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Kısa Süreli Depolamanın Siyah Sarımsak Başları ve Soyulmuş Dişlerinin Fizikokimyasal Kalitesindeki Rolü

Selen AKAN

Ankara Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Ankara

Sorumlu Yazar: sakan@agri.ankara.edu.tr

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Öz

Siyah sarımsak, taze sarımsağın yüksek nem ve sıcaklıktaki kontrollü koşullarda fermantasyonu sonucu üretilmektedir. Günümüze kadar, siyah sarımsak işleme teknolojileri üzerine pekçok çalışma yapılmıştır ancak siyah sarımsağın gıda kalitesini etkileyen ana gösterge olan depolama koşulları konusunda çok az şey bilinmektedir. Üstelik siyah sarımsağın uygun depolama koşullarının bilinmesi, küresel ve yerel pazarların gereksinimlerini karşılamak için çok önemlidir. Bu nedenle, araştırmada siyah sarımsak baş ve soyulmuş dişlerinin 4°C'de ve %55-70 oransal nemde kraft kağıt ambalajlarda kısa süreli (21 gün) depolamanın fizikokimyasal kalitesine etkilerinin belirlenmesi amaçlamıştır. Depolama süresince suda çözünür kuru madde içeriği, pH, renk (*L*, a*, b**), titre edilebilir asitlik (sitrik ve laktik asit), su aktivitesi, antioksidan kapasite ve toplam fenolik içerikleri analiz edilmiştir. Sonuç olarak, siyah sarımsağı baş olarak depolamanın pH, renk (*a**), laktik ve sitrik asit üzerinde olumlu etkisi olmuştur. Ayrıca, depolama süresi boyunca siyah sarımsak başlarında antioksidan kapasite ve toplam fenolik içerikleri de korunmuştur. Soyulmuş diş olarak depolamanın sadece *b** değeri üzerinde etkisi bulunmuştur. Genel olarak, bu araştırma, yürütülen koşullar altında kısa süreli depolamanın siyah sarımsağın fizikokimyasal özelliklerinde zararlı değişikliklere yol açmadığını göstermiştir. Farklı depolama koşullarının siyah sarımsağın kalitesine etkilerini açıklamaya yönelik daha fazla çalışmaya ihtiyaç bulunmaktadır.

Anahtar kelimeler: Siyah sarımsak, kalite, toplam fenolik bileşik, antioksidan aktivite.

The Role of Short-Term Storage on Physicochemical Quality of Black Garlic Bulbs and Peeled Cloves

Abstract

Black garlic is produced by fermentation of raw garlic under controlled conditions with high humidity and temperature. To date, many studies have been carried out on the processing technology of black garlic but little is known about the storage conditions, which are the main indicators for affecting the food quality of black garlic. Also knowing the proper storage conditions of black garlic is essential to meet the requirements of global and domestic markets. Therefore, the research aimed to determine the effects of short-term storage periods (21 days) on the physicochemical quality of bulbs and peeled cloves of black garlic during storage at 4°C and 55-70% relative humidity in the kraft paper bags. During the storage period, soluble solids content, pH, color (*L*, a*, b**), titratable acidity (citric and lactic acid), water activity, antioxidant capacity, and total phenolic content were analyzed. As a result, the storage of black garlic bulbs had a positive effect on pH, color (*a**), lactic and citric acid. Moreover, antioxidant capacity and total phenolic content were maintained in stored black garlic bulbs during the storage period. Storage as peeled clove was only effective on color *b** value. In general, this research demonstrated that short-term storage under conducted conditions did not lead to detrimental changes in physicochemical attributes of black garlic. More studies are needed to explain the effects of different storage conditions on the quality of black garlic.

Key words: Black garlic, quality, total phenolic content, antioxidant capacity.

Introduction

Garlic has been widely used due to its rich nutritional content and medicinal properties since ancient times. However, garlic consumption is limited depending on undesirable odours and intense taste. Hence, in recent years, new forms of garlic have been introduced to reduce these discomforts and expand consumption. Among the various forms, black garlic is the most important one; it is a crucial processed form due to biological effects and it is utilized in the pharmacy and cosmetic sectors as well as in food (Akan, 2014). Black garlic is produced by fermentation of fresh garlic at 40-90 °C temperature with 85-90% relative humidity during 1-3 months without any additional treatment (Kim et al., 2012; Kang, 2016). After processing raw garlic for obtaining black garlic, some changes have occurred in sensory characteristics such as dark color, jelly-like/chewiness/springiness texture, off-odour, and sweet/syrupy/vinegar/acidic/balsamic taste (Toledano-Medina et al., 2016; Zhang et al., 2016). The heating process is preferred in the food sector to extend the range of colors, and to improve the sensory quality and tastes of foods (Zhang et al., 2015). Previously mentioned alterations in the black garlic resulted from chemical transformations, including Maillard reaction, caramelization, and oxidation of phenols (Molina-Calle et al., 2017). The maillard reaction leads to the formation of a typical dark brown color in the black garlic and leads to the synthesis of some new antioxidant compounds. Wakamatsu et al. (2019) reported that Maillard products contain acetic acid, carboxylic acid, and picolinic acid moieties, which show strong antioxidant activity. On the other hand, fructan hydrolysis brings about sweet taste and textural changes during the Maillard reaction (Kang, 2016). Black garlic contains a high amount of polysaccharides, reducing sugar, protein, organic acid, a β-carboline alkaloid (Lu et al., 2017) and melanoidin pigment, as well as sulfur compounds. Black garlic is a great source of phenolic compounds and has strong antioxidant activities (Queiroz et al., 2009; Angeles et al., 2016). Several studies reported that black garlic shows a wide range of therapeutic effects including antiallergic, anti-ageing, antimicrobial, antiviral, anticarcinogenic, regulation of blood glucose, blood lipid and triglyceride levels, suppression of cardiovascular and neurodegenerative diseases (Alzheimer, Parkinson, MS, Huntington, ischemic brain disorders), and protection against UV-B ray's effects (Kim et al., 2012; Angeles et al., 2016; Akan and Tuna Gunes, 2018; Czompa et al., 2018). Therefore, black garlic's popularity is increasing day by day due to its rich nutritional content and promising medicinal effects. To supply throughout the year, it is necessary to preserve the quality of black garlic mainly depending on the processing technique and storage conditions. Storage conditions such as temperature, humidity, light, oxygen levels, time, packaging, and water activity are key factors to maintain the quality and the prolong shelf life of black garlic. However, many studies have been carried out on the processing technology of black garlic but there is little information about the storage conditions of black garlic (Angeles et al., 2016; Zhang et al., 2016; Kandemirli et al., 2020). A report by Qiu et al. (2018) stated that when the black garlic processing is improved, the storage period would be prolonged. Black garlic is commonly stored as peeled cloves or bulbs in the refrigerator. According to the report of Ding et al. (2020), stored black garlic gave the best results when stored at 4°C in aluminum-laminated polyethylene bags. In addition, the authors emphasized that the influences of different packaging materials and storage conditions on texture, water retention, and thermal stability of black garlic are unknown.

Based on the above, it is necessary to conduct research because there is still a lack of study that discusses the storage ability of black garlic. Therefore, the aims of this research are first to determine storage losses of black garlic in quality during a short-time period, and secondly to compare the efficacy of storage as a whole bulb or peeled cloves on maintaining some quality parameters in black garlic during short-term storage.

Material and Method

Materials

In this research, the garlic cultivar ''Taşköprü'' was harvested from the production area (Taşköprü district of Kastamonu province of Turkey) and the fresh/raw garlic bulbs were transported to the black garlic company (Edovital Ltd., Kastamonu Province, Turkey) for making black garlic. Kraft paper bags with a combination of polyethylene terephthalate (PET) and polyethylene (PE) (Kraft50/PET12/PE50, 85 × 140 × 50 mm, 112µ thickness) were purchased from a local market (Ankara, Turkey). These bags were selected based on the results of a previous study (Ding et al., 2020).

Storage conditions

Following getting black garlic (BG) bulbs from the company, the bulbs were separated into cloves and peeled by hand. The other remaining part of the BG was prepared as a whole bulb for the experiment. Both BG whole bulbs and peeled cloves were weighed 250 g for each packaging. Then, BG samples were packed in a commercial kraft paper bag by using Packtech, PCS-200 (300W, 220/240V, 50/60 Hz) under storage conditions. After that, all samples were stored for 21 days at 4°C and 55-70% relative humidity (RH) conditions. The storage temperature of BG was chosen mainly based on exporter demands and supermarket conditions in Turkey, and a previous report on BG (Ding et al., 2020). The BG bulbs and peeled cloves were analyzed for quality parameters at weekly intervals. This research was carried out at the Postharvest Physiology Laboratory (Department of Horticulture) and Food Laboratory (Department of Food Engineering) in the Ankara University, Ankara, Turkey.

Quality assessments

Soluble solids content (SSC) was determined using a digital Abbe refractometer (Leica 10480, Germany) and results are expressed in %. pH value was measured by a pH meter (Eutech, Singapore). Color values were determined with a colorimeter (Minolta CR200, Japan) on CIE L^* a^* b^* color space system (L^* = 0 black and L^* = 100 white, a^* (red-green) and b^* (yellow-blue)). An automatic titrator (DL 50 Mettler Toledo) was used to measure the titratable acidity (TA) of cloves in squeezed BG juice and results were given as citric acid % and lactic acid %. Water activity (aw) was determined with an Aqualab Series 3/3TE meter with a temperature stabilizer. Antioxidant capacity (AOC) was done based on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity (RSA) by following the procedure described by Zhang et al. (2015). The absorbance values (Ai) were measured at 517 nm using Shimadzu UV/VIS spectrophotometer. Control (A0) group contains BG sample without DPPH solution, the mixture of 2.5 mL anhydrous ethyl alcohol and 0.5 mL garlic sample's absorbance value is Aj. RSA was calculated using the following equations:

RSA (%) = ((1− (Ai − Aj)) A0) ×100

The total phenolic content (TPC) was analyzed by Folin–Ciocalteu method following the procedure described by Toledano-Medina et al. (2016). The absorbance values of the samples were measured at 765 nm using a spectrophotometer. TPC values were used to compare to a calibration curve prepared with a series of gallic acid standards (75, 100, 200, 250, 300 mg kg-1). TPC results were expressed as a g of gallic acid equivalents (GAE) per kg of the lyophilized sample (dry weight, DW) (g GAE kg^{-1}).

Experimental design and statistical analyses

All experiments were carried out in triplicate and each package was considered one replication. At least ten BG bulbs randomly selected from each package were used for the quality assessments. This experiment was set as a randomized experimental design. Data were expressed as mean ± standard error using ANOVA with MINITAB Software (Trial Version, United Kingdom) at $p \leq 0.05$ probability level. To determine the significance of the difference among means, Duncan's Multiple-Range Test (MSTAT-C software) was used at $p \leq 0.05$ error level. Furthermore, data were subjected to the Pearson correlation test at $p \leq 0.05$ and $p \leq 0.01$ errors level to determine possible relationships among the assessments in this study.

Results and Discussion

Soluble solids content (SSC) is an important marker to evaluate the flavor and nutrition quality of foods (Xiao et al., 2020). Storage period (SP) ($p = 0.165$), clove-bulb (CB) ($p = 0.583$) and SP × CB effects ($p = 0.819$) were not found significant on the SSC values (Table 1). The SSC values of BG varied between 43.15 to 43.57%. These results do not support the earlier findings of Bedrníček et al. (2021), who determined higher values (50-60%), and this difference is probably caused by garlic variety and processing steps. The highest value was determined in bulbs as 43.66% on the 21st day of the storage and the lowest value in bulbs as 43.19% on the 7th day of storage. These values were found higher than two varieties of BG in a report by Toledano-Medina et al. (2019) and a possible reason for this could be a variety difference rather than the storage period, which directly affects the SSC values of fresh or processed foods.

The pH is the best indicator to be used for quality control of BG. In this parameter, only the CB effect was found significant ($p \leq 0.05$) on pH levels of BG (Table 1). Although there were statistical differences between whole bulbs and peeled cloves, the range of values was relatively small in those samples. Namely, higher pH values were found in bulbs as 4.49 compare to the peeled cloves as 4.44 (Table 1). These results are in line with a report by Yuan et al. (2018) and Bedrníček et al. (2021). Previous reports stated that lower pH values of BG could be associated with a higher acidity (Liang et al., 2015; Nassur et al., 2017).

During BG processing, the decrease in pH was an important indicator of Maillard reaction (Zhang et al., 2015; Yuan et al., 2018). However, Moreno et al. (2006) indicated that the Maillard reaction can even take place in the dehydrated garlic during storage period. Likewise, Özkan et al. (2003) stated that non-enzymatic browning reactions are continuous events that continue at a certain rate depending on storage conditions. Another report by Yang et al. (2019) showed that the Maillard reaction occurs during food processing and storage. In fact, such an effect has occurred in this parameter. Namely, the pH of peeled garlic cloves was found to be lower than the bulbs. Therefore, this result is an indication that Maillard reaction still continues in the cloves. This result is consistent with the findings of other researchers. However, this result could not be obtained in bulbs.

Table 1. Effect of storage of black garlic as bulbs and cloves for 21 days under 4°C, 55-70% RH conditions on SSC, pH, color parameters (L*, a* and b*), titratable acidity (citric and lactic acid %) and water activity (aw).

Storage period (SP) (day)	SSC (%)	pH	*L**	*a**	*b**	Citric Acid (%)	Lactic Acid (%)	a_w
0	43.15±0.12	4.50±0.01	25.32±0.18	3.10± 0.07	3.30±0.04	0.95±0.01	0.86± 0.01	0.85±0.01
7	43.21±0.12	4.50±0.01	25.34±0.18	3.18± 0.07	3.33±0.04	0.95±0.01	0.86± 0.01	0.85±0.01
14	43.35±0.12	4.46±0.01	25.36±0.18	3.06± 0.07	3.26±0.04	0.90±0.01	0.82± 0.01	0.85±0.01
21	43.57±0.12	4.44±0.01	25.38±0.18	3.00± 0.07	3.23±0.04	0.90±0.01	0.82±0.01	0.85±0.01
Clove-bulb (CB)								
Clove	43.34±0.10	4.44±0.01b*[1]	25.47±0.15	3.09± 0.05b	3.41±0.03a	0.91±0.01b	0.82±0.01 b	0.86±0.01
Bulb	43.42±0.10	4.49±0.01a	25.25±0.15	3.17± 0.05a	3.14±0.03b	0.93±0.01a	0.85±0.01 a	0.85±0.01
SP × CB								
0th day × clove	43.16±0.17	4.49±0.02	25.33±0.26	3.09±0.10	3.31±0.06	0.95±0.02	0.86±0.01	0.85±0.01
0th day × bulb	43.14±0.17	4.51±0.02	25.31±0.26	3.11±0.10	3.29±0.06	0.95±0.02	0.86±0.01	0.85±0.01
7th day × clove	43.23±0.17	4.46±0.02	25.46±0.26	3.17±0.10	3.51±0.06	0.95±0.02	0.87±0.01	0.86±0.01
7th day × bulb	43.19±0.17	4.53±0.02	25.22±0.26	3.18±0.10	3.16±0.06	0.95±0.02	0.85±0.01	0.85±0.01
14th day × clove	43.31±0.17	4.45±0.02	25.47±0.26	3.11±0.10	3.38±0.06	0.90±0.02	0.78±0.01	0.86±0.01
14th day × bulb	43.40±0.17	4.48±0.02	25.20±0.26	3.02±0.10	3.15±0.06	0.91±0.02	0.86±0.01	0.85±0.01
21st day × clove	43.47±0.17	4.41±0.02	25.49±0.26	3.00±0.10	3.34±0.06	0.89±0.02	0.80±0.01	0.86±0.01
21st day × bulb	43.66±0.17	4.46±0.02	25.27±0.26	2.99±0.10	3.12±0.06	0.92±0.02	0.83±0.01	0.85±0.01
Significant Effects								
SP	0.165 ns	0.156 ns	0.990 ns	0.243 ns	0.256 ns	0.121 ns	0.100 ns	0.931 ns
CB	0.583 ns	0.050	0.327 ns	0.040	0.000	0.048	0.013	0.153 ns
SP × CB	0.819 ns	0.840 ns	0.999 ns	0.883 ns	0.487 ns	0.904 ns	0.054 ns	0.918 ns

*: mean ± standard error of mean (n=10). [1]Letters show differences between clove and bulb (P ≤ 0.05). ns: non-significant.

The color change is related to the result of many reactions such as non-enzymatic browning reactions and pigment destruction (Wong and Stanton, 1993). (Table 1). According to the results, average *L** values in bulbs (25.25) were very similar to that of peeled garlic cloves (25.47) (Table 1). The results showed that both SP and CB effects were not significant on the *L** values of BG. Therefore, these results seem to indicate that storage at 4°C for 21 days did not affect the change of *L** values in BG samples. Regarding *a** and *b** values in the experiment, there were clear differences between stored BG bulbs and BG peeled cloves. Storage as BG bulbs resulted in higher *a** values (3.17) than that of peeled cloves (3.09) (Table 1). However, *b** values exhibited different behaviour and the higher *b** values were recorded in peeled cloves (3.41) compare to the bulbs (3.14). According to the experience, this situation may have resulted from the peeling process, which is exposure to air and light for long hours, as mentioned in Toledano-Medina et al. (2016) reports. Another important factor could be absorption of high moisture from air atmosphere during the peeling of BG cloves as reported by Prachayawarakorn et al. (2004).

BG contained many organic acids such as formic, acetic, pyroglutamic, 3-hydroxypropionic, and succinic acid (Liang et al., 2015, Lu et al., 2017). Acidity above 4% causes an unpleasant acid taste in BG (Zhang et al., 2016) and the acidity limit should be between 2% and 2.5% in BG (Toledano-Medina et al., 2019). Lactic acid is the prominent organic acid in BG, and this could be responsible for unique flavor of BG (Lee et al., 2010).

Moreover, lactic acid could have contributed to the strong antioxidant capacity in BG (Groussard et al., 2000). Another main organic acid is citric acid in BG (Lee et al., 2010). In the experiment, the citric and lactic acid were affected by only the CB variable (Table 1). It was also found that storage of BG as a bulb led to more acidity than peeled cloves. Namely, citric (0.93%) and lactic acid (0.85%) in BG bulbs were higher than in peeled garlic cloves (0.91% and 0.82%, respectively). These values were dissimilar with previous BG reports by Kang et al. (2011) and Toledano-Medina et al. (2016). Considering the experience, these differences in citric and lactic acid contents may be due to either the different process temperatures or varieties.

Water activity (a_W) is an important parameter to predict food stability and safety considering microbial growth, deterioration rate, and physical properties. As expected, the results exhibited that both short-term SP and CB had no significant effect on a_W (Table 1). These results are in agreement with those reported by Toledano-Medina et al. (2016), in which stated that a_W was not significantly affected by storage as bulbs or cloves during storage period. The results confirm that storage at 4°C may have a protective effect on a_w against increasing in a_w values of BG, and this situation supplied food safety during the storage period. In addition, the water activity of BG bulbs and peeled cloves were on average 0.85 and 0.86, which is in line with the results of (a_w<0.85) previous report (Toledano-Medina et al., 2016).

Table 2. Effect of storage of black garlic as bulbs and cloves for 21 days under 4°C, 55-70% RH conditions on antioxidant capacity (AOC) and total phenolic content (TPC).

Storage period (SP) (day)	**AOC (RSA%)**	**TPC (g GAE kg^{-1} DW)**
0	80.54 ± 1.00	19.46 ± 0.34
7	80.50 ± 1.00	19.44 ± 0.34
14	78.50 ± 1.00	19.16 ± 0.34
21	77.67 ± 1.00	18.65 ± 0.34
Clove-bulb (CB)		
Clove	78.00 ± 0.81 b*[1]	18.56 ± 0.27 b
Bulb	79.88 ± 0.81 a	19.61 ± 0.27 a
SP × CB		
0th day × clove	80.25 ± 1.41	19.26 ± 0.48
0th day × bulb	80.83 ± 1.41	19.66 ± 0.48
7th day × clove	78.67 ± 1.41	18.88 ± 0.48
7th day × bulb	82.33 ± 1.41	20.00 ± 0.48
14th day × clove	77.67 ± 1.41	18.49 ± 0.48
14th day × bulb	79.33 ± 1.41	19.84 ± 0.48
21st day × clove	77.21 ± 1.41	18.30 ± 0.48
21st day × bulb	78.54 ± 1.41	19.00 ± 0.48
Significant Effects		
SP	0.163 ns	0.286 ns
CB	0.015	0.020
SP × CB	0.455 ns	0.789 ns

*: mean ± standard error of mean (n=10). 1Letters show differences between clove and bulb (p ≤ 0.05).
ns: non-significant.

BG has a strong antioxidant capacity (AOC), which has a critical importance for human health. AOC of BG could be related to the total polyphenols, flavonoids, and intermediate compounds of the Maillard reaction (Hwang et al., 2011; Choi et al., 2014; Lu et al., 2017). AOC level was not significantly influenced by SP (p = 0.163) but, only CB (p = 0.015) effect was found significant. BG bulbs exhibited much higher AOC level (79.88%) compared to peeled BG cloves (78.00%) (Table 2). Thus, in opinion, the minor difference could be resulted from peeling process. A very similar value of AOC (80%) was also observed in BG bulbs and BG peeled cloves in Lu et al. (2017) report. On the other hand, the average initial values of this study are higher than values of Lee et al. (2010) and Nassur et al. (2017) as 52-69% and 56.87%, respectively. Conversely, Zhang et al. (2015) and Toledano Medina et al. (2016) found AOC values as above 90% by using various processing techniques. In addition, some previous studies reported different findings on BG. Guangyong et al. (2010) stated that the AOC of BG increased during the storage, whereas Priadi et al. (2019) noted the antioxidant content of BG can decrease during storage. According to the experience, the increase might be related to ongoing fermentation during the storage period. The decrease was related to factors causing damage to antioxidant compounds including light, oxygen, high temperature, and water vapor (Priadi et al., 2019).

As shown in Table 2, no changes in total phenolic content (TPC) were observed during the storage period. Significant differences for TPC were attractive among BG bulbs and peeled cloves ($p \leq 0.05$). TPC results were 18.56 and 19.61 g GAE kg-1 DW in BG cloves and bulbs, respectively. These TPC values were higher than the values of Toledano-Medina et al. (2019) but lower than the results of Nassur et al. (2017)'s report. On the contrary, Toledano-Medina et al. (2016) found that BG peeled cloves have a higher polyphenols content than BG bulbs. This difference may have resulted from exposure to different conditions (temperature and humidity) during peeling of BG cloves at long hours. This situation might have also emerged from different genotypes, processing techniques, and storage conditions.

Based on the results of Pearson correlation test, it was revealed that SSC was positively correlated with *L** (r^2 = 0. 466) (Table 3). The pH was highly correlated with AOC and TPC (r^2 = 0.639 and r^2 = 0.593, respectively) and also correlated with citric and lactic acid (r^2 = 0.265 and r^2 = 0.248). In addition, *L** values only positive correlated with AOC (r^2 = 0.457). Moreover, *b** values were negatively correlated with aw (r^2 = 0.485) and AOC (r^2 = 0.209). Furthermore, citric acid was positively correlated with both AOC (r^2 = 0.247) and a_w (r^2 = 0. 041) (Table 3).

Table 3. Correlation between assessments investigated in black garlic stored at 4°C, 55-70% RH conditions.

Assessments	SSC	pH	*L**	*a**	*b**	Citric Acid	Lactic Acid	a_w	AOC
pH	0.175[1]								
L*	0.466*[2]	0.267							
a*	-0.291	-0.159	0.278						
b*	-0.248	-0.172	-0.004	0.127					
Citric acid	0.088	0.265*	0.009	0.060	-0.087				
Lactic acid	-0.253	0.248*	0.273	0.387	0.065	0.155			
a_w	0.170	-0.050	0.029	-0.158	-0.485*	0.041*	-0.281		
AOC	0.266	0.639**[3]	0.457*	0.293	-0.209*	0.247*	0.350	0.045	
TPC	-0.086	0.593**	0.440	-0.018	-0.069	0.155	0.406	0.050	0.278

[1]Pearson correlation coefficient. r^2, -1, +1, [2*] *P ≤ 0.05*, [3**] *P ≤ 0.01*.

Conclusion

Black garlic plays a crucial role in human nutrition and health and it is a promising food to develop high-quality processed products as used in both pharmacy and cosmetic sectors. However, it is important to know the factors affecting the biochemical quality, which give rise to compounds responsible for the amelioration effect of black garlic. A series of studies have focused on the processing technology of black garlic and there was a rare study on storage conditions of black garlic. Therefore, to gain insights into the effect of the short-term storage period on the physicochemical quality of black garlic bulbs and peeled cloves were studied. Based on the results, stored black garlic bulbs maintained the pH, *a** value, citric and lactic acid, antioxidant capacity, and total phenolic content. Peeled black garlic cloves only preserved the *b** values. It can be also concluded that storage for three weeks allowed to rule out the quality loss in black garlic. More studies should be conducted to determine the proper storage conditions of black garlic, the present results will be useful for future studies to understand the role of storage on the quality of black garlic and to provide greater stability.

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