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Physicochemical and antioxidant properties of garlic (*A. sativum*) prepared by different heat treatment conditions

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Abstract The objective of this study was to investigate the physicochemical characteristics and antioxidant potential of garlic processed using different heat treatments conditions, which is an effective method for removing the unpleasant odor and taste of raw garlic. The pH and soluble solid content of raw garlic (pH 6.07, 7.7°Bx) were almost equal or slightly higher than that of processed garlic samples (pH 5.06-6.09, 7.1-7.4°Bx). The color of processed garlic was also significantly affected. The amounts of amino acids such as γ-amino-*n*-butyric acid and few essential amino acids also increased after the thermal treatment of garlic. The antioxidant potentials of red and black garlic were higher than that of raw garlic. The polyphenol content of processed garlic (38.51-81.51 μg gallic acid equivalent/g sample) was significantly higher than that of raw garlic (30.66 μg gallic acid equivalent/g sample). These results indicated that heat treatment for different durations under a controlled environment enhanced the nutritional and functional properties of garlic.

Keywords: *Allium sativum*, antioxidant pothential, heat treatment, polyphenol content

Introduction

Garlic (*Allium sativum*) has been used as a culinary seasoning and a medicinal herb for a long time (Butt et al., 2009). It contains various nutrients and functional materials like anthocyanin, glycosides, essential oil, flavonoids, lectins, fructan, adenosine, pectin, vitamins B1, B2, B6, C and E, prostaglandins, biotin, essential amino acids, nicotinic acid, glycolipids, fatty acids and phospholipids (Bozin et al., 2008). Allicin, one of the major phytochemicals of garlic, is well known for its pharmacological properties, including antibacterial, antihyperlipidaemia, antitumour, and immunoregulatory activity (Ye and Zhang, 2003).

Unpleasant odor and taste are main reasons for the limited consumption of raw garlic in many countries in spite of its high food and medicinal values. The unpleasant odor and taste of raw garlic could be eliminated by heat treatment. Thermal treatment could also improve the palatability of garlic (Capuano and Fogliano, 2011). Thus, heat treatment has been considered as an effective technique to process the raw garlic and to improve the flavor and quality, and further enrich the processed garlic with new functions (Corzo-Martinez et al., 2007). When garlic is subjected to heat treatment, its bioactive aspects are greatly influenced (Corzo-Martinez et al., 2007). Heat treatment changes alliin and deoxidised alliin to allyl sulfurcontaining compounds, and some of which in thermal degradation have a fragrant smell (Lanzotti, 2006). The heat treatment also causes many unstable and unpleasant compounds in raw garlic to get converted into stable and tasteless compounds.

Black garlic, a processed product of raw garlic, is prepared by exposing the whole raw garlic to high temperature (70~80°C) environment under controlled humidity conditions for 1~3 months without additives (Kim et al., 2012). This processed black garlic has a fruity taste and is edible in uncooked form. In addition, the black garlic does not cause abdominal pain or other gastrointestinal problems (Bae et al., 2012). Black garlic has higher antioxidant potential than fresh garlic (Corzo-Martinez et al., 2007) and are more effective in preventing metabolic diseases and alcoholic hepatotoxicity (Ide and Lau, 1999).

The heat treatment may lead to nonenzymatic browning reactions, such as the Maillard reaction, caramelisation and the chemical oxidation of phenols. The nonenzymatic browning reactions can provide the black garlic a typical dark brown color, and lead to the formation of some antioxidant compounds (Osada and Shibamoto, 2006). Considering the non-enzymatic reactions during thermal treatments as well as nutritional and functional value of heat treated garlic, the objective of this study was to investigate the quality characteristics and antioxidant potentials of heat treated garlic for different aging periods.

Materials and Methods

Chemical and Materials

Folin-Ciocalteu phenol reagent and 1,1-diphenly-2-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (St. Louis, MO, USA). All the chemical and reagents were analytical grade. Fresh garlics (*Allium sativum* L.) from the 2018 harvest season were obtained from a local market in Namhae-gun, Korea.

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Preparation of garlic sample

Garlic cloves were separated from the bulbs and peeled off for treatment. Three different samples were prepared from the raw/fresh garlic cloves. The samples were named by their color developed with different aging durations as W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.

All garlic samples were freeze-dried and ground into powder using a commercial grinder (HIL-G-501, Hanil Co., Seoul, Korea). The pulverized samples were stored at 4 until analyses.

Determination of pH and total soluble solid

Five grams of sample powder was mixed with 45 mL of distilled water. The pH value of the sample mixture was determined using a pH meter (Model 210; Hanna, Seoul, Korea). The total soluble solid (TSS) content of the sample powder was measured by following the method described in the Official Methods of the National Tax Service (2006).

Color measurement

The International Commission on Illumination (CIE) Lab color scale was used to determine Hunter L* (lightness), a* (redness, + or greenness,), and b* (yellowness, + or blueness,) values of the garlic powders. Color values were determined using a Chroma Meter (CR-300; Minolta Corporation, Osaka, Japan). A Minolta calibration plate (Y_{CIE}=94.5, X_{CIE}=0.3160, Y_{CIE}=0.3330) and a Hunter lab standard plate (L*=97.51, a*=0.18, b*= +1.67) were used to standardize the instrument with D65 illuminant as described earlier (Kim et al., 2014).

Determination of free amino acid

Amino acid composition of the garlic powder was determined using an amino acid analyzer (Biochrom-20, Pharacia Biotech Co., Stockholm, Sweden) by following the method described earlier (Je et al., 2005). Sample powder (1 g) was hydrolyzed with 6 N hydrochloric acid (10 mL) in a sealed-vacuum ampoule at 110°C for 24 h. The hydrochloric acid was eliminated by evaporating using a rotary evaporator, and then the extract was mixed with 5 mL 0.2 M sodium citrate buffer (pH 2.2).

For the determination of free amino acid content in the garlic powders, the sample (1.5 g) was homogenized (12,000 rpm, 2 min) with ice-cold 6% (v/v) perchloric acid (10 mL) in an ice bath using an ACE homogenizer (Nissei AM-7, Nihonseikei Kaisha Ltd., Tokyo, Japan) and then incubated in ice for 30 min. Two milliliters of the reaction mixture was mixed with 1 mL lithium citrate buffer (pH 2.2) and the mixture was used to determine the free amino acids using the amino acid analyzer.

Determination of mineral composition

The sample powder (0.5 g) was digested in a mixture of 15 mL nitric acid (65%) and 2 mL H_2O_2 (35%). The sample mixture was diluted with an equal volume of distilled water. The mineral elements in the garlic powders were determined using an inductively coupled plasma atomic emission spectrometer (ICP AES; Varian Inc., Victoria, Australia) by following the method described by Skujins (1998). The instrument was calibrated using known standards for each mineral.

DPPH radical scavenging activity

The DPPH radical scavenging potential of garlic powders was determined by following the method described by Blois (1958). One gram of sample powder was extracted with 10 mL absolute methanol at room temperature for 3 h. The mixture was centrifuged at 1,660×*g* for 10 min, and the supernatant was filtered through a syringe filter (0.22 μm). An equal volume (100 μL) of sample extract and freshly prepared DPPH solution (0.1%, w/v in methanol) was mixed in microplate wells and left in dark for 30 min. The optical densities of reaction mixtures were measured at 517 nm using a microplate spectrophotometer (Multiskan GO, ThermoFischer Scientific, Vantaa, Finland). The DPPH radical scavenging activity was calculated using the following equation.

$$\text{DPPH radical scavenging potential (\%)} = [1-(AA_b)/A_o]\times 100$$

where A is the absorbance of sample and DPPH mixture, and A_b is the absorbance of sample and methanol mixture, and A_o is the absorbance of DPPH and methanol mixture.

ABTS radical scavenging activity

The ABTS radical scavenging activity of garlic powder was determined following the method described by Re et al. (1999). The radical cation of ABTS (ABTS+) was produced by mixing an equal volume of potassium persulfate (2.5 mM) and ABTS (7 mM) and incubating in the dark for 16 h. The solution was diluted with distilled water to get the absorbance value near to 0.7. Twenty microliters of sample extracts (as prepared for DPPH assay) were mixed with 180 μL of ABTS solution and the absorbance of reaction mixture was measured at 734 nm using a spectrophotometer (Multiskan GO, Thermo Fischer Scientific). The ABTS radical scavenging activity was calculated using the following equation.

$$\text{ABTS radical scavenging activity (\%)} = [(A_{Ctrl}-A_{Sample})/A_{Ctrl})]\times 100$$

where A_{Ctrl} is the absorbance of ABTS radical cation and A_{Sample} is the absorbance of a mixture of ABTS radical solution and sample extract.

Polyphenol content

The polyphenol content in garlic samples was determined following the Folin-Ciocalteau method (Singleton, 1999). Sample extracts of garlic powders were prepared as in the DPPH assay. The sample extracts (50 μL) was mixed with 2% (w/v) aqueous Na_2CO_3 (1000 μL) and allowed to react for 3 min. After 3 min, 50 μL of 1 N Folin-Ciocalteau reagent was added to the mixture and incubated in dark for 30 min at room temperature. The absorbance value of reaction mixtures was measured at 750 nm using a

microplate spectrophotometer (Multiskan GO, Thermo Fischer Scientific). Gallic acid was used as standard to make calibration curve. Polyphenol content was determined as gallic acid equivalents (μg GAE/g dry weight).

Statistical analysis

Data were subjected to analysis of variance using SAS 9.4 (SAS Institute, Cary, NC, USA) and significant differences among the samples were determined using Tukey test at 5% probability. The mean values of triplicate measurements were considered for statistical analysis unless otherwise mentioned in any specific analysis.

Results and Discussion

General chemical properties

The pH and soluble solid contents of garlic samples were significantly different with heat treatments and/or aging time (Table 1). The pH values of R-G (5.18) and B-G (5.06) were significantly lower than those of W-G (6.07) and Y-G (6.09). The soluble solid contents of processed garlic samples were significantly reduced as compared to the raw garlic. The highest value of soluble solid content was found in R-G (7.4°Bx) followed by B-G (7.3°Bx) and Y-G (7.1°Bx).

Similar results of decreased pH in the aged garlic were also found in a previous study (Kang, 2016). The reduction in pH values of heat-treated garlic samples was, in part, resulted due to the production of browning compounds, including carboxylic acid, and decreased basic amino acids by combining with sugar upon heat treatment (Bae et al., 2014). In the present study, the soluble solid content of processed garlic was lower than that of raw garlic. This reduced soluble solid content in the processed garlic was in opposite to a previous report (Ríos-Ríos et al., 2016) which might be due to the variation in treatment conditions including temperature and relative humidity.

Color

The color of processed garlic is an important factor from the viewpoint of consumers' preference. The color values of processed garlic were significantly affected by the heat treatments, as expected. The highest lightness, redness, and yellowness values were found in Y-G (L value: 54.26), R-G (a value: 5.30), and Y-G (b value: 24.32), respectively (Table 2).

Color of foods plays a big role in buying behavior of consumers. The change in color of different garlic samples might be due to an extended drying and high temperature (Cui et al., 2003). Similar results of color variations found in the present study of heat-treated garlic were found in a previous study (Choi et al., 2014). The color variations in heat-treated garlics might have resulted due to the Maillard reaction, known as non-enzymatic browning reaction.

Table 1. General chemical properties of heat-treated garlic for different aging times

Properties	Sample[1)]			
	W-G	Y-G	R-G	B-G
pH	6.07±0.01a[2]	6.09±0.01a	5.18±0.04b	5.06±0.01c
Soluble solid (°Bx)	7.7±0.0a	7.1±0.1d	7.4±0.0b	7.3±0.1c

[1)]W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.
[2)]Values are mentioned as mean±SD of triplicate measurements, Values followed by different letters in the same row are significant different (p<0.05).

Table 2. Hunter color values of heat-treated garlic for different aging times

Sample	Color value[1)]		
	L* (Lightness)[2)]	a* (Redness)	b* (Yellowness)
W-G	51.19±0.58b[3)]	-0.89±0.04c	9.04±0.70b
Y-G	54.26±0.12a	-1.29±0.03d	24.32±0.06a
R-G	35.63±0.14c	5.30±0.03a	5.59±0.25c
B-G	34.86±0.03d	4.39±0.25b	4.39±0.17d

[1)]W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.
[2)]L: lightness (100, white; 0, black), a: redness (-, green; +, red), b: yellowness (-, blue; +, yellow).
[3)]Values are mentioned as mean±SD of triplicate experiments. The values followed by the different letters in the same column are significantly different, according to Tukey test (p<0.05).

Table 3. DPPH and ABTS radical scavenging activities and polyphenol contents of heat-treated garlic for different aging times

Sample[1)]	DPPH (% Inhibition)	ABTS (%)	Polyphenol content (μg GAE*/ g sample powder)
W-G	85.38±0.51c[2)]	24.26±1.21d	30.66±1.56d
Y-G	56.20±0.69d	38.58±0.69c	38.51±0.55c
R-G	89.27±0.28b	83.83±0.23a	81.51±0.24a
B-G	90.80±0.42a	79.27±0.32b	60.79±0.11b

[1)]W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.
[2)]Values are mentioned as mean±SD of triplicate experiments. Values followed by different letters in the same column are significantly different (p<0.05).
*GAE: Gallic acid equivalents.

Free amino acid

A total of 8 and 23 essential and non-essential amino acids were detected in at least one garlic sample (Table 4). All 8 essential

amino acids were detected in all samples but not all 23 non-essential amino acids were detected in all garlic samples. The highest amount of essential amino acid was found in B-G (9.43 mg/g sample powder) followed by W-G (7.85 mg/g sample powder) and R-G (7.74 mg/g sample powder). However, total amino acid content of raw garlic, W-G (57.66 mg/g sample powder) was higher than those of the processed garlic samples, Y-G (1.37 mg/g sample powder), R-G (38.38 mg/g sample powder), and B-G (44.01 mg/g sample powder). The amino acid content of Y-G was much lower than the other samples. The ratio of essential to non-essential amino acids was the highest for B-G (0.27 mg/g sample powder) followed by R-G (0.25 mg/g sample powder), Y-G (0.23 mg/g sample powder), and W-G (0.16 mg/g sample powder). The content of γ-amino-*n*-butyric acid (GABA) was 1.13, 0.01, 1.53, and 2.77 μg/g in W-G, Y-G, R-G, and B-G, respectively. The heat treatment significantly increased the GABA contents of R-G and B-G.

The variation in amino acid content was probably due to the degradation of proteins or peptides, which may result from enzymatic hydrolysis or non-enzymatic hydrolysis, such as pyrolysis (Liang et al., 2015). Thermal processing, perhaps caused by reactions with reducing sugars, such as the Maillard reaction might also have

Table 4. Free amino acid composition (mg/g sample powder) of heat-treated garlic for different aging times

Amino acid	Sample[1)]			
	W-G	Y-G	R-G	B-G
Essential amino acid				
L-Threonine	1.17±0.02a[2)]	0.02±0.01d	0.74±0.02c	1.03±0.04b
L-Valine	1.20±0.03c	0.07±0.01d	2.27±0.03b	2.73±0.07a
L-Methionine	0.21±0.05a	0.01±0.01b	0.24±0.02a	0.28±0.03a
L-Isoleucine	0.41±0.02c	0.02±0.01d	0.78±0.02b	0.99±0.02a
L-Leucine	0.38±0.01a	0.04±0.01c	1.07±0.03b	1.11±0.03b
L-Phenylalanine	1.01±0.02b	0.05±0.01c	1.03±0.05b	1.34±0.02a
L-Lysine	2.82±0.03a	0.04±0.02d	1.41±0.02c	1.73±0.02b
L-Histidine	0.65±0.02a	0.01±0.01c	0.21±0.01b	0.21±0.03b
Total essential amino acid	7.85	0.26	7.75	9.42
Non-essential amino acid				
O-Phospho-L-serine	0.45±0.01a	0.09±0.01b	ND[*]	ND
Taurine	ND	0.08±0.02a	ND	ND
L-Aspartic acid	11.03±0.15a	0.05±0.03d	1.54±0.02c	2.16±0.01b
L-Serine	0.95±0.02c	0.03±0.01d	1.13±0.02a	1.05±0.02b
L-Glutamic acid	2.07±0.03c	0.30±0.02d	2.91±0.03a	2.81±0.03b
L-Sarcosine	ND	ND	0.16±0.02a	0.18±0.03a
L-α-Aminoadipic acid	ND	0.02±0.01a	ND	ND
Glycine	0.41±0.03a	0.01±0.01d	0.18±0.03c	0.26±0.05b
L-Alanine	2.71±0.02a	0.11±0.02d	1.67±0.03c	1.83±0.01b
L-Citrulline	ND	0.02±0.01a	ND	ND
L-α-Amino-n-butylric acid	ND	ND	ND	0.02±0.01a
L-Cystine	0.23±0.01c	ND	0.71±0.02b	1.01±0.03a
Cystathionine	0.11±0.03c	0.01±0.01d	0.40±0.01a	0.37±0.01b
L-Tyrosine	1.72±0.02a	0.07±0.01d	1.17±0.05c	1.38±0.02b
β-Alanine	0.14±0.03c	0.01±0.01d	0.28±0.03b	0.52±0.03a
D,L-β-Aminoisobutyric acid	ND	0.02±0.01a	ND	ND
γ-Amino-n-butyric acid	1.13±0.05c	0.01±0.01d	1.53±0.02b	2.77±0.07a
Ethanolamin	0.08±0.02a	0.02±0.01b	0.04±0.01b	0.04±0.01b
Ammonia	0.46±0.03a	0.06±0.02c	0.29±0.02b	0.46±0.03a
Hydroxylysine	0.08±0.01a	ND	ND	ND
L-Ornithine	0.28±0.02a	0.02±0.01c	0.09±0.02b	0.11±0.01b
L-Arginine	27.02±2.12a	0.08±0.01c	16.96±1.31b	18.66±2.00b
Proline	0.94±0.01b	0.11±0.02c	1.57±0.02a	0.96±0.01b
Total non-essential amino acid	49.81	1.12	30.63	34.59
Total	57.66	1.38	38.38	44.01

[1)]W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.
[2)]Values are mentioned as mean±SD of triplicate experiments. Values followed by different letters in the same row are significantly different ($p<0.05$).
[*]ND: non-detectable.

Table 5. Mineral content (mg/kg dry powder) of heat-treated garlic for different aging times

Mineral Element	Sample[1)]			
	W-G	Y-G	R-G	B-G
K	13,221.85±11.23b[2)]	575.25±10.17d	15,294.47±9.78a	11,952.68±15.17c
Ca	697.80±6.79a	224.99±6.23d	467.02±7.12b	401.09±10.66c
Na	1,254.58±8.88a	303.957±5.37b	192.12±1.15d	262.74±2.90c
Mg	701.17±8.00a	208.91±2.71d	682.31±5.66b	568.48±3.21c
Mn	8.07±0.02b	7.74±0.02c	9.72±0.07a	9.68±0.18a
Cu	6.80±0.03a	4.94±0.17c	6.01±0.12b	6.22±0.17b
Zn	18.63±1.23c	12.41±1.66d	24.39±0.98b	26.52±0.71a
As	ND*	ND	ND	ND
Cd	ND	ND	ND	ND
Hg	ND	ND	ND	ND
Pb	ND	ND	ND	ND
Total	15,908.9	1,338.197	16,676.04	13,227.41

[1)]W-G: raw garlic without any treatment, Y-G: yellow garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 3 days, R-G: Red garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 4.5 days, and B-G: Black garlic prepared by heating the fresh garlic under controlled condition of 60 and 60% relative humidity for 10 days.
[2)]Values are mentioned as mean±SD of triplicate experiments. Values followed by different letters in the same row are significantly different ($p<0.05$).
*ND: non-detectable. Detection limit: AS; <10 mg/kg, Cd; <5 mg/kg, Hg; <10 mg/kg, and Pb; <5 mg/kg.

played roles in causing variations in amino acid contents of raw and processed garlic samples (Ichikawa et al., 2006). Foods containing higher ratios of essential to non-essential amino acids are considered good from the protein deposition viewpoint (Reeds, 2000). Glutamic acid is a precursor for the synthesis of GABA in plant tissues (Nikmaram et al., 2017). GABA is thought to be related to learning and memory; against stroke and neurodegenerative diseases; relieving anxiety, sedation, anticonvulsant; and muscle relaxation functions (Oh and Oh, 2004). The foods containing high GABA are known as brain foods and believed to play roles in different bioactive functions, including regulating blood cholesterol and pressure, decreasing insomnia and depression, and relieving pain (Dhakal et al., 2012). GABA is also reported to have function against diabetes (Reeds, 2000). The increased GABA contents in red and black garlics shows that heat treatment technology could be adopted to enhance the nutritional value of raw garlic.

Mineral content

The amount of mineral elements in raw and processed garlics was significantly different according to aging time (Table 5). The most abundant mineral found in the raw and processed garlic samples was K. Garlic samples R-G (15,294 mg/kg) had the highest and Y-G (575.25 mg/kg) had the lowest amounts of K among the samples. Na contents of processed garlic samples (192.12-303.98 mg/kg) were significantly reduced as compared to the raw garlic (1,254 mg/kg). Samples R-G and B-G had significantly higher amounts of Mn and Zn than in W-G. The total mineral contents of garlic samples were in the order of R-G>W-G>B-G> Y-G.

The amounts of several mineral elements found in the heat-treated garlic samples were increased compared to the raw garlic. The increased mineral contents in the processed garlics than in the raw garlic might be due to the physiological changes occurred during heat treatment (Kang, 2016). High Na and low K intake are reported to have association with hypertension and cardiovascular disease risk (Luta, 2018). Thus the elevated K and reduced Na in the processed garlic could be an ideal food to improve health. Zn is associated with growth, development, differentiation, DNA synthesis, RNA transcription, and cellular apoptosis (MacDiarmid et al., 2000). Thus, heat treatment could be an effective technique to reduce the amount of undesirable element like Na and to increase the amount of others like K and Zn, making the processed garlic more beneficial to human health.

DPPH and ABTS radical scavenging activities and polyphenol contents

The DPPH and ABTS radical scavenging activities and polyphenol content of processed garlic were higher than those of raw garlic (Table 3). The ABTS radical scavenging activity and polyphenol content of R-G (83.83% and 81.51 μg GAE/g sample powder) were more than three- and two-time higher as compared to W-G (24.26% and 30.66 μg GAE/g sample powder).

The result of higher polyphenol content in aged garlic as compared to the raw was in agreement with that of Jastrzebski et al. (2007). This increased phenolic content might be due to heat treatment (Xu et al., 2007). The aging treatment did not have constantly increased the antioxidant potential and polyphenol contents of processed garlic samples. Gorinstein et al. (2008) also found that the garlic processing conditions affect the contents of bioactive compounds of the processed garlic, such as polyphenols, and that this is influenced by the type and duration of treatment. The change in total phenols content affects the total antioxidant capacity of heat-processed garlic (Jastrzebski et al., 2007). Although significant, the heat treatment was not found to effectively improve the DPPH scavenging potentials of the processed garlics. However, ABTS radical scavenging activities and polyphenol contents of

the processed garlics were remarkably increased by the heat treatments. One of the reasons for this discrepancies might be due to the complex nature of the antioxidant potential of foods as an outcome of various factors, including the partitioning properties of particular antioxidants, the oxidation conditions, and the physical state of the oxidizable substrate (Frankel and Meyer, 2000). Thus, an increment in a particular antioxidant, including total polyphenol content, might not always contribute to an enhanced antioxidant potentials as found in W-G and Y-G. Consumption of antioxidant-rich foods is considered as a preventive way to control various diseases (Serafini, 2006).

Conclusion

Garlic cloves were subjected to heat treatment at controlled conditions of 60°C and 60% relative humidity for 3, 4.5, and 10 days. The physicochemical characteristics and antioxidant potentials of garlic processed at the different aging time were investigated. The pH and soluble solid content of processed garlic samples were significantly reduced as compared to unprocessed raw garlic. The color of processed garlic was also varied by heat treatments. The amounts of amino acids like γ-amino-*n*-butyric acid and few essential amino acid contents of the processed garlic were also increased. Minerals like K, Mn, and Zn were increased in some of the heat-treated garlic samples. The antioxidant potentials and polyphenol content of processed garlic samples were enhanced by the heat treatments. Overall results of this study showed that heat treatments under controlled humidity conditions could be carried out to enhance the nutritional and functional values of garlic.

Conflict of interest

The authors declare no conflict of interest.

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