared with fenugreek seed flour, red pepper, fresh garlic and enough water (Tekinsen and Dogruer, 2000; Aksu et al., 2020b). Cemen paste (CP) imparts pastırma its appearance, colour, texture, aroma and taste, prevents oxidation by reducing contact with air, prevents excessive drying, protects against external factors and pests, and protects against microbial spoilage due to the antibacterial and antifungal effect of fresh garlic (Tekinsen and Dogruer, 2000; Aksu et al., 2020c). However, the consumption of pastırma causes a sharp and unpleasant odor due to the CP, and this complaint is typically detected after sweating (Ahhmed, 2014). This pungent odor originating from fresh garlic and fenugreek seeds is considered to be responsible for the off-flavor in pastırma and is a major disadvantage that limits pastırma consumption. Reducing and/or eliminating this off-flavor is requested by some consumers (Ahhmed et al., 2017). In addition, many manufacturers are trying to overcome this problem by scraping the cemen layer from the surface and offering the product without CP to meet consumer demand.

Garlic (*Allium sativum*) has been widely used as a culinary and medicinal food since ancient times (Morbidoni et al., 2001), and is an important component used at high rates between 10% and 35% in the formulation of CP (Tekinsen and Dogruer, 2000). Many studies have reported that fresh garlic has a wide range of bioactive effects, including antimicrobial, antiviral, anticancer, antioxidant, and antihypertensive properties (Yun et al., 2014; Bayan et al., 2014; El-Saber Batiha et al., 2020). On the other hand, despite its numerous health benefits, the consumption of fresh garlic is limited due to adverse effects such as unpleasant garlic breath and body odor, allergic reactions, gastrointestinal issues, and skin problems (Stevinson et al., 2000; Morbidoni et al., 2001). Therefore, many new applications are being studied for new garlic products with more advanced sensory and beneficial properties (Toledano-Medina et al., 2016). In this context, many methods such as fermentation, aging, heating, and consumption of various foods (tea and similar beverages, herbs, and several dairy products) are applied to obtain garlic that is more delicious and odorless (Negishi et al., 2002, 2004; Bae et al., 2014; Munch and Barringer, 2014; Mirondo and Barringer, 2016; Ozcan-Sinir and Barringer, 2021). The most widely used processing method among these methods is heat application.

Black garlic (BG) production is carried out by aging the whole raw garlic in an environment of 60-90 °C and 70-90% relative humidity (RH) for a certain period without any additional processing and additives (Zhang et al., 2016; Qiu et al., 2020). Heat treatment of raw garlic results in significant changes in taste, color, texture and nutrient content, and some characteristic properties are formed. The final product is characterized by a soft and elastic texture, black cloves, and sweet-sour taste (Toledano-Medina et al., 2016), and can be consumed directly only by peeling, as the offensive odor of fresh garlic disappears (Wang et al., 2010). The phenolic substance content and antioxidant potential of BG are much higher than that of raw garlic (Toledano-Medina et al., 2016; Qiu et al., 2020). In addition, bioactive and beneficial effects of BG such as antitumor, anticancer, antioxidant, antimicrobial, hepatoprotective, and preventing gastrointestinal problems and metabolic diseases have been reported (Sasaki et al., 2007; Wang et al., 2010;

Jung and Sohn, 2014; Shin et al., 2014; Chen et al., 2018; Kim et al., 2019; Ahmed and Wang, 2021). BG does not cause stomach and intestinal issues seen in fresh garlic consumption (Zhang et al., 2016). In line with this information, BG may offer the promising potential to increase consumer acceptance of pastırma CP and improve its bioactive properties. In our previous study, the effect of BG aged at different times on the overall quality of CP during 90 days of storage was evaluated (Turan and Şimsek, 2022). However, there is no study investigating the optimum amount of BG for use in the production of CP.

The objectives of the present study are; i) to investigate the effects of different BG concentrations on the physicochemical, antioxidant, textural and sensory attributes of pastırma CP; and ii) to determine the optimal BG concentration for the production of CP in terms of bioactive properties and consumer acceptance.

MATERIALS AND METHODS

Materials

Freshly harvested (in July) fresh garlic was procured from Taşköprü (Kastamonu, Türkiye), and paprika, red pepper powder and fenugreek seed flour were supplied from Kadıoğlu Baharat Inc. (Mersin/Türkiye). (±)-6-Hydroxy-2,5,7,8 tetramethylchromane-2-carboxylic acid (Trolox), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tripyridyl-striazine (TPTZ) were purchased from Sigma-Aldrich (Steinheim, Germany), and 2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid (ABTS) was bought from Alfa Aesar (St. Ward Hill, MA, USA). Folin-Ciocalteu reagent (FCR), hydrochloric acid (HCl), gallic acid, ethanol, sodium acetate, potassium persulfate, sodium carbonate (Na_2CO_3), and iron(III) chloride hexahydrate ($FeCl_3.6H_2O$) were used from Merck (Darmstadt, Germany).

Production of BG

BG production was carried out by heating whole fresh garlic bulbs in a climate chamber (T120, ILDAM, Ankara, Türkiye) for 35 days at the temperature (70°C) and RH (80%) norms recommended by Zhang et al. (2016). The produced BG samples were stored at 4°C until used.

Preparation of cemen pastes

CP samples were prepared according to the recipe reported by Aksu et al. (2006) with minor modifications, which included flour of fenugreek seeds (500 g), red pepper powder (75 g paprika + 75 g hot red pepper), clean drinkable water (1200 ml) and crushed garlic (350 g). In this dough formulation, the amount of ingredients other than fresh garlic was kept constant and different concentrations of BG were used for the treatments instead of fresh garlic. Accordingly, CP containing 15% (326.5 g) fresh garlic in the total dough mixture was evaluated as the control group. Other CP samples produced by using 10% (205.6 g), 15% (326.5 g) and 20% (462.5 g) BG in the dough formulation were coded as BG-10, BG-15 and BG-20, respectively. All produced cemen pastes (CPs) were filled in airtight jars and stored at refrigerator temperature (4°C) for 24 h, then analyzes were carried out.

Moisture content, pH and instrumental color analysis

The moisture content was detected by calculating the weight loss after the CPs were kept in an oven (Nükleon, NST-120, Ankara, Türkiye) at 105°C until they reached a stable weight (Cemeroglu, 2010). The pH values of the CPs diluted with distilled water and homogenized with UltraTurrax (IKA-T18, Staufen, Germany) were measured using a Mettler Toledo pH meter (S210, Switzerland) (Yetim et al., 2017). A Minolta colorimeter (CR-410, Osaka, Japan) with 2° standard observer and D65 illuminant was used for the measurement of L^* (lightness), a^* (redness), and b^* (yellowness) color values. Instrument calibration was performed with white calibration ceramic just before color readings were taken.

Spectrophotometric analyzes

Extraction of bioactive compounds

CP samples (5 g) were weighed into polypropylene tubes and the total volume was adjusted to 50 mL with distilled water. Afterwards, the homogenized mixtures were kept in an Isolab ultrasonic bath (Wertheim, Germany) at 60 °C for 1 hour and extraction was carried out. To obtain the extract, centrifugation (D-37520, Sigma, Germany) was performed at 4000 rpm for 10 minutes and the supernatant was collected.

Total phenolic substance content (TPSC)
TPSC of CP extracts in mg gallic acid equivalent (GAE) per 100 g was determined using the Folin-Ciocalteu procedure (Singleton et al., 1999). 1 mL of the CP extract (100 mg/mL) transferred to the test tube was fortified with 0.5 mL of FCR and 0.25 mL of Na_2CO_3 solution (20%, w/v). The volume of the mixture was adjusted to a total of 10 mL with distilled water. After an incubation period of 30 minutes in the dark and at room temperature, absorbance readings versus control were made at 760 nm in a spectrophotometer (Shimadzu UVmini-1240, Japan).

Antioxidant activity
DPPH free radical reducing activity (DPPH-FRRA) analysis of the CP extracts was carried out according to Bursal and Gulcin (2001) with minor modifications. Briefly, different concentrations of CP extracts (20 mg/mL) were mixed with ethanol to adjust the total volume to 3 mL. Then, 500 μL of DPPH test solution (0.1 mM) was fortified to the mixture. After thorough vortexing, the mixtures were incubated at 30 ºC for 30 minutes in the dark. The absorbance readings were taken at 517 nm.

ABTS free radical reducing activity (ABTS-FRRA) analysis was performed by the protocol described by Bursal and Gulcin (2001). First, the ABTS test solution (ABTS-TS) containing potassium persulfate (2.45 mM) and ABTS aqueous solution (2 mM) were allowed to stand in the dark for 12 hours for the radical formation process. The ABTS-TS was diluted with phosphate buffer until the absorbance was 0.750±0.02 at 734 nm. Subsequently, different concentrations of CP extracts and diluted ABTS test solution were mixed in a total volume of 4 mL, and absorbance values were measured at 734 nm after 30 minutes.

FRAP (ferric reducing antioxidant power) analysis was carried out following the method described by Benzie and Strain (1996) with some modifications. Primarily, FRAP reagent was prepared by mixing 10 mmol/L TPTZ (in 40 mmol/L HCl), 20 mmol/L $FeCl_3.6H_2O$, and 0.3 mol/L acetate buffer (pH 3.6) solutions in appropriate volumetric ratios (1:1:10). Then, an aliquot (0.1 mL) of sample extract (20 mg/mL) was mixed with distilled water (0.9 mL) and FRAP reagent (2 mL). The absorbance of the mixture was read at 593 nm in the spectrophotometer after an incubation period of 4 minutes at 37 °C. The results of all three antioxidant activity assays were calculated as μg TE (Trolox equivalent) per 100 mg CP.

Textural properties
Texture parameters of CPs such as firmness (g), stickiness (g), work of shear (g.s), and work of adhesion (g.s) parameters were determined using a TA-TX Plus texture analyzer (Stable Micro Systems, Surrey, UK). The device was equipped with a suitable load cell (5 kg) and probe (TTC Spreadability Rig, HDP/ SR). Following calibration, a portion of the sample in the refrigerator was transferred onto the female cone and permeated with a corresponding male cone. The test conditions for analysis were follows: Trigger type, automatic; test mode, compression; trigger force, 1 g; distance, 12 mm; pre-test speed 3.0 mm/s; test speed, 1.0 mm/s; post-test speed, 5.0 mm/s. Eight measurements were averaged for each sample.

Sensory evaluation
Sensory analysis of CP samples was made by 8 trained assessors (6 men, 2 women) working at Ordu University Faculty of Agriculture. Attention was paid to assessors' familiarity with CP and pastırma, and the frequency of consumption of these products. Before the sensory evaluation, preliminary information was given about the properties of BG and CP. The presentation of randomly coded samples with different letters to the evaluators was made on white plates. The assessors rated CPs for color, odor, taste, spreadability, and general appreciation using a hedonic scale of 1-9 points (1 "not preferred", 5

"moderately preferred" and 9 "extremely preferred"). During the transition between samples, assessors were offered bread to clear any residual taste.

Statistical analysis

The experiment was carried out in three replications. All data were subjected to one-way ANOVA using Minitab 18 program, taking into account treatments (Control, BG-10, BG-15 and BG-20) as a factor. A comparison of significant differences (P <0.05 level) between the means was made by applying the Tukey test.

RESULTS AND DISCUSSION

Moisture content and pH values

Moisture content, pH and instrumental color values of CPs incorporated with different concentrations of BG are presented in Table 1. The highest moisture content was determined in the traditional CP with 56.10%. The moisture content of CP decreased with the addition of BG compared to the control (P <0.05). However, no statistical differences were observed between the moisture content of the groups with BG (P >0.05). The decrease in moisture content with BG treatment can be attributed to the lower moisture content of BG compared to fresh garlic (Bae et al., 2014; Choi et al., 2014). The findings for the moisture content of the control CP were in agreement with Ahhmed et al. (2017) and lower than the content reported by Aksu et al. (2020b).

Similarly, the addition of BG to the CP significantly decreased the pH values (P <0.05) and this decrease was dependent on the increasing concentration of BG (Table 1). Accordingly, the pH values decreased in the BG-10, BG-15 and BG-20 groups compared to the control (6.04) and were determined as 5.50, 5.31 and 5.20, respectively. There was no significant difference among the groups with 15% and 20% BG in terms of pH values (P >0.05). Choi et al. (2014) determined that the pH value of BG produced by heat treatment at 70 ºC and 90% RH for 35 days decreased with increasing ripening time and became 3.74 at the end of 35 days. Similarly, the pH value of BG aged for 33 days at 72 ºC and 90% relative humidity was determined as 3.49 (Toledano-Medina et al., 2016). In accordance with our study, the pH value of control CP has been reported in the literature in the range of 5.60-6.07 (Aksu et al., 2006; Yetim et al., 2017; Aksu et al., 2020b, 2020c, 2021). On the other hand, the amount, type and quality of the components used in the preparation of CP, as well as the inclusion of additional additives in the formulation cause changes in pH values. In this context, Aksu et al. (2006) determined that the pH values of CPs produced using different levels (0-25%) of fresh garlic increased linearly with increasing fresh garlic levels. In addition, previous studies reported that pH values of CPs were significantly changed by the addition of fruit and vegetable extracts such as red beet (Aksu et al., 2020a), red cabbage (Aksu et al., 2020b, 2020c), and raspberry (Aksu et al., 2021), as well as some acidic additives such as yoghurt serum, lemon juice, pickle juice, turnip juice, gilaburu juice, and citric acid (Yetim et al., 2017).

Table 1. Moisture content, pH and instrumental color values (L^*, a^*, b^*) of cemen pastes treated with different concentrations of black garlic

	%Moisture	pH	L^* (Lightness)	a^* (Redness)	b^* (Yellowness)
Control	57.09±0.50^a	6.04±0.04^a	32.83±0.25^a	14.82±0.79^a	12.62±0.07^a
BG-10	52.67±0.81^b	5.50±0.02^b	25.78±0.22^b	7.87±0.53^b	5.21±0.08^b
BG-15	51.30±0.27^b	5.31±0.06^c	23.92±0.82^c	5.85±0.12^c	3.72±0.10^c
BG-20	49.78±1.08^b	5.20±0.04^c	22.88±0.22^c	4.27±0.19^d	3.15±0.07^d

Control: Traditional cemen paste produced with fresh garlic.
BG-10, BG-15, and BG-20: Cemen pastes produced using black garlic at 10%, 15% and 20% concentrations, respectively.
Different letters (a-d) in the same column indicate significant differences between treatments (P <0.05).

Color (*L, *a** and *b**) values**

Table 1 presents the *L** (lightness), *a** (redness) and *b** (yellowness) color values of CPs containing fresh garlic and different concentrations of BG. Treatment with BG caused a decrease in *L**, *a** and *b** color values of CPs compared to the control sample (P <0.05). The highest and lowest *a** and *b** values were found in the control and BG-20 groups, respectively (P <0.05). The decrease in *a** and *b** values was dependent on increasing BG concentration (P <0.05). The *L** values of all BG-treated samples were lower (P <0.05) compared to the control with fresh garlic. However, the BG-15 and BG-20 treatments had similar *L** values (P >0.05). BG has a darker color and lower color values (*L**, *a** and *b**) than fresh garlic due to the brown-colored compounds formed as a result of the Maillard reaction (Choi et al., 2014; Toledano-Medina et al., 2016). Therefore, the decrease in the color values of CP with the addition of BG compared to the control is an expected result. CP color is an important quality criterion for pastırma, as it directly affects consumer preferences. In this context, providing and maintaining the desired redness is very important for pastırma production (Aksu et al., 2020b, 2020c). The use of BG adversely affected the color quality by decreasing the lightness and redness values of the CP, and this negative effect became more pronounced with increasing concentration. On the other hand, pH is an important factor affecting the color formation and color stability in CP. Aksu et al (2020b) determined that redness increased as pH decreased (pH 4.0 and 4.5) in CPs adjusted to different pH values (pH 4.0 to 6.0) and produced by adding anthocyanin-rich red cabbage extract. The researchers also determined that pH 5.0 was the threshold value for achieving the desired color and its stability during storage. In this context, the decreased pH value of CP due to the addition of BG can contribute to the formation and stability of the desired color when used with extracts rich in anthocyanins, which present a red color in acidic conditions.

Antioxidant capacity

Table 2 shows the changes in TPSC and antioxidant activities of CPs containing different concentrations of BG compared to the control. Antioxidant activity was evaluated by three different methods: DPPH-FRRA, ABTS-FRRA, and FRAP. It was observed that as the concentration of BG increased in the CP formulation, the TPSC and antioxidant activity values also increased. The lowest values for all three antioxidant activity assays and TPSC were determined in the control sample (P <0.05). TPSC of CPs increased between 27.09-38.02% with the addition of BG at different concentrations (P <0.05). Similarly, FRAP values increased by 15.65-24.82%, DPPH-FRRA values increased by 56.43-118.91%, and ABTS-FRRA values increased by 32.43%-51.37% depending on the increasing BG concentration (P <0.05). As seen in Table 2, the highest increase was determined in the BG-20 group containing 20% BG, while there was no statistically significant difference between BG-15 and BG-20 groups in terms of TPSC, ABTS-FRRA and FRAP values (P >0.05). According to these results, the addition of BG improved the bioactive properties of pastırma CP by increasing its TPSC and antioxidant activity. Compared to fresh garlic, BG has a very high TPSC and antioxidant activity (Choi et al., 2014; Toledano-Medina et al., 2016; Qiu et al., 2020). Martínez-Casas et al. (2017) determined that the TPSC of BG (820.4 mg GAE/100 g) is approximately 10 times higher than that of fresh garlic (77.86 mg GAE/100 g). Similarly, Toledano-Medina et al. (2016) determined that the content of phenolic substances and antioxidant activity of BG produced at different temperature-time norms increased between 3-6 times and 6.5-9.5 times, respectively, compared to fresh garlic. It can be stated that this increase in antioxidant activity is caused by newly formed or increased antioxidant compounds during the BG production process. Some antioxidants such as melanoidins, S-allyl cysteine (SAC), β-carboline derivatives, polyphenols, 5-hydroxymethyl furfural, Amadori and Heyns compounds contribute to antioxidant activity (Bae et al., 2014; Qiu et al., 2020).

Textural properties

The textural analysis results are shown in Figure 1. The substitution of fresh garlic with BG in the CP formulation decreased the firmness and stickiness values compared to the control (P <0.05), but this decrease was not affected by the concentration of BG (P >0.05). All black garlic treatments had lower work of shear values than those in the control (P <0.05), with the reduction being most pronounced in the BG-10 group. The increase in work of adhesion values with BG treatment was significant (P <0.05) only in the BG-15 and BG-20 groups compared to the control. The soft, flexible and chewy structure of BG (Zhang et al., 2016; Qiu et al., 2020) was also reflected in the texture features of CP. There is an inverse relationship between the work of shear and spreadability. The low firmness and work of shear values contribute to the increase in spreadability (Nikolić et al., 2014). Accordingly, the texture analysis results showed that more force was required to spread the control sample and the addition of BG increased the spreadability of the CP.

Table 2. Changes in total phenolic substance content (TPSC), DPPH-free radical reducing activity (DPPH-FRRA), ABTS-free radical reducing activity (ABTS-FRRA), and Ferric reducing antioxidant power (FRAP) of cemen pastes treated with different concentrations of black garlic

	TPSC (mg GAE/100 g)	DPPH-FRRA (µg TE/100 g)	ABTS-FRRA (µg TE/100 g)	FRAP (µg TE/100 g)
Control	80.87±0.33[c]	47.15±2.76[d]	118.64±2.73[c]	72.52±3.05[b]
BG-10	102.78±0.80[b]	74.85±0.95[c]	171.14±4.42[b]	83.87±1.24[a]
BG-15	108.37±0.88[a]	97.13±1.38[b]	193.70±2.64[a]	88.02±2.05[a]
BG-20	111.62±1.15[a]	104.75±1.56[a]	206.56±1.92[a]	90.52±1.38[a]

Control: Traditional cemen paste produced with fresh garlic.
BG-10, BG-15, and BG-20: Cemen pastes produced using black garlic at 10%, 15% and 20% concentrations, respectively.
Different letters (a-d) in the same column indicate significant differences between treatments (P <0.05).

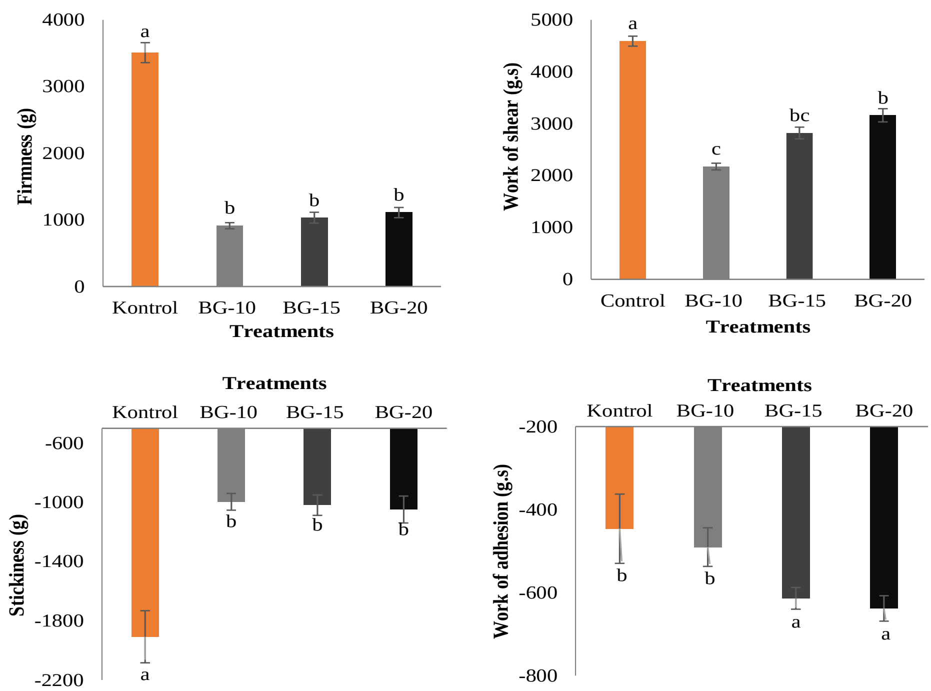

Figure 1. Textural properties of cemen pastes treated with different concentrations of black garlic
Control: Traditional cemen paste produced with fresh garlic.
BG-10, BG-15, and BG-20: Cemen pastes produced using black garlic at 10%, 15% and 20% concentrations, respectively.
Different letters (a-c) indicate significant differences between treatments (P <0.05).

Sensory evaluation

The sensory evaluation results in which CPs produced using different concentrations of BG were compared with traditional CP in terms of color, odor, taste, spreadability and general appreciation parameters are shown in Figure 2. The use of BG as a fresh garlic substitute in the formulation caused a significant decrease in color scores ($P < 0.05$).

This decrease shows parallelism with instrumental color values (Table 1). As stated in the previous sections, the color of CP is an important factor influencing consumer choices when purchasing pastırma. Therefore, BG-added CPs with a dark color received lower scores from the assessors. Although the color scores decreased as the BG concentration increased, there was no significant difference between the BG groups ($P > 0.05$). Regarding the texture analysis, the assessors perceived the BG-20 sample as harder and less spreadable than the BG-15 group. The odor scores showed that CPs containing BG were liked more than the control group with fresh garlic. The lowest and highest odor scores were determined in the control and BG-15 groups, respectively (Figure 2, $P < 0.05$,). Similarly, the sweet-sour taste of BG was also reflected in the sensory evaluation scores. The lowest taste scores were in the control sample, while the BG-15 group was scored as more palatable by the assessors ($P < 0.05$). In general, the assessors emphasized that the roasted aroma was higher in the BG-20 group containing 20% BG. The increase in soluble solids content, including glucose, sucrose and fructose, as a result of hydrolysis of polysaccharides is considered to be responsible for the sweet taste of BG (Toledano-Medina et al., 2016; Qiu et al., 2020). In addition, the concentration of sulphurous volatile compounds decreases during BG production, while the presence of compounds that offer a sweet and roasted aroma increases (Molina-Calle et al., 2017). This may have contributed to the higher taste scores of the CPs with BG.

On the other hand, the fact that BG is free from pungent and unpleasant odor compared to fresh garlic resulted in higher odor scores in groups with BG. Consumption of raw garlic results in an irritating mouth (garlic breath) that can linger from a few hours to days. Diallyl disulfide (DADS), allyl methyl disulfide, allyl mercaptan, and allyl methyl sulfide (AMS) are the main compounds associated with garlic breath (Mirondo and Barringer, 2016). Since this unpleasant breath and persistent body odor is an irritating problems in social and daily life, some people avoid garlic consumption (Amiraian and Sobal, 2009; Sharma et al., 2011). In addition, garlic consumption is not at the desired level in Türkiye due to its pungent smell and taste (Akan and Unuvar, 2017). This is an important factor limiting the consumption of pastırma produced by coating with CP containing a high amount of fresh garlic. Therefore, using BG instead of fresh garlic in the production of CP can be an effective solution to overcome this problem. Considering the parameters of odor, taste, spreadability and general appreciation, the highest scores were determined in the BG-15 group. Accordingly, the use of 15% BG as a substitute for fresh garlic can be recommended as the optimal concentration for the sensory acceptability of pastırma CP. On the other hand, color values and aromatic substances change significantly during the final drying stage from covering with CP to obtaining the final product pastırma (Kaban, 2009; Aksu et al., 2020a). Therefore, it is important and necessary to determine the sensory acceptability of the final product produced using CPs with BG. A recent study found that the use of BG in the formulation of CP enhanced sensory acceptance by reducing the content of sulfur compounds and increasing the presence of esters and terpenes that offer fruity-sweet flavor (Turan and Şimsek, 2022). Similarly, in a study investigating the use of miso (Japanese fermented soybean paste) instead of traditional pastırma CP, it was reported that off-flavor caused by sulfur compounds in pastırma was eliminated by the miso coating with fruity aroma notes and the flavor was improved (Ahhmed et al., 2017).

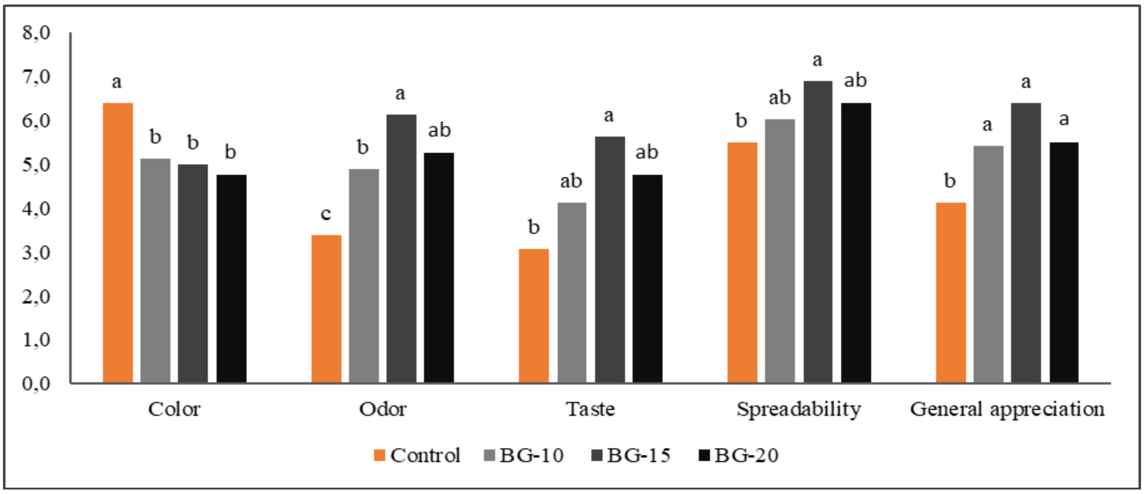

Figure 2. Sensory evaluation of cemen pastes treated with different concentrations of black garlic
Control: Traditional cemen paste produced with fresh garlic.
BG-10, BG-15, and BG-20: Cemen pastes produced using black garlic at 10%, 15% and 20% concentrations, respectively.
Different letters (a-b) indicate significant differences between treatments (*P* <0.05).

CONCLUSION

This study showed that the use of BG as an alternative to fresh garlic in the formulation of CP improved the bioactive content, sensory acceptance and textural properties, but negatively affected the color values. Although the addition of 20% BG offered the highest TPSC and antioxidant activity, the use of 15% BG was rated by the assessors as the threshold level for sensory acceptance. Considering all the results, 15% BG can be recommended as the optimal concentration alternative to fresh garlic to increase sensory acceptability and bioactive properties in CP. In addition, further studies are needed to evaluate the effect of CPs produced by using different substitute mixtures of fresh and BG on the quality of pastırma.

DECLARATION OF COMPETING INTEREST

The authors have declared no conflict of interest.

AUTHORS' CONTRIBUTIONS

Emre Turan: Conceptualization, methodology, investigation, formal analysis, writing-review & editing. Atilla Şimşek: Project administration, supervision, conceptualization, methodology, writing - review & editing. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

This study was supported by Ordu University Scientific Research Projects Coordination Unit within the scope of project number AR-1642. The authors also thank Mehmet İPEK (Taşköprü District Directorate of Food, Agriculture and Livestock) for providing Taşköprü fresh garlic.

REFERENCES

Ahhmed, M.A. (2014). Traditional cured meat-making process degrades the proteins of *M. latissimus dorsi* of bovine. *International Food Research Journal*, 21(1): 139-148.

Ahhmed, A., Özcan, C., Karaman, S., Öztürk, İ., Çam, M., Fayemi, P.O., ... Yetim, H. (2017). Utilization of fermented soybeans paste as flavoring lamination for Turkish dry-cured meat. *Meat Science*, 127: 35-44, doi: 10.1016/j.meatsci.2016.12.011

Ahmed, T., Wang, C.K. (2021). Black Garlic and its bioactive compounds on human health diseases: A Review. *Molecules*, 26(16): 5028, doi: 10.3390/molecules26165028

Akan, S., Unuvar, I. (2017). Sarımsak üretim ve ticaretinin ekonomik önemi. III. International Balkan and Near East Social Sciences (IBANESS) Congress Series, 04-05 March, Edirne/Türkiye.

Aksu, M.I., Kaya, M., Oz, F. (2006). Inhibition of *Escherichia coli* O157: H7 in cemens with different garlic levels. *American Journal of Food Technology*, 1: 59-65, doi: 10.3923/ajft.2006.59.65

Aksu, M.I., Erdemir, E., Turan, E., Sat, I.G. (2020a). Effects of red beet extracts on protein and lipid oxidation, colour, microbial, sensory properties and storage stability of Turkish pastırma. *Journal of Stored Products Research*, 89: 101721, doi: 10.1016/j.jspr.2020.101721

Aksu, M.I., Turan, E., Sat, I.G. (2020b). Effects of lyophilized red cabbage water extract and pH levels on the quality properties of pastırma cemen paste during chilled storage. *Journal of Stored Products Research*, 89: 101696, doi: 10.1016/j.jspr.2020.101696

Aksu, M.I., Turan, E., Sat, I.G., Erdemir, E., Oz, F., Gurses, M. (2020c). Improvement of quality properties of cemen paste of pastirma by lyophilized red cabbage water extract. *Journal of Food Processing and Preservation*, 44(9): e14714, doi: 10.1111/jfpp.14714

Aksu, M.I., Turan, E., Sat, I.G., Erdemir, E. (2021). Red raspberry (*Rubus ideaus* L.) extracts: A novel ingredient in cemen paste. *Journal of Food Processing and Preservation*, 45(11): e15930, doi: 10.1111/jfpp.15930

Amiraian, D.E., Sobal, J. (2009). Dating and eating. Beliefs about dating foods among university students. *Appetite*, 53(2): 226-232, doi: 10.1016/j.appet.2009.06.012

Bae, S.E., Cho, S.Y., Won, Y.D., Lee, S.H., Park, H.J. (2014). Changes in S-allyl cysteine contents and physicochemical properties of black garlic during heat treatment. *LWT-Food Science and Technology*, 55(1): 397-402, doi: 10.1016/ j.lwt.2013.05.006

Bayan, L., Koulivand, P.H., Gorji, A. (2014). Garlic: A review of potential therapeutic effects. *Avicenna Journal of Phytomedicine*, 4(1): 1-14.

Benzie, I.F., Strain, J.J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Analytical Biochemistry*, 239(1): 70-76. doi: 10.1006/ abio.1996.0292

Bursal, E., Gülçin, I. (2011). Polyphenol contents and in vitro antioxidant activities of lyophilised aqueous extract of kiwifruit (*Actinidia deliciosa*). *Food Research International*, 44(5): 1482-1489, doi: 10.1016/j.foodres.2011.03.031

Cemeroglu, B. (2010). Food Analysis. Food Technology Association Publications (No:34), Ankara, Türkiye.

Chen, Y.A., Tsai, J.C., Cheng, K.C., Liu, K.F., Chang, C.K., Hsieh, C.W. (2018). Extracts of black garlic exhibits gastrointestinal motility effect. *Food Research International*, 107: 102-109, doi: 10.1016/j.foodres.2018.02.003

Choi, I.S., Cha, H.S., Lee, Y.S. (2014). Physicochemical and antioxidant properties of black garlic. *Molecules*, 19(10): 16811-16823, doi: 10.3390/molecules191016811

Cakici, N., Aksu, M.I., Erdemir, E. (2015). A survey of the physico-chemical and microbiological quality of different pastırma types: A dry-cured meat product. *CyTA-Journal of Food*, 13(2): 196-203, doi: 10.1080/19476337.2014.938123

El-Saber Batiha, G., Magdy Beshbishy, A., G Wasef, L., Elewa, Y.H., A Al-Sagan, A., El-Hack, A., ... Prasad Devkota, H. (2020). Chemical constituents and pharmacological activities of garlic (*Allium sativum* L.): A review. *Nutrients*, 12(3): 872, doi: 10.3390/ nu12030872

Jung, I.C., Sohn, H.Y. (2014). Antioxidation, antimicrobial and antithrombosis activities of aged black garlic *(Allium sativum* L.). *Microbiology and Biotechnology Letters*, 42(3): 285-292, doi: 10.4014/kjmb.1407.07002

Kaban, G. (2009). Changes in the composition of volatile compounds and in microbiological and physicochemical parameters during pastırma processing. *Meat Science*, *82*(1), 17-23. https://doi.org/10.1016/j.meatsci.2008.11.017

Kim, K.J., Kim, S.H., Shin, M.R., Kim, Y.J., Park, H.J., Roh, S.S. (2019). Protective effect of S-allyl cysteine-enriched black garlic on reflux esophagitis in rats via NF-κB signaling pathway. *Journal of Functional Foods*, 58: 199-206, doi: 10.1016/j.jff.2019.04.040

Martínez-Casas, L., Lage-Yusty, M., López-Hernández, J. (2017). Changes in the aromatic profile, sugars, and bioactive compounds when purple garlic is transformed into black garlic. *Journal of Agricultural and Food Chemistry*, 65(49): 10804-10811, doi: 10.1021/ acs.jafc.7b04423

Mirondo, R., Barringer, S. (2016). Deodorization of garlic breath by foods, and the role of polyphenol oxidase and phenolic compounds. *Journal of Food Science*, 81(10): C2425-C2430, doi: 10.1111/1750-3841.13439

Molina-Calle, M., Priego-Capote, F., de Castro, M.D.L. (2017). Headspace-GC–MS volatile profile of black garlic vs fresh garlic: Evolution along fermentation and behavior under heating. *LWT-Food Science and Technology*, 80: 98-105, doi: 10.1016/j.lwt.2017.02.010

Morbidoni, L., Arterburn, J.M., Young, V., Mullins, D., Mulrow, C., Lawrence, V. (2001). Garlic: Its history and adverse effects. *Journal of Herbal Pharmacotherapy*, 1(1): 63-83, doi: 10.1080/J157v01n01_06

Munch, R., Barringer, S.A. (2014). Deodorization of garlic breath volatiles by food and food components. *Journal of Food Science*, 79(4): C526-C533, doi: 10.1111/1750-3841.12394

Negishi, O., Negishi, Y., Ozawa, T. (2002). Effects of food materials on removal of Allium-specific volatile sulfur compounds. *Journal of Agricultural and Food Chemistry*, 50(13): 3856-3861, doi: 10.1021/jf020038q

Negishi, O., Negishi, Y., Yamaguchi, F., Sugahara, T. (2004). Deodorization with ku-ding-cha containing a large amount of caffeoyl quinic acid derivatives. *Journal of Agricultural and Food Chemistry*, 52(17): 5513-5518, doi: 10.1021/jf049693j

Nikolić, I., Dokić, L., Krstonošić, V., Šereš, Z., Šoronja–Simović, D. (2014). Possibility of the production of functional low-fat food spread of hull-less pumpkin seed flour from rheological and textural aspect. *Journal of Texture Studies*, 45(4): 324-333, doi: 10.1111/jtxs.12078

Ozcan-Sinir, G., Barringer, S.A. (2021). Deodorization of garlic odor by fresh and dried herbs using SIFT-MS. *The Journal of FOOD*, 46(2): 358-366, doi: 10.15237/gida.GD21029

Qiu, Z., Zheng, Z., Zhang, B., Sun‐Waterhouse, D., Qiao, X. (2020). Formation, nutritional value, and enhancement of characteristic components in black garlic: A review for maximizing the goodness to humans. *Comprehensive Reviews in Food Science and Food Safety*, 19(2): 801-834, doi: 10.1111/1541-4337.12529

Sasaki, J.I., Lu, C., Machiya, E., Tanahashi, M., Hamada, K. (2007). Processed black garlic (*Allium sativum*) extracts enhance anti-tumor potency against mouse tumors. *Medicinal and Aromatic Plant Science and Biotechnology*, 1(2): 278-281.

Sharma, S., Shankar, T.P., Koirala, B. (2011). Halitosis: A serious social problem. *Health Renaissance*, 9(2): 106-111, doi: 10.3126/ hren.v9i2.4983

Shin, J.H., Lee, C.W., Oh, S.J., Yun, J., Kang, M.R., Han, S.B., ... Kang, J.S. (2014). Hepatoprotective effect of aged black garlic extract in rodents. *Toxicological Research*, 30(1): 49-54, doi: 10.5487/TR.2014.30.1.049

Singleton, V.L., Orthofer, R., Lamuela-Raventós, R.M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology*, 299: 152–178, doi: 10.1016/S0076-6879(99)99017-1

Stevinson, C., Pittler, M.H., Ernst, E. (2000). Garlic for treating hypercholesterolemia: A meta-analysis of randomized clinical trials. *Annals of Internal Medicine*, 133(6): 420-429, doi: 10.7326/ 0003-4819-133-6-200009190-00009

Tekinsen, O.C., Dogruer, Y. (2000). Her Yönüyle Pastırma. Selçuk Üniversitesi Basımevi, 124, Konya, Türkiye.

Turan, E., Şimsek, A. (2022). Black garlic as a substitute for fresh garlic to reduce off-lavor and enhance consumer acceptance and bioactive properties in cemen paste. *Journal of Food Processing* *and Preservation*, 46(2): e16246, doi: 10.1111/jfpp.16246

Toledano-Medina, M.A., Pérez-Aparicio, J., Moreno-Rojas, R., Merinas-Amo, T. (2016). Evolution of some physicochemical and antioxidant properties of black garlic whole bulbs and peeled cloves. *Food Chemistry*, 199: 135-139, doi: 10.1016/j.foodchem.2015.11.128

Wang, D., Feng, Y., Liu, J., Yan, J., Wang, M., Sasaki, J.I., Lu, C. (2010). Black garlic (*Allium sativum*) extracts enhance the immune system. *Medicinal and Aromatic Plant Science and Biotechnology*, 4(1): 37-40.

Yetim, H., Ekici, L., Ozcan, C., Ozturk, I., Tornuk, F., Karaman, S. (2017). Effects of some food juices and additives on some physicochemical, textural, color, microbiological and sensory properties of cemen paste. *Journal of Food Processing and Preservation*, 41(3): e12950, doi: 10.1111/jfpp.12950

Yun, H.M., Ban, J.O., Park, K.R., Lee, C.K., Jeong, H.S., Han, S.B., Hong, J.T. (2014). Potential therapeutic effects of functionally active compounds isolated from garlic. *Pharmacology & Therapeutics*, 142(2): 183-195, doi: 10.1016/j.pharmthera.2013.12.005

Zhang, X., Li, N., Lu, X., Liu, P., Qiao, X. (2016). Effects of temperature on the quality of black garlic. *Journal of the Science of Food and Agriculture*, 96(7): 2366-2372, doi: 10.1002/jsfa.7351