Germinated barley as a functional ingredient in chicken sausages: effect on physicochemical and technological properties at different levels

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Abstract The objective of this study was to evaluate the effect of germinated barley (GB) levels on physicochemical and technological properties of cooked chicken sausages. The chicken sausages were formulated with 0–4 % GB. Addition of GB increased pH and yellowness but decreased lightness of the cooked chicken sausages. However, there was no difference in redness among treatments ($P > 0.05$). Based on the positive effects of GB on measurements related to water and/or fat retention ability, such as emulsion stability, cooking loss, and thawing loss, such results depended upon the added amount of GB. In addition, apparent viscosity increased with increasing levels of GB, resulting in hardness, springiness, and chewiness ($P < 0.05$). These results could be associated with polysaccharides contained in GB, such as insoluble fiber, β -glucan, and starch. Therefore, our results suggests that GB could be a functional ingredient to improve physicochemical and technological properties of chicken sausages and optimal level of GB was determined as minimum 2 %.

Keywords Barley · Chicken breast · Dietary fiber · Germination · Sausage

Introduction

Barley (*Hordeum vulgare*), which is one of the five main crops in the world, along with rice, wheat, corn, and soybean, is rich in vitamin B groups, minerals, and carbohydrates, as well as soluble and insoluble dietary fiber (Arora et al. 2010). The total dietary fiber in barley ranges from 11 % to 34 %. In particular, β -glucan contained in barley has received great attention due to its functionality (Izydorczyk et al. 2000), which has been known to provide various health benefits including reducing blood cholesterol and controlling glycemic index in the human body (Regand et al. 2009; Wolever et al. 2010).

Recently, the several steps of processing, such as dehulling, cooking, and/or germination, have been applied to improve nutritional and functional properties of barley; most of all, the germination has been recognized as a notable method to modify the characteristics and composition of cereals, contributing to an increase of vitamins and antioxidants (Hübner et al. 2010). During germination, β -glucan in oat or barley decomposes into low molecular weight and/or monosaccharide due to enzymatic hydrolysis of β -glucanase. Low molecular weight β -glucan could easily form into a soft gel (Charalampopoulos et al. 2002). Moreover, numerous studies have reported the physiological benefit of germinated barley in human health. Kanauchi et al. (1999) reported that fractions of germinated barley contained low-lignified hemicellulose and glutamine-rich protein and suggested that they have an effect on improving the proliferation of intestinal epithelial cells and defecation. Sharma and Gujral (2010) reported that barley germinated for 24 h exhibited an increase in total phenolic content and antioxidant activity when compared to barley before germination. Based on these studies about the positive physiological effect of germinated barley, thus, it can be possible to develop functional meat products.

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In meat products, barley as well as β -glucan has been used as a functional ingredient to manufacture low and reduced fat meat products, due to its functionality (Shand 2000; Morin et al. 2002, 2004). According to Lee (2008), the germination decreased the total amount of β -glucan but increased the solubility of β -glucan in well-modified barley. However, no information has been published on the effect of germinated barley levels on quality attributes of meat products.

Chicken breast, which contains low fat content, has been recognized as an excellent source to produce low fat meat products. According to Choi et al. (2009), however, chicken meat is regarded as having lower processing properties in comparison to beef and pork. For this reason, the effective application of additives, salt, and phosphate are needed to enhance quality and to diversify chicken products. Currently, it has been reported that the addition of dietary fiber from natural source, such as wheat and oat (Talukder and Sharma 2010), apple (Verma et al. 2010), and soybean (Kumar et al. 2013), could improve quality characteristics of chicken meat products, such as nugget and patty. Thus, a natural ingredient which have technological functionality, such as water holding and binding capacity, emulsion stability, and gelling ability, can be a proper source to overcome the limited practical use of chicken breast in meat products.

Therefore, the objectives of this study were (Álvarez and Barbut 2013) to investigate the physicochemical and textural properties of cooked chicken sausages containing various germinated barley levels and (Arora et al. 2010) determine the optimal adding level of germinated barley for manufacturing emulsified chicken meat products.

Materials and methods

Preparation of germinated barley (GB)

Barley (*Hordeum vulgare*) which was geminated in water immersion at room temperature for 24 h was purchased from a local market. To additionally remove moisture, germinated barley (GB) was dried in a hot air dryer (Enex-Co-600, Enex, Korea) at 50 ± 1 °C for 24 h (<5 % final moisture), and then cooled at room temperature. GB was blended finely using a food blender and passed through <0.5 mm (35 mesh) in size. The GB powder were vacuum-packaged with PE/nylon film using a model HFV-600 T vacuum packaging system (Hankook Fujee Industries Co., Ltd., Korea), and stored in a refrigerator until used for chicken sausage manufacture.

Manufacture of chicken sausages

Chicken sausages were manufactured according to the procedure described by Choi et al. (2012). Fresh chicken breast (broiler, *M. pectoralis major*, moisture 74.95 %, protein

22.58 %, fat 1.09 %, ash 1.31 %) and pork back fat (moisture 12.73 %, fat 85.73 %) were purchased from a local processor. Chicken breast and pork back fat were ground though a grinder equipped with 8 mm plate (Hankook Fijee Industries Co., Ltd., M-12S, Korea). Each sample batch consisted of five emulsions differing in composition with respect to the addition of GB powder (0, 1, 2, 3, and 4 %). All chicken emulsions were composed by 50 % chicken breast muscle, 25 % pork backfat, and 25 % ice. The ingredients were emulsified using a silent cutter (Nr-963,009, Scharfen, Germany) with 1.5 % sodium chloride. The temperature of the emulsion during the preparation was maintained below 12 °C during emulsion, which was monitored by a temperature probe (Kane-May, KM330, Germany). Each of the emulsions was individually vacuum-packaged in polyethylene bags and stored in a 4 °C refrigerator until analysis.

Physicochemical analysis

pH measurements

The pH values of cooked chicken sausages were determined with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH values of samples were measured by blending a 5 g sample with 20 ml distilled water for 60 s in a homogenizer at 8000 rpm (Ultra-Turrax SK15, Janke & Kunkel, Germany). All determinations were performed in triplicate ($n = 3/\text{treatment}/\text{replication}$).

Color measurements

The color of chicken emulsion was determined using a colorimeter (Minolta Chroma meter CR-210, Japan; illuminate C, calibrated with a white plate, CIE $L^* = +97.83$, CIE $a^* = -0.43$, CIE $b^* = +1.98$). Eight measurements for each of eight locations on the surface of samples were taken. CIE L^* (lightness), CIE a^* (redness), and CIE b^* (yellowness) values were recorded ($n = 5/\text{treatment}/\text{replication}$).

Emulsion stability

The chicken emulsion was analyzed for emulsion stability using the method of Bloukas and Honikel (1992) with the following modifications. At the middle of a 15 mesh sieve, pre-weighed graduated glass tubes (Pyrex Chojalab Co., Korea, volume: 15 ml, graduated units: 0.2 ml) were filled with emulsion. The glass tubes were closed using cap and heated in a water bath (75 ± 1 °C) for 30 min. After cooling to 4 ± 1 °C, to facilitate fat and water layer separation, the water and fat separated in the bottom of each graduated glass tube were measured and calculated as follows;

Water release (ml/g) = [(the water layer (ml)/weight of raw emulsion (g)] $\times$ 100 and fat release (ml/g) = [(the fat layer

(ml)/weight of raw emulsion (g)] $\times$ 100 (Choi et al. 2010) ($n = 3/\text{treatment/replication}$).

Protein solubility

Procedures described by Joo et al. (1999) were modified and used to determine the solubility of the sarcoplasmic and myofibrillar proteins. To determine total protein solubility, 2 g of sample was weighed into a centrifuge tube, and then 20 ml of ice-cold 1.1 M KI in 0.1 M phosphate buffer (pH 7.4) was added. The sample and buffer were homogenized together on ice for 20 s using a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Japan) set at 1500 rpm, and were left to stand on a shaker at 4 °C overnight. The mixtures were centrifuged at $6000 \times g$ for 15 min and the protein concentrations of the supernatants were determined using the biuret method (Gornall et al. 1949). To determine water-soluble protein, a second sample was subjected to the same extraction procedure for homogenization, shaking, centrifugation, and protein determination are described above, using 0.025 M phosphate buffer (pH 7.4). The solubility of salt-soluble protein, including myofibrillar protein, was calculated as the difference between total protein and water-soluble protein ($n = 3/\text{treatment/replication}$).

Cooking and thawing loss

The chicken emulsion was stuffed into collagen casing (#240, NIPPI, Japan; approximate diameter of 25 mm) using a model IS-8 stuffer (Sirman, Italy) and was cooked in a 75 and 100 °C water bath for 30 min, respectively. And then the cooked samples were cooled to room temperature at 21 °C for 3 h. After cooling, the chicken sausages cooked at two temperatures were reweighed and the cooking loss individually calculated as follows (Choi et al. 2012);

Cooking loss (%) = [(weight of raw sample (g) – weight of cooked sample (g))/weight of raw sample (g)] $\times$ 100 ($n = 3/\text{treatment/replication}$).

The thawing loss of cooked chicken sausages was evaluated to determine effect of GB on emulsion stability during freezing and thawing processing, according to the method described by Defreitas et al. (1997) with slight modifications. The cooked sample under above mentioned condition was weighed and individually vacuum-packaged in a polyethylene bag. And the sample was frozen in a – 20 °C freezer for 24 h. The frozen sample was thawed in a 4 °C refrigerator for 24 h, and then was reweighed. Totally, two frozen-thawed cycles were repeated under the identical conditions. The thawing loss was calculated as follows;

1st thawing loss (%) = $(A - B)/A \times 100$ and 2nd thawing loss (%) = $(B - C)/B \times 100$. Where, A = the weight of cooked sample (g), B = the weight of the sample after one frozen-

thawed cycle (g), C = the weight of the sample after two frozen-thawed cycles ($n = 3/\text{treatment/replication}$).

Textural analysis

Apparent viscosity

Emulsion viscosity was measured in triplicate with a rotational viscometer (HAKKE Viscotester® 550, Thermo Electron Corporation, Germany) set at 10 rpm (Choi et al. 2012). The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with emulsion and allowed to rotate under a constant shear rate at s^{-1} for 60 s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at $(18 \pm 1 \text{ }^{\circ}\text{C})$ viscosity testing was also recorded (Shand 2000) ($n = 3/\text{treatment/replication}$).

Texture profile analysis (TPA)

Texture profile analysis was performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems, England). Cooked samples were taken from the central portion of each meat batter. Prior to analysis, samples were allowed to equilibrate to room temperature (20 °C, 3 h). The conditions of texture analysis were as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described (Bourne 1978) ($n = 6/\text{treatment/replication}$).

Statistical analysis

Experimental design was a randomized complete block design. A total of three independent replicates were conducted. Data were analyzed using SPSS (SPSS Inc., Chicago, IL, USA) for one-way ANOVA to determine the significance of main effect (GB levels). Duncan's multiple range test ($P < 0.05$) was used to determine differences between treatment means.

Result and discussion

pH and color of chicken sausages

The effect of germinated barley (GB) powder levels on pH and color characteristics of cooked chicken sausages is shown in Table 1. The pH values of chicken sausages ranged from 6.06 to 6.17, and the pH value increased when the GB level increased ($P < 0.05$). As a similar result, Morin et al. (2002)

Table 1 pH and color characteristics of cooked chicken sausages formulated with various levels of germinated barley (GB)

Traits	Germinated barley levels					SEM ¹⁾
	0 %	1 %	2 %	3 %	4 %	
pH value	6.06 ^c	6.07 ^c	6.13 ^b	6.17 ^a	6.17 ^a	0.010
Color parameters						
CIE L* (lightness)	84.46 ^a	82.92 ^b	82.75 ^b	82.64 ^b	80.46 ^c	0.301
CIE a* (redness)	0.65	0.07	0.12	0.03	0.34	0.058
CIE b* (yellowness)	10.41 ^c	10.47 ^b	10.66 ^{ab}	10.89 ^{ab}	11.41 ^a	0.091

¹⁾ SEM: standard error of the mean^{a-c} Means sharing different letters in the same row are significantly different ($P < 0.05$)

reported that addition of 0.3 % barley β -glucan resulted in increased pH value for reduced-fat breakfast sausage (6.51) when compared to a control (6.39). In this study, the pH value of GB was 6.22, which was a higher value than that of the chicken breast muscle (5.88). Thus, high pH value of GB could increase pH value of cooked chicken sausages. Similarly, in previous studies regarding the utilization of cereal dietary fibers on meat products, the pH value of meat products was considerably affected by the original pH of added cereal flours. As supporting results to this finding, Choi et al. (2011) reported that the increased rice bran fiber levels significantly contributed to an increased pH value of salt-soluble porcine protein gel. Yılmaz and Dağlıoğlu (2003) reported that the addition of 10 % oat bran resulted in the increased pH value of meatball. In general, optimal gelation of chicken breast muscle, contributing to strong gel, is formed at pH 6.3 (Lesiów and Xiong 2003). In addition, Lan et al. (1995) reported that water-holding capacity of chicken breast increased with an increasing pH within 5.5–7.0. Thus, it was likely that the increase in pH to 6.30 might be positive impacts on water-holding capacity and texture of chicken sausages, although the gap in the pH between treatments was small.

An increase in GB levels decreased lightness but increased yellowness of cooked chicken sausages. However, GB had no influence on redness of the chicken sausages ($P > 0.05$). Previously, Álvarez and Barbut (2013) reported that barley β -glucan (0–0.6 %) caused increase in yellowness of cooked meat emulsion but did not affect lightness. Similar results were reported by Choi et al. (2010, 2011), who reported that additives, which were made from cereal bran or flour, mainly contributed to an increase in yellowness of meat products due to the brown color of cereal bran or flour. In addition, Yılmaz and Dağlıoğlu (2003) indicated that the increased yellowness of meatball resulted from carotenoid pigments contained in cereal bran. According to Li and Beta (2012), the barley included carotenoids (174–850 $\mu\text{g/kg}$) such as zeaxanthin and lutein. In this study, it was seemed that natural pigments derived from barley bran including carotenoids could affect color alternation.

Protein solubility and emulsion stability of chicken meat batters

The protein solubility of meat batter has been extensively used to predict and determine the cooking yield, emulsion stability, and textural properties of final products after thermal processing (Feiner 2006). In our study (Fig. 1), the solubility of total, salt-soluble, and water-soluble proteins in chicken meat batter were not affected by the adding level of GB ($P > 0.05$). Kim et al. (2013) reported that dietary fiber extracted from brewer's spent grain decreased the salt-soluble protein of chicken patties and suggested that decreased protein solubility resulted from the decline of the pH value due to the dietary fiber extracted from brewer's spent grain. The protein solubility of meat and meat emulsion are fundamentally affected by altering pH (Feiner 2006), and no differences in protein solubility of chicken meat emulsion might be associated with the negligible effect on GB on the pH value.

The emulsion stability was affected by several factors, including fat and moisture contents, water holding capacity, and the presence of non-meat ingredient including dietary fiber (Choi et al. 2010). The increase in GB levels decreased both water and fat releases; significant reduction in water and fat

Fig. 1 Protein solubility of chicken meat batters formulated with different germinated barley (GB) levels of 0–4 %

release were observed for chicken meat batter containing 2 % GB ($P < 0.05$). However, there were no significant differences in water and fat releases among 2–4 % GB treatments ($P > 0.05$). Previously, Álvarez and Barbut (2013) reported that barley β -glucan reduced fat loss of meat emulsion. In addition, numerous previous studies have reported that improvement of emulsion stability due to addition of dietary fiber from cereal sources, which could improve water and fat retention ability. Choi et al. (2010) reported that a combination of 2 % rice bran and grape seed oil reduced total expressible fluid and fat loss of reduced-fat meat emulsion. Hughes et al. (1998) reported that starch contributed to an increase in emulsion stability of frankfurters. Talukder and Sharma (2010) noted that addition of 5 % wheat and oat bran improved emulsion stability of chicken patties. Thus, the results of emulsion stability in current study could result from the effect of polysaccharides contained in GB, such as β -glucan, insoluble fiber, and starch (Fig. 2).

Cooking loss and thawing loss of cooked chicken sausages

The effect of GB levels on cooking loss of chicken sausages cooked at two temperatures (75 and 100 °C) is shown in Fig. 3. Considering the large variation of thermal processing temperatures of several meat products, the determination of cooking loss of chicken sausages was conducted at two temperatures. At 75 °C cooking, the all GB treatments had a significantly ($P < 0.05$) lower cooking loss than the control (0 % GB); this effect was also observed for addition of GB minimally at 1 %, whereas addition of GB above 2 % showed reduction in cooking loss of chicken sausages cooked at 100 °C. However, there was no difference in cooking loss between T3 (3 % GB) and T4 (4 % GB) treatments, regardless of cooking temperature. Previously, it was well known that addition of cereal dietary fiber had a great effect on reduction

Fig. 2 Emulsion stability (water and fat release) of chicken meat batters formulated with different germinated barley (GB) levels of 0–4 %. **a, b** Means sharing different letters within each experiment are significantly different ($P < 0.05$)

Fig. 3 Cooking loss (75 and 100 °C) of chicken sausages containing various germinated barley (GB) levels of 0–4 %. **a–c** Means sharing different letters within each experiment are significantly different ($P < 0.05$)

in water release of meat products; this effect was based on the water and fat retention ability of dietary fiber. Furthermore, the improving effect of starch on cooking loss of meat emulsions was also reported (Hughes et al. 1998; Zhang and Barbut 2005). Thus, the decrease in cooking loss with adding GB could be affected by polysaccharides including dietary fiber and starch contained in GB. As well as, our result was in agreement with previous finding that addition of dietary fiber over a certain level had no or little improvement of cooking loss of meat products (Choi et al. 2010; Talukder and Sharma 2010; Álvarez and Barbut 2013; Kim et al. 2013).

The effect of GB levels on thawing loss of cooked chicken sausages is shown in Fig. 4. In the first frozen-thawed cycle, no significant difference in thawing loss of cooked chicken sausages was observed ($P < 0.05$). In succession, the second frozen-thawed cycle caused additional water loss of cooked

Fig. 4 Thawing loss of chicken sausages containing various germinated barley (GB) levels of 0–4 %. The one of frozen-thawed cycles mean that cooked chicken sausages were frozen in a –20 °C freezer for 24 h and thawed in a 4 °C refrigerator for 24 h. **a–c** Means sharing different letters between treatments within each frozen-thawed cycle are significantly different ($P < 0.05$)

Fig. 5 Comparison of apparent viscosity of chicken meat batters formulated with germinated barley (GB) levels of 0–4 %

chicken sausages; however, an increase in GB level inhibited the water loss. As a result, all GB treatments showed lower thawing loss than the control ($P < 0.05$). Even though the effect of dietary fiber on cooking yield or loss of uncooked and cooked meat product has been extensively reported, in frozen meat product, the information on the effect of dietary fiber has been relatively limited. Sánchez-Alonso et al. (2007) referred to absorption of free water by insoluble cereal fiber but suggested that relative amount of fiber was needed to reduce water loss of fish sausages during frozen storage. According to López-López et al. (2010), addition of 3.3 % Wakame considerably decreased thawing loss of low-salt and low-fat beef patties, and this effect resulted in the improvement of protein solubility and stabilizing protein meat matrix due to sodium and potassium in Wakame. Thus, it seemed that dietary fiber has a certain effect on reduction in thawing loss, in addition, particular components contained in dietary fiber source could potentially play a very important role in this result. Based on this suggestion, the presence of starch in GB could be one reason of reduction in thawing loss because starch can improve freeze-thaw stability (Jiménez Colmenero et al. 1996). Consequently, the addition of GB

can greatly reduce water loss during thermal processing within adaptable temperature and freezing-thawing processing, and this effect depended upon the added amount of GB in cooked chicken sausages.

Apparent viscosity of meat batters

Rheological properties of chicken meat batter formulated with various levels of GB, by using apparent viscosity, are shown in Fig. 5. Increased measurement time resulted in decreased apparent viscosity of chicken meat batters, which is one of the characteristics of a thixotropic fluid. In addition, apparent viscosity of chicken meat batter increased when added levels of GB increased. Our result was in agreement with the results of Shand (2000) who reported that cereal dietary fiber increased apparent viscosity and suggested that improvement of apparent viscosity was related to emulsion stability. Similarly, Choi et al. (2011) indicated that addition of rice bran fiber increased apparent viscosity of salt soluble protein gel. In addition, Zhang and Barbut (2005) indicated that the addition of starch improved the rheological properties of chicken meat batter. Thus, the dietary fiber and starch contained in GB could improve the apparent viscosity of chicken meat batters.

Texture profile analysis (TPA) of cooked chicken sausages

The effect of GB levels on textural properties of cooked chicken sausages is presented in Table 2. Statistical results indicated that texture parameters were differently affected by the added levels of GB. As added levels of GB increased, hardness, springiness, and chewiness of cooked chicken sausages slightly increased. However, there were no significant differences in cohesiveness and gumminess among all treatments ($P < 0.05$). Dietary fiber can be largely categorized as soluble and insoluble, and the types of dietary fiber had a great effect on textural properties of meat products. In previous studies, insoluble dietary fibers (Sánchez-Alonso et al. 2007; Choi et al. 2011) and starch (Hughes et al. 1998; Zhang and Barbut 2005) contributed to

Table 2 Texture profile analysis (TPA) of cooked chicken sausages formulated with various levels of germinated barley (GB)

Traits	Germinated barley levels					SEM ¹⁾
	0 %	1 %	2 %	3 %	4 %	
Hardness (kg)	0.223 ^B	0.248 ^{AB}	0.244 ^{AB}	0.252 ^A	0.254 ^A	0.004
Springiness	0.878 ^C	0.916 ^B	0.941 ^{AB}	0.957 ^A	0.943 ^A	0.006
Cohesiveness	0.508	0.497	0.492	0.510	0.500	0.004
Gumminess ²⁾ (kg)	0.129	0.129	0.128	0.135	0.134	0.002
Chewiness ³⁾ (kg)	0.113 ^B	0.118 ^{AB}	0.120 ^{AB}	0.130 ^{AB}	0.127 ^A	0.002

¹⁾ SEM: standard error of the mean

²⁾ Gumminess: hardness × cohesiveness

³⁾ Chewiness: springiness × gumminess

^{A-C} Means sharing different letters in the same row are significantly different ($P < 0.05$)

the increase in hardness, accompanying with the increase in gumminess and chewiness. However, the effect of dietary fiber on springiness and cohesiveness varied according to the natural source for dietary fiber. Regarding the effect of barley β -glucan on textural properties, Morin et al. (2002) noted that 0.8 % β -glucan produced softer and juicier cooked sausage, which showed low compression force, for this reason, and indicated that excessive amounts of β -glucan caused undesirable textural properties of cooked sausages. Similarly, Álvarez and Barbut (2013) reported decreased values for textural parameters, including hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness, due to addition of β -glucan (0–0.6 %), and noted the improvement of hardness and gumminess with adding 6 % inulin. Thus, we recommended that combined addition of β -glucan and texture modifiers is one proper way to enhance textural properties of emulsified meat products. In this study, GB contained both insoluble (mainly cellulose from barn parts), soluble (mainly β -glucan) fibers, and starch, as a result, the problem which is an undesirable texture with only addition of β -glucan was naturally overcome.

Conclusion

In conclusion, GB exhibited positive effects on measurements related to water and/or fat retention ability, such as emulsion stability, cooking loss, and thawing loss. In addition, apparent viscosity, hardness, springiness, and gumminess increased with increasing added levels of GB. These results could be associated with polysaccharides contained in GB, such as insoluble fiber, β -glucan, and starch. Consequently, our results suggested that GB could be a functional non-meat ingredient to improve physicochemical and technological properties of chicken sausage and optimal adding levels of GB was determined as minimum 2 %. As well as, GB may provide stable water binding ability to meat products under high temperature and freezing/thawing process. Further studies about changes in content of useful components in GB during manufacturing processing (physical impact and thermal stability) would be investigated to confirm the practical use of GB as a functional non-meat ingredient.

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