TITLE PAGE

- Korean Journal for Food Science of Animal Resources -

Upload this completed form to website with submission

	Fill in information in each box below
Article Type	Articles
Article Title	Physiochemical Properties of Chicken Breast Sausage with Red Ginseng Marc Powder
Running Title (within 10 words)	Physiochemical Properties of Chicken Sausage with Red Ginseng Marc Powder
Author	Sun-hwa Shin1, Won-Seok Choi1*
Affiliation	1 Korea National University of Transportation, Jeungpyeng, Korea
Special remarks – if authors have additional information to inform the editorial office	
ORCID (All authors must have ORCID) https://orcid.org	Won-Seok Choi (https://orcid.org/0000-0002-3398-9180) Sun-Hwa Shin (https://orcid.org/0000-0001-6746-502X)
Conflicts of interest List any present or potential conflict s of interest for all authors. (This field may be published.)	The authors declare no potential conflict of interest.
Acknowledgements State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available. (This field may be published.)	
Author contributions (This field may be published.)	Conceptualization: Choi WS, Shin SH. Data curation: Choi WS, Shin SH. Formal analysis: Choi WS, Methodology: Choi WS. Shin SH. Software: Choi WS, Shin SH. Validation: Choi WS. Investigation: Choi WS, Shin SH Writing - original draft: Choi WS, Shin SH. Writing - review & editing: Choi WS, Shin SH
Ethics approval (IRB/IACUC) (This field may be published.)	This manuscript does not require IRB/IACUC approval because there are no human and animal participants.

CORRESPONDING AUTHOR CONTACT INFORMATION

For the corresponding author (responsible for correspondence, proofreading, and reprints)	**Fill in information in each box below**
First name, middle initial, last name	Won-Seok Choi
Email address – this is where your proofs will be sent	choiws@ut.ac.kr
Secondary Email address	choiws@paran.com
Postal address	Department of Food Science and Technology, College of Health and Life Science, Korea National University of Transportation, Jeungpyeng 27909, Korea
Cell phone number	+82-10-5103-3800
Office phone number	+82-43-820-5249
Fax number	+82-43-820-5240

Abstract

This study explored the physiochemical and rheological properties of chicken breast sausages containing red ginseng marc which contains useful components but is discarded. When compared to the control group, the use of red ginseng marc significantly increased the water holding capacity as the particle size increased. As for the change in color value, addition of red ginseng marc resulted in an increase in *a* and *b* values; as the quantity was increased and particle size decreased, the *a* and *b* values increased significantly. The smaller the particle size of red ginseng marc, the greater was the radical scavenging activity. According to the results of the measurement of the viscoelasticity of chicken breast sausage containing red ginseng marc, the G' and G'' values increased with increasing amounts of red ginseng marc and particle size. Neither the addition of red ginseng marc nor its amount or particle size had any significant effect on gel formation temperature. The Texture profile analysis (TPA) experiment examined the average TPA measurements of each sample under different measurement conditions, and no significant difference between the red ginseng marc and control groups were observed. In conclusion, when red ginseng marc is used in chicken breast sausages, the water holding capacity, antioxidant capacity, and viscoelastic properties are affected. Red ginseng marc can possibly be utilized in high value-added processed meat products if its quantity and particle size are altered based on product characteristics.

Keywords : red ginseng marc, chicken breast sausages, physiochemical and rheological properties

Introduction

Traditionally, 20%–30% of fat is added during the sausage-making process to enhance binding capacity, texture, and taste. However, manufacturers have shifted to using low-calorie fat alternatives in an effort to reduce fat content, while maintaining texture and convenience, to address the needs of health-conscious consumers (Chin and Lee, 2002; Choe and Kim, 2019; , Jeong et al., 2010; Kwak et al., 2010).

Fat substitutes should not only be lower in calories than actual fat, but should also share similar physical properties, such as lubricating quality, binding capability, and water holding capacity, as well as having similar volume and taste. Hydrophilic colloids and non-meat proteins derived from soybeans or milk are the most widely used substances as fat substitutes (Chin and Chung, 2002; Choi and Chin, 2002).

In the manufacturing process, red ginseng product, which is one of the representative health functional foods, produces red ginseng marc (RGM), which constitutes about 65% of the production (Chang, 2007). Although RGM is rich in nutrients, it is primarily used as animal feed or compost or is disposed because of its high water content that makes it susceptible to *deterioration* caused by spoilage microorganisms (Jung et al., 2015; Cho et al., 2013).

RGM contains large amounts of acidic polysaccharides and effective ingredients, such as ginsenoside, which allow for various biological activities, as well as a high level of dietary fiber; thus, it is believed to serve as a substitute for fat in meat products (Ha et al., 2017; Kim et al., 2002; Lee and Do, 2002; Park and Kim 2006). Moreover, RGM, which has been hygienically collected, handled, processed, manufactured, or managed for the specific purpose of consumption, can be used as a food ingredient per the standards of the Ministry of Food and Drug Safety; hence, it would be valuable for use as a food material (Ministry of Food and Drug Safety, 2017).

Research on the combination of RGM with processed foods has so far been limited to red ginseng wine, muffins, bread, sponge cake, yackwa, and sweetened RGM, and no studies have been conducted on processed meat products (Han et al., 2007; Jo and Kim, 2014; Jung et al., 2015; Kim and In, 2013; Park et al., 2008; Zang et al., 2014).

Therefore, this study aimed to examine the physiochemical and rheological properties of a sausage prepared by adding RGM, which contains useful components but is discarded, to inexpensive chicken breast to determine its suitability as a functional additive for processed meat products.

Materials and Methods

Ingredients

Frozen chicken breasts (CheonIkFood, Busan, Korea) and pork back fat (Shindon, Asan-si, Chungnam, Korea) were purchased and stored in a −21℃ freezer (IBK-500F, InfoBiotech, Dajeon, Korea), and the supplementary ingredients included spices (ISFI, Braine-l'Alleud, Belgium), salt (Shinan Sea Salt Co., Ltd., Shinan, Jeonam, Korea), sugar (CJ Cheiljedang Co. Ltd., Incheon, Korea), collagen casings (NDX Collagen Casing, Viscofan, Ceske Budejovice, Czech), and soy protein isolate (ESFood, Gunpo, Gyeonggi, Korea). Before the curing salt mixing process, salt and nitrate (ESFood, Gunpo, Gyeonggi, Korea) were mixed in a 1:1 ratio, and extra salt was added as per the required proportion. Curing salt was prepared using this method in a proportion of 99.7% salt and 0.3% nitrite.

Preparation of red ginseng marc powder

Chungbuk Ginseng Agricultural Cooperative (Jeungpyeong, Chungbuk, Korea) provided RGM, which was processed through hygienic treatment separately after the six-time water extraction, and was then dried for 12 h using a 60℃ hot air dryer (ThermoStable SOF–W 155, Daihan Scientific, Seoul, Korea), pulverized in a blender (Variable Speed Blender LB10, Waring, Torrington, USA), and used in sausage manufacturing at varying amounts and particle sizes.

Preparation of chicken breast sausages with red ginseng marc powder

The mixing ratio for chicken breast sausage was modified and used based on the research of Kim and Lee (2019) and Shin (2021) (Table 1). Frozen chicken breasts and pork back fat were stored at 2℃ for 12 h and then ground in a meat chopper (MGB-32, Hankook fujee Industries Co., Ltd., Suwon, Gyeonggi, Korea) before they were completely defrosted. A hole plate (Hankook fujee Industries Co., Ltd., Suwon, Gyeonggi, Korea) with a diameter of 6 mm was used. The pre-processed samples were mixed and emulsified according to the mixing ratio, and the temperature of the dough was monitored frequently throughout the process to avoid the temperature from exceeding 15℃; the dough was filled in a collagen casing of diameter 26 mm and then heated using a smokehouse (HSCO-10E3, Hyoshintech CO., Ltd., Incheon, Korea) to reach 72℃ in the center. Following the heating of the sausages, they were immediately cooled in ice water, and their surfaces were sterilized using grain alcohol (Korea Ethanol Suppplies Company, Siheung, Gyeonggi, Korea). The samples prepared were vacuum-packed and refrigerated at 4℃ before being used in the experiment. Using RGM-free samples as a control group and by referring to existing studies for the optimum amount and size of the powder particles, the powder samples of all powders that passed through the 25-mesh sieve (particle size ≤ 710 ㎛) were labeled based on the amount added: the sample with added amount of 1.5% (w/w) as T1, and the sample with added amount of 3% (w/w) as T2. Based on the particle size, powder samples that passed through a 50-mesh sieve, after passing through the 25-mesh sieve (ChungGye Industrial MFG., Co., Seoul, Korea), were referred to as P2 (particle size ≤ 300 ㎛; 1.5%(w/w)), while those that did not pass through the 50-mesh sieve were referred to as P1 (300 ㎛ ≤ particle size ≤ 710 ㎛; 1.5%(w/w)).

Crude moisture content

Crude moisture content of samples (sausage) was measured using a hot air dryer (ThermoStable SOF–W 155, Daihan Scientific, Seoul, Korea) set at 110℃. On a stainless-steel weighing plate (CY1226, Chunyangsa, seoul, Korea) with a constant weight has been calculated, 3 g of ground sample was accurately placed, dried, and cooled in a dryer, and the constant weight was calculated according to the equation below:

$$\text{Crude moisture content (\%)} = ((a-b) / (b-c)) \times 100.$$

a: Mass of weighing plates and samples

b: Mass when the constant weight is reached after drying

c: Mass of a weighing plate

pH

5 g of the samples (sausage) were placed in a sterile filter bag (SF0500, Central Science Trade Co., Ltd., Tokyo, Japan) with 20 mL of distilled water and homogenized in a stomacher (LS-400, Bnfkorea, Gimpo, Gyeonggi, Korea) for one minute. Thereafter, the filtrate was measured thrice using a pH meter (HI 2211, Hanna instruments, Seoul, Korea)

Water Holding Capacity

To measure the water-holding capacity, the Wierbicki and Deatherage methods (1958) were modified and used. In a 50 mL conical tube (SPL life sciences, Pocheon, Gyeonggi, Korea), 1 g of dried gauze and 5 g of sample (sausage) were placed, and the tube was heated in a water bath (WCB-22, Daihan Scientific, Seoul, Korea) at 70°C for 30 min, followed by centrifugation (CF-10, Daihan scientific, Daejeon,Korea) at 25°C and 1000 rpm for 10 min. Next, the weight of the centrifuge tube and gauze was measured without the sample, and the water holding capacity was calculated according to the following equation:

$$\text{WHC (\%)} = (a-(b-c) / a) \times 100$$

a: Sample weight (g)

b: Weight of centrifuges and gauze without sample after centrifugation (g) c: Weight of empty centrifuges and gauze (g)

DPPH radical scavenging activity

DPPH radical-scavenging activity was measured using the Blois method (1958). 1 g of sample (sausage) was placed in a sterile filter bag with 10 mL of 70% (v/v) ethanol, homogenized for 90 s using a stomacher, and then centrifuged at 1350 rpm using a centrifuge to serve as samples. 160 μL of the 0.2 mM DPPH solution (Reagent Chemicals, Comscience, Gwangju, Korea) was added to 40 μL of the sample, incubated at room temperature for 30 min, and absorbance was measured using a microplate reader (EPOCH2NS, BioTek Instruments, Winooski, USA) at a wavelength of 517 nm.

Color Evaluation

A colorimeter (Chromameter CR-300, Minolta Corporation, Ramsey, NJ, USA) was used to measure the L^*, a^*, and b^* values, and a Minolta calibration plate (No. 18833087, Y = 91.8, x = 0.3136, y = 0.3196) was used as the standard colorimetric plate. For samples (sausages), the inner cross sections were used for color measurement. The △E value was calculated according to the following equation:

$$\triangle E = \sqrt{(L^*_{control} - L^*_{test})^2 + (a^*_{control} - a^*_{test})^2 + (b^*_{control} - b^*_{test})^2}$$

Stress & temperature sweep test

Stress sweep, frequency sweep, and temperature sweep tests were performed using a rheometer (AR1500EX, TA Instrument, DE, US). In order to investigate the section where there was a flat-shaped straight line for G’, a stress sweep test was run at 0–20 Pa, 20℃, and 1 Hz, and the experiments were conducted under 5 Pa, as shown in Figure 2. The range for the temperature sweep test of samples (dough state) was set between 25℃ and 75℃ to verify the gel formation point and values of G' and G" (Chattong and Apichartsrangkoon, 2009)..

Rheological properties

Approximately 2–3 g of sample (dough state) was collected and spread widely on the plate, with the height set to 1550 μm using a 40 mm parallel plate to be trimmed. The experiment was conducted by setting the gap to 1500 μm and placing it on the solvent trap. Then, using the built-in program, the temperature was raised to 80℃ and cooled to 25℃, and the frequency sweep test of sample (sausage) was performed at 0.01–10 Hz based on Chattong and Apichartsrangkoonb's studies.

Texture Profile Analysis

The texture was measured using a Texture Analyzer (TA-XT plus, Stable Micro System Ltd., Godalming, Surrey, U.K.). An aluminum cylinder probe with a diameter of 35 mm was used. Previous studies on sausage texture measurement and a preliminary experiment in which the sausage did not collapse were used as references (Andrès et al., 2006; Juliana et al., 2020; Lee et al., 2018; Shin and Choi, 2021; Zhu et al., 2017). The measurement conditions were set at a strain ratio of 20% and 30%, and a cross-head speed of 1 mm/s, 2 mm/s, and 5 mm/s. The experiment was repeated for at least five times at a temperature of approximately 25℃ (Table 2). The sample (sausage) was shaped into a cylindrical shape with a diameter of 26 mm and height of 20 mm using a Cork Borer (Changshin Science, Seoul, Korea) and Cutting Tool (Extended Craft Knife A/ECB, Stable Micro Systems, Godalming, UK) then, the casing was removed and measured. Among several texture parameters that can be derived from TPA experiments, this experiment used hardness, adhesiveness, cohesiveness, chewiness, and springiness.

Statistical Analysis

For all experiments, at least three replications were performed, and the SPSS software package (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA) was used to verify the significance of the results. One-way ANOVA was used to test for significant differences among three or more groups. After testing for homogeneity of variance, a post hoc test was performed using the Scheffe method for equal variances or the Dunnett T3 method for non-equal variances. To identify significant differences between the two groups, the T-test was used.

Results and Discussion

Crude water content, pH, and water holding capacity

In all groups of samples, the one with different concentrations (1.5% and 3%), different sizes (300 ㎛ ≤ particle size ≤ 710 ㎛ and particle size ≤ 300 ㎛), and the control had approximately 64% of water content, and no significant difference was found among them (Table 2). Heating chicken breast with a regular pan resulted in a high loss of water content with only about 60% of the water being retained, but when heated with the steam method, the water content is reported to remain at approximately 64%, which is similar to the result of the water content (~64%) in this experiment (Jeon et al., 2014). Furthermore, the results from previous studies on low-fat sausages containing curcumin extract and paprika powder as fat substitutes are similar to the results of this experiment, which supports the confirmation that both the amount and particle size of red ginseng marc (RGM) did not significantly affect water content (Kim and Chin, 2018; Kim et al., 2007a).

The pH of the RGM powder (10% [w/v] solution) was 5.10, which is lower than the pH of the chicken breast, so the sausage containing RGM had a slightly lower pH value than the control, and there were no significant differences due to the difference in the added amount and particle size (Table 2). In the current study, the pH of cooked sausage ranged from 6.3 to 6.4, similar to the pH of sausage found in other studies (Table 2) (Choi and Chin, 2020; Kim et al., 2007a; Kim et al., 2018).

A higher water holding capacity (WHC) means that less moisture will evaporate during reheating, making it easier for the item to maintain its shape; the water holding capacity is directly related to juiciness, which refers to the amount of liquid that is released when chewing meat (Moon, 2002). As discussed in this paper, WHC describes the ability of meat to retain moisture when physical deformations, including pressure, heating, grinding, and cutting, are applied, whereas water binding capacity (WBC) refers to the ability to absorb external moisture (Wierbicki and Deatherage, 1958).

The WHC for the control group was 69.79%, and for T1 (1.5%) and T2 (3%), it was 72.35% and 74.23%, respectively; however, there were no significant differences among them (Table 2).

As the meat products are heated, the meat protein shrinks and moisture effuses simultaneously, reducing its ability to hold water. In regard to this phenomenon, Zhuang et al. (2018) reported that when gelation begins, during which an actomyosin agglomerate is formed, the moisture effused creates water channels that interfere with meat protein aggregation, thus degrading meat quality. The addition of insoluble dietary fibers would increase WHC at this stage, since their water-absorbing properties would remove moisture from the water channels or would form polysaccharide chains to create a porous matrix structure (Zhao et al., 2018). In this experiment, although no significant differences were observed, the WHC tended to increase as the amount of RGM increased, and there was a significant difference in the WHC between control and sausages with a RGM of P1 particle size (300 ㎛ ≤ particle size ≤ 710 ㎛). The WHC of P1 was 77.63%, and that of P2 (particle size ≤ 300 ㎛) was 73.25%, indicating that when RGM of a P1 particle size was added, WHC increased (Table 2). According to Auffret et al. (1994), fiber matrix damage and deformation in the pore decay during pulverization might lead to different water holding capacities; for citrus fibers, the smaller the particle size, the lower the capacity to hold water (Ye et al., 2015). The findings of these studies are very similar to those of the present study.

DPPH radical scavenging activity

The antioxidant capacity of sausages containing RGM was measured using the DPPH radical scavenging assay.

The DPPH radical scavenging activity of the sausage with 3% RGM was increased significantly compared to the control ($p < 0.05$), which is believed to be due to the large amount of acidic polysaccharides with antioxidant effects that are present in RGM (Table 2). According to a study by Jung et al. (2015), the DPPH radical scavenging activity was higher than that of the control group when the RGM powder concentration was 3% but showed no significant difference; a significant difference began to appear at a concentration greater than 6%.

The examination of the antioxidant capacity by difference in particle size revealed that there were significant increases in the values of DPPH radical scavenging activity ($p < 0.05$, Table 2) in samples containing small RGM particles (P2, particle size ≤ 300 ㎛) as compared to samples containing large RGM particles (P1, 300 ㎛ ≤ particle size ≤ 710 ㎛). Lee and Do (2002) stated that the smaller than 3.35 mm the particle size of RGM, the more effective the extraction of acidic polysaccharides contained within RGM, which corroborates the findings of the present study.

Meanwhile, alcohol-extracted RGM has been shown to contain more acidic polysaccharides that have anti-cancer and immune activation capacity than water-extracted RGM that are used as experimental materials in this study (Chang et al., 2007; Kwak et al., 2003).

Color Value

The value of lightness (L), the measure of sample brightness, was significantly smaller ($p < 0.05$) in the group containing RGM compared to the control group, but there was no significant difference according to the amount of RGM added (Table 3). Compared to the control group, the value *a* for redness and the value *b* for yellowness were significantly higher in the group containing RGM, and with increased addition of RGM, these values increased significantly ($p < 0.05$, Table 5). During the process of steaming and drying red ginseng at high temperatures, enzymatic browning is known to occur in the early stage of steaming, followed by the Maillard reaction during the drying process, which determines the color of red ginseng (Kim, 1973; Lee et al., 1995). Accordingly, it is believed that the chromaticity of values *a* and *b* increases when the amount of RGM is increased due to the creation of browning reaction products such as maltulosyl arginine, fructosyl arginine, and melanoidin polymer (Kim et al., 2007b).

When the particle size of RGM changed, *L* values decreased significantly with smaller particle sizes, whereas *a* and *b* values increased significantly with smaller particle sizes (Table 3). Kim (2013) reported that as the particle size decreases, the internal structure becomes tighter and keeps light from being reflected, thereby reducing the brightness. Meanwhile, chicken breasts are known to contain lower levels of myoglobin than other parts or meat, showing higher lightness values relative to pork and beef after and before heating (Jeon et al., 2014).

In conclusion, within the scope of this experiment, the amount of RGM added and its particle size were found to affect the color of chicken breast sausage.

Frequency sweep test

The measurement of the viscoelasticity of samples (sausages with T1, T2, and P1, P2 of RGM) by setting the frequency range to 0.01–10 Hz yielded the $G > G''$ form for all samples, suggesting that the samples possess viscoelastic properties close to those of solids (Fig. 1).

Increasing the RGM amount increased the G and G″ values, and as the frequency increased, the G and G″ values also increased (Fig. 1). Fibers absorb moisture bound to proteins and create ‘concentrated proteins’. It also forms a branch-like shape that produces internal resistance and friction, increasing the G and G″ values (Zhuang et al., 2019). The RGM used in this experiment was believed to have played a role.

The viscoelastic characteristics of the sample showed a curve, as illustrated in Figure 1, which is similar to that seen in several other studies, and this curve demonstrates a flat-shaped increase, indicating that the sample possesses the properties of a weak gel (Correa et al., 2018).

It was confirmed that the larger the particle size (P1, 300 ㎛ ≤ particle size ≤ 710 ㎛) of RGM, the higher the G’ and G” values. Regarding the reason why large particle sizes have higher G’ and G” values compared to smaller particle sizes, Sendra et al. (2010) noted that at the same volume, smaller particles have a greater total amount, and consequently more destructive effects on the matrix. This study found that sausages with small-particle RGM showed similar viscoelasticity properties to the control group, which was consistent with the results of Moreira et al. (2010) in which flour dough with small-particle chestnut powder displayed similar rheological properties to the control group.

Temperature sweep test

The change in the G values of the sample (dough with T1, T2, and P1, P2 of RGM) during the heating process is mainly due to the denaturation of the myofibrillar protein, which changes from a highly viscous to a highly elastic state as the temperature increases. The G′ value changes in temperatures between 25–29℃ can result from hydrogen bonding and molecular interaction, and denaturation of myosin head, a muscle contraction protein, is known to occur in this temperature range. In addition, at temperatures of 55–60℃, myosin tails denature and aggregate, while at temperatures of 63–75℃, covalent or noncovalent bonds form a 3D network of the protein matrix (Bolger et al., 2018; Liu et al., 2019).

At temperatures 25–75℃, the values of G and G″ of the samples containing RGM were higher than those of the control group. A higher amount of RGM contributed to higher G and G″ values. The G slope for all samples dropped sharply at around 25–31℃, then moderately declined near 32–53℃, and then abruptly increased from 53°C upward (Fig. 2). Many studies claim that the gelation point of meat exists where either the G value rebounds drastically or the phase angle (tan*Φ*) value dramatically decreases (Pereira et al., 2016). Accordingly, in this study, the gel formation temperature of the samples was estimated to be approximately 53°C, and it was found that adding RGM did not significantly affect the gelation point.

The varying particle size of the added RGM had no significant effect on changing the gelation point of the sausages, so each remained similar to the other at approximately 53°C (Fig. 2).

The study by Dogan et al. (2018) examined the rheological properties of hydrophilic colloids, guar gum, xanthan gum, and pectin with different particle sizes exposed at the same temperature and found that smaller particles had smaller G values. The results of Wang et al. (2015) also concluded that pork dough containing soybean curd powder of large particle size showed continuously higher G values than the control group when heated to 80℃, and these results are consistent with those in this study.

TPA under different measurement conditions

Texture profile analysis (TPA) is a method for measuring mechanical properties that mimic the texture perceived by humans, and depending on the conditions of the measurement, both the measurement value and the significant difference between the samples may change (Shin and Choi, 2020; Shin and Choi, 2021). The best measurement conditions for TPA were those consistent with the sensory evaluation. Accordingly, in the absence of a sensory evaluation, six measurement conditions were established in reference to previous studies, and the experimental results are summarized in Table 4 (Shin and Choi, 2021; Lee et al., 2018; Uzlasir et al., 2020; Wang et al., 2018).

A comparison of TPA results for sausages with varying amounts of RGM showed no significant difference in hardness between the control, T1 (1%), and T2 (3%) at a cross-head speed of 1.0 mm/s and strain ratios of 20% and 30%. However, different measurement conditions produced different types of significant differences. In other words, the same type of significant difference occurred between samples (T1 and T2) at a strain ratio of 20% and cross-head speeds of 2.0 mm/s and 5.0 mm/s, and at a strain ratio of 30% and a cross-head speed of 2.0 mm/s and 5.0 mm/s. However, significant differences that were completely different type from the previous ones occurred between samples at a cross-head speed of 1.0 mm/s and strain ratio of 20% and 30%. In the case of chewiness, there was no significant difference between the samples (T1 and T2) at a strain ratio 30% and a cross-head speed of 1.0 mm/s and 5.0 mm/s, and a strain ratio 20% and cross-head speed 2.0 mm/s and 1.0 mm/s, but under the rest of the conditions, there was a significant difference that appeared in a completely different type, as it did in hardness. In other words, in situations where significant differences occurred between samples, completely different types of significant differences occurred between samples as the measurement conditions changed.

Likewise, sausage samples with RGM varying in particle size showed significant differences of different types between samples depending on the measurement conditions. Under the condition of a strain ratio of 30% and cross-head speeds of 2.0 mm/s and 5 mm/s, and a strain ratio of 20% and cross-head speeds of 1 mm/s and 2 mm/s, there was no significant difference between the control, P1 (300 ㎛ ≤ particle size ≤ 710 ㎛), and P2 (particle size ≤ 300 ㎛) samples in both hardness and chewiness. In addition, in both cases of hardness and chewiness, a significant difference of totally different types occurred between samples under all measurement conditions, where a significant difference between samples also occurred.

Since the measurement values and significant differences vary depending on the measurement conditions, the mean and standard deviation of all measured samples were obtained and are illustrated in Fig. 3.

The TPA parameters of RGM-added sausages changed irregularly when the measurement conditions, that is, the cross-head speed, were different. In other words, Fig. 3 (top), arranged according to the strain ratio, showed a significant increase in hardness ($R^2 = 0.8884$, $p = 0.005$) and chewiness ($R^2 = 0.9805$, $p = 0.000$) when the strain ratio increased, but in Fig. 3 (bottom) arranged according to the cross-head speed, no significant tendency (increase or decrease) was observed with increasing cross-head speed. Similarly, a study by Shin and Choi (2020) on texture measurement of tofu by TPA method also discovered that when strain ratio increases, hardness ($R^2=0.9908$, $p<0.06$) and chewiness ($R^2=0.9986$, $p<0.02$) tend to increase. It has been found that the increase in hardness and chewiness caused by an increase in strain ratio at the same cross-head speed is primarily due to the densification of the molecular structure with an increase in the strain ratio (Choi & Lee, 1998).

TPA characteristics

The TPA analysis results demonstrated that both the measurement values and significant differences between samples varied depending on the measurement conditions. Therefore, to examine the average texture characteristics (tendency), the resulting values from the six measurement conditions were compiled and presented as average mean values (Fig. 4).

The difference in the amount of RGM added led to an increase in the average hardness value of the sausage, while the average value of springiness and cohesiveness tended to decrease, but there was no significant difference with the control (Fig. 4 (top)).

A study by García et al. (2002) substituted fat with dietary fiber derived from grain and fruit in sausage and found that adding 1.5% did not significantly change the hardness of the sausage when compared to the control group, but adding 3.0%, significantly increased it. However, this is the result under specific measurement conditions, and it is judged that it may be different from the average value result in this experiment.

The change in texture caused by the difference in particle size of RGM resulted in an increase in the average value of cohesiveness due to particle size, but there was no significant difference (Fig. 4 (bottom)).

According to a study by Bae et al. (2018), when sausages were manufactured by adding pork skin, the larger the particle size of the pork skin, the harder it was to be distributed evenly in the emulsified sausage, which could increase the chewiness. Using a meatball containing rice bran (10%, w/w) with varying particle sizes as a fat substitute, Huang et al. (2005) demonstrated that when rice bran particle size decreased, meatballs tended to increase in hardness, viscosity, and chewiness, while springiness and cohesiveness did not differ significantly. Although the results of these experiments did not exhibit the same tendency as those in this experiment, if the TPA parameters are measured under specific measurement conditions that show results similar to sensory evaluation, it is thought that the amount and particle size of RGM can affect the texture characteristics of chicken breast sausages.

Conclusion

When red ginseng marc (RGM) which contains useful components but is discarded was used for the sausage, there was no significant effect on the moisture content of sausages compared to the control within the experimental range, but a slight pH change was observed, and the water holding capacity increased significantly when the particle size was large (P1; 300 ㎛ ≤ particle size ≤ 710 ㎛). The change in color of sausage caused by RGM showed a decrease in the *L* value and an increase in *a* and *b* values, with *a* and *b* values increasing significantly even further as more RGM was added and its particle size became smaller. The DPPH radical scavenging activity was significantly higher in the RGM sample, and increased as the amount of RGM increased, and the particle size decreased. The measurement of viscoelasticity of chicken breast sausage made with found that with increasing amounts of RGM and increasing particle size, the values of G and G″ increased. According to the temperature sweep test performed to determine the gelation point, the sausage gelation temperature was 53℃, which was unaffected by the addition of RGM, the amount added, and the particle size. The TPA test results showed that the measurement values differed according to the change in the measurement conditions, and different types of significant differences were observed between the samples. Analysis of the TPA measurements of all samples averaged under various measurement conditions showed irregular values of hardness and chewiness, especially as the cross-head speed changed. The TPA measurements of each sample under various measurement conditions were averaged, and the results showed no significant difference between the RGM-added group and the control. In conclusion, RGM as a functional additive affected the water holding capacity, antioxidant capacity, and viscoelastic properties of chicken breast sausages. That is, when the RGM with a larger particle size (P1; 300 ㎛ ≤ particle size ≤ 710 ㎛) was added, the water holding capacity of chicken breast sausage increased, and antioxidant capacity and viscoelasticity of chicken breast sausage increased as the amount of addition of RGM increased. However, as the RGM with a larger particle size (P1; 300 ㎛ ≤ particle size ≤ 710 ㎛) was added, the viscoelasticity increased, but antioxidant capacity decreased. Therefore, it is believed that RGM, which is usually discarded, could be used as a new material in high-value-added upcycle meat processing products by adjusting the amount and particle size of RGM according to the product characteristics.

References

Andrés SC, García ME, Zaritzky NE, Califano AN. 2006. Storage stability of low-fat chicken sausages. Journal of Food Engineering. 72:311-319.

Auffret A, Ralet M.C, Guillon F, Barry J.L, Thibault J.F. 1994. Effects of drying temperature and particle size on hydration properties of dietary fiber powder from lime and cabbage by-products; Effect of grinding and experimental conditions on the measurement of hydration properties. LWT 27:166–172.

Bae SH, Cho BW, Cho SK, Kim BW, Seo JK, Yoo JG, Shin TS. 2018. Changes of quality characteristics and physico-chemical properties of emulsified sausages depend on different particle sizes of pork rind added. J Agric Life Sci 52:109-122.

Blois MS. 1958. Antioxidant determinations by the use of a stable free radical. Nature 181:1199-1200.

Bolger Z, Bruton N.P, Monahan F.J. 2018. Impact of inclusion of flaxseed oil (pre-emulsified or encapsulated) on the physical characteristics of chicken sausages. J Food Eng 230:39-48.

Chang EJ, Park TK, Han YN, Hwang KH. 2007. Conditioning of the extraction of acidic polysaccharide from red ginseng marc. Kor J Pharmacogn 38:56-61.

Chattong U, Apichartsrangkoonb A. 2009. Dynamic viscoelastic characterisation of ostrich-meat yor (Thai sausage) following pressure, temperature and holding time regimes. Meat Sci 81:426-432.

Chin KB, Chung BK. 2002. Development of low-fat meat processing technology using interaction between meat protein and hydrocolloids -I. J Korean Sco Food Sci Nutr 31: 438-444.

Chin KB, Lee HC. 2002. Development of low-fat meat processing technology using interaction between meat protein and hydrocolloids- II. J Korean Sco Food Sci Nutr 31: 629-635.

Cho ML, Yoon SJ, Kim YB. 2013. The nutritional composition and antioxidant activity from Undariopsis peterseniana. Ocean Polar Res 35:273-280.

Choe JH, Kim HY. 2019. Quality characteristics of reduced fat emulsion-type chicken sausages using chicken skin and wheat fiber mixture as fat replacer. Poult Sci J 98:2662-2669.

Choi JS, Chin KB. 2020. Evaluation of rheological properties of pork myofibrillar protein gel and quality characterics of low-fat model sausage with pea protein concentrate and transglutaminase. J Korean Soc Food Sci Nutr 49: 617-624.

Choi SH, Chin KB. 2002. Development of low-fat comminuted sausage manufactured with various fat replacers similar textural characteristics to those with regular-fat counterpart.

Korean j Food Sci Technol 34: 577-582.

Choi WS, Lee CH. 1998. Effect of compression test conditions on the textural parameters of imitation crab-leg product. Korean J Food Sci Technol 30:1077-1084.

Correa DA, Castillo P.M.M, Martelo R.J. 2018. Effect of the fat substitution on the rheological properties of fermented meat emulsions. Contemp Eng Sci 13:619-627.

Dogan M, Aslan D, Gurmeric V. 2018. The rheological behaviors and morphological characteristics of different food hydrocolloids ground to sub-micro particles: in terms of temperature and particle size. Food Measure 12:770–780.

García ML, Dominguez R, Galvez MD, Casas C, Selgas MD. 2002. Utilization of cereal and fruit fibres in low fat dry fermented sausages. Meat Sci 60:227-236.

Ha YJ, Kim SK, Yoo SE, Yoo SK. 2017. Separation and purification of antioxidant activity acidic polysaccharide from red ginseng marc. KOCS 34:915-923.

Han IJ, Kim RY, Kim YM, Ahn CB, Kim DW, Park KT, Chun SS. 2007. Quality characteristics of white bread with red ginseng marc powder. J East Asian Soc Dietary Life 17:242-249.

Huang SC, Shiau CY, Liu TE, Chu CL, Hwang DF. 2005. Effects of rice bran on sensory and physico-chemical properties of emulsified pork meatballs. Meat Sci 70:613-619.

Jeon KH, Kwon KH, Kim EM, Kim YB, Sohn DI, Choi JY. 2014. Effect of cooking methods with various heating apparatus on the quality characteristics of chicken. Culi Sci & Hos Res 20:201-213.

Jeong HJ, Lee HC, Chin KB. 2010. Effect of red beet on quality and color stability of low-fat sausages during refrigerated storage. Korean J Food Sci Ani Resour 30: 1014-1023

Jo EH, Kim MH. 2014. Quality characteristics of Jung-Kwa made with ginseng by different manufacturing methods. Culinary Science & Hospitality Research 20:161-170

Juliana L. Lima, Bianca B.T. Assis, Narciza M.O. Arcanjo, Mercia de S. Galvão, Lary S. Olegário, Taliana K. A. Bezerra, Marta S.Madruga. 2020. Impact of use of byproducts (chicken skin and abdominal fat) on the oxidation of chicken sausage stored under freezing. J Food Sci 85:1114-1124.

Jung YM, Oh HS, Kang ST. 2015. Quality characteristics of muffins added with red ginseng marc powder. J Korean Soc Food Sci Nutr 44:1050-1057.

Kim DC, In MJ. 2013. Changes in fermentative characteristics of red ginseng wine using enzymatically hydrolyzed red ginseng marc. J Korea Academia-Industrial Cooperation Society 14: 6290-6295.

Kim DY. 1973. Studies on the browning of red ginseng. J Kor Soci of Agri Chem Biotech 16:60-77.

Kim GH, Chin KB. 2018. Physicochemical and textural properties of low-fat pork sausages with paprika powder. J Korean Soc Food Sci Nutr 47:917-925.

Kim IS, Jin SK, Park KH, Jeong KJ, Kim DH, Yang MR, Chung YS. 2007a. Quality characteristics of low-fat sausage containing curcumin extract during cold storage. Korean J Food Sci Ani Resour 27:255-261.

Kim JM, Lee MH, Lee JS. 2018. Quality characteristics of sausage prepared with Orostachys japonicus poder. J Korean Soc Food Sci Nutr 47: 1036-1043.

Kim OS. 2013. Physiological and quality characteristics of bakery products added with mosi leaf powder. Ph.D. thesis, Sejong Univ., Seoul, Korea.

Kim YJ. Park CW, Yeom MH, Lee BK, Lee JY, Joo KM. 2007b. Cosmetic composition which contains melanoidin. KR Patent KR10-0779876B1.

Kim YK, Lee SH. 2019. Development of chicken breast sausage with addition of mealworm. Culi Sci & Hos Res 25:81-87.

Kim YS, Park KM, Shin HJ, Song KS, Nam KY, Park JD. 2002. Anticancer activities of red ginseng acidic polysaccharide by activation of macrophages and natural killer cells. Yakhak hoeji 46:113-119.

Kwak JH, Kim KBWR, Song EJ, Lee CJ, Jung JY, Choi MK, Kim MJ, Ahn DH. 2010. Effect of salt soluble protein extracts from anchovy on quality characteristics of sausage. J Korean Soc Food Sci Nutr 39: 1839-1845.

Kwak YS, Shin HJ, Song YB, Park JD. 2003. Isolation of immunomodulatory antitumor active polysaccharide from red ginseng by-product and its physico chemical properties. J Korean Soc Food Sci Nutr 32: 752-757.

Lee JW, Do JH. 2002. Extraction condition of acidic polysaccharide from korean red ginseng marc. J Ginseng Res 26:202-205.

Lee JW, Lee SK, Do JH, Sung HS, Shim KH. 1995. Browning reaction of fresh ginseng (Panax ginseng C. A. Meyer) as affected by heating temperature. Korean J Ginseng Sci 19:249-253.

Lee SH, Kim GW, Choe JH, Kim HY. 2018. Effect of buckwheat powder on the physicochemical and sensory properties of emulsion-type sausage. Korean J Food Sci An 38: 927-935.

Liu X, Ji L, Zhang T, Xue Y, Xue C. 2019. Effects of pre-emulsification by three food-grade emulsifiers on the properties of emulsified surimi sausage. Journal of Food Engineering 247:30-37.

Ministry of Food and Drug Safety. 2017. FAQ-Food, Livestock products, health functional food. Available from : https://www.mfds.go.kr/brd/m_218/view.do?seq=30771. Accessed at Oct 18, 2020.

Moon YH. 2002. Effect of adding polyphosphate on the water holding capacity and palatability of boiled pork loin. Korea J Food Sci Ani Resour. 22: 130-136.

Moreira R, Chenlo F, Torres MD, Prieto DM. 2010. Influence of the particle size on the rheological behaviour of chestnut flour doughs. J Food Eng 100: 270-277.

Park SH, Kim WJ. 2006. Study of Hongsambak for Medicinal Foods Applications - Nutritional composition, antioxidants contents and antioxidative activity -. Korean J Orient Physiol Pathol 20:449-454.

Park YR, Han IJ, Kim MY, Choi SH, Shin DW, Chun SS. 2008. Quality characteristics of sponge cake prepared with red ginseng marc powder. Korean J Food Cookery Sci 24:236-242.

Pereira J, Zhou GH, Zhang WG. 2016. Effect of rice flour on emulsion stability, organoleptic characteristics and thermal rheology of emulsified sausage. J Food Nutr Res. 4: 216-222.

Sendra E, Kuri V, Fernandez-Lopez J, Sayas-Barbera E, Navarro C, Perez-Alvarez JA. 2010. Viscoelastic properties of orange fiber enriched yogurt as a function of fiber dose, size and thermal treatment. LWT. 43:708-714.

Shin SH, Choi WS. 2020. Variations in textural parameter values of tofu due to different measurement conditions. J Korean Soc Food Sci Nutr 49:646-651.

Shin SH, Choi WS. 2021. Variation in significant difference of sausage textural parameters measured by texture profile analysis (TPA) under changing measurement conditions. Food Sci Anim Resour 41: 739-747.

Shin SH. 2021. Effects of red ginseng marc powder on the quality properties of chicken breast sausage. Master’s thesis, Korea National University of Transportation, Jeungpyeong-gun, Korea.

Uzlasir T, Aktas N, Gercekaslan KE. 2020. Pumpkin seed oil as a partial animal fat replacer in bologna-type sausages. Food Sci Anim Resour 40: 551-562.

Wang S, Chang T, Wang C, Shi L, Wang W, Yang H, Cui M. 2015. Effect of particle sizes of soy okara on textural, color, sensory and rheological properties of pork meat gels. J Food Qual 38:248-255.

Wang WH, Wang X, Zhao WP, Gao GX, Zhang XW, Wang YB, Wang YN. 2018. Impact of pork collagen superfine powder on rheological and texture properties of harbin red sausage. J Texture Stud 49: 300-308.

Wierbicki E, Deatherage RE. 1958. Water content of meats, determination of water-holding capacity of fresh meats. J Agric Food Chem 6:387-392.

Ye FY, Tao BB, Liu J, Zou Y, Zhao GH. 2015. Effect of micronization on the physicochemical properties of insoluble dietary fiber from citrus (Citrus junos Sieb. ex Tanaka) pomace. Food Sci Technol Int 22:246-255.

Zang OH, Park JH, Kim SH, Lee SY, Moon B. 2014. Quality characteristics of Yackwa with red ginseng marc powder. Korean J Food Cook Sci 30: 800-805.

Zhao GH, Zhang RF, Dong LH, Huang F, Tang XJ, Wei ZC, Zhang MW. 2018. Particle size of insoluble dietary fiber from rice bran affects its phenolic profile, bioaccessibility and functional properties. LWT 87:450-456.

Zhu XX, Ning C, Li SY, Xu P, Zheng YD, Zhou CL. 2017. Effects of l-lysine/l-arginine on the emulsion stability, textural, rheological and microstructural characteristics of chicken sausages. Int J Food Sci Technol 53:88-96.

Zhuang X, Han M, Bai Y, Liu Y, Xing L, Xu X, Zhou G. 2018. Insight into the mechanism of myofibrillar protein gel improved by insoluble dietary fiber. Food Hydrocoll 74:219-226.

Zhuang X, Han M, Jiang X, Bai Yun, Zhou H, Li C, Xu XL, Zhou GH. 2019. The effects of insoluble dietary fiber on myofibrillar protein gelation: Microstructure and molecular conformations. Food Chem 275:770-777.

Table 1. Formulation (g/kg) of chicken breast sausage with the addition of red ginseng marc powder.

Ingredients (g)		Control	T1[1)]	T2	P1 (1.5%)	P2 (1.5%)
Main	Chicken Breast	600	600	600	600	600
	Pig back fat	200	185	170	185	185
	Red Ginseng Marc	0	15	30	15	15
	Ice water	200	200	200	200	200
Additional	Spice	6 (0.6%)				
	NPS[2)]	15 (1.5%)				
	Sugar	9 (0.9%)				
	Isolated soy protein	12 (1.2%)				

[1)] T1, red ginseng marc 1.5% (w/w); T2, red ginseng marc 3.0% (w/w); P1, red ginseng marc powder samples (300 μm ≤ particle size ≤ 710 μm); P2, red ginseng marc powder samples (particle size ≤ 300 μm).

[2)] NPS, Nitrite Pickling Salt (ordinary salt with 0.3% of Sodium Nitrite ($NaNO_2$)).

Table 2. Crude moisture contents, pH, Water holding capacity and DPPH radical scavenging activity of chicken breast sausage with different amounts and particle sizes of red ginseng marc powder.

Samples	Moisture contents (%)	pH	Water holding capacity	DPPH
Control[1)]	$64.25\pm0.93^{2)a}$	$6.44\pm0.02^{2)a}$	$69.79\pm1.41^{2)b}$	40.12 ± 0.73^{cd}
T1	64.57 ± 1.43^{a}	6.38 ± 0.00^{b}	72.35 ± 2.04^{ab}	41.87 ± 0.85^{bc}
T2	64.51 ± 1.06^{a}	6.36 ± 0.01^{bc}	74.23 ± 1.92^{ab}	42.50 ± 0.89^{b}
P1	63.78 ± 1.24^{a}	6.35 ± 0.01^{cd}	77.63 ± 2.45^{a}	39.05 ± 0.72^{d}
P2	65.39 ± 1.26^{a}	6.32 ± 0.01^{d}	73.25 ± 2.30^{ab}	45.71 ± 0.60^{a}

[1)] Control, no red ginseng marc added; T1, red ginseng marc 1.5% (w/w); T2, red ginseng marc 3.0% (w/w); P1, red ginseng marc powder samples (300 ㎛ ≤ particle size ≤ 710 ㎛); P2, red ginseng marc powder samples (particle size ≤ 300 ㎛).

[2)] Mean±SD.

[a-d] Mean in the same column with different letters are significantly different ($p<0.05$). _

Table 3. Color values of chicken breast sausage with different amounts and particle sizes of red ginseng marc powder.

	Control [1)]	T1	T2	P1	P2
L (lightness)	72.46±0.56$^{2)a}$	67.40±0.21^{cd}	66.68±0.40^{d}	69.63±0.35^{b}	67.99±0.27^{c}
a (redness)	3.56±0.07^{d}	4.46±0.09^{c}	4.87±0.07^{ab}	4.84±0.11^{b}	5.09±0.02^{a}
b (yellowness)	10.31±0.08^{e}	12.18±0.11^{d}	14.46±0.16^{b}	13.69±0.18^{c}	14.87±0.01^{a}
△E value	-	5.47±0.15	7.23±0.24	4.60±0.26	6.57±0.18

[1)] Control, no red ginseng marc added; T1, red ginseng marc 1.5% (w/w); T2, red ginseng marc 3.0% (w/w); P1, red ginseng marc powder samples (300 ㎛ ≤ particle size ≤ 710 ㎛); P2, red ginseng marc powder samples (particle size ≤ 300 ㎛).

[2)] Mean±SD.

[a-d] Mean in the same row with different letters are significantly different ($p<0.05$).

Table 4. Variation in the values of textural properties of chicken breast sausage with different amounts and particle sizes of red ginseng marc powder as a functions of strain ratio and cross-head speed in TPA test.

(a) different amount

Test conditions[1)]	Red ginseng marc sausage samples		
	Control[1)]	T1	T2
1.0mm/s 20%			
Hardness(N)	16.11±1.55^{a}[2)]	17.06±2.01^{a}	18.27±1.18^{a}
Adhesiveness(N.sec)	-0.67±0.46^{a}	-0.83±0.35^{a}	-0.66±0.45^{a}
Springiness	0.86±0.05^{a}	0.83±0.06^{a}	0.81±0.06^{a}
Cohesiveness	0.79±0.01^{a}	0.79±0.03^{a}	0.76±0.02^{a}
Chewiness(N)	9.48±1.68^{a}	10.84±2.01^{a}	11.36±1.19^{a}
2.0mm/s 20%			
Hardness(N)	16.20±2.02^{b}	15.51±1.01^{b}	19.85±0.50^{a}
Adhesiveness(N.sec)	-0.74±0.08^{a}	-0.14±0.08^{b}	-0.34±0.42^{ab}
Springiness	0.91±0.023^{a}	0.84±0.03^{b}	0.84±0.02^{b}
Cohesiveness	0.85±0.03^{a}	0.80±0.02^{b}	0.80±0.02^{b}
Chewiness(N)	10.97±1.54^{a}	10.53±0.27^{a}	12.81±1.34^{a}
5.0mm/s 20%			
Hardness(N)	15.20±2.83^{b}	17.90±1.57^{b}	23.42±2.15^{a}
Adhesiveness(N.sec)	-0.42±0.22^{ab}	-0.60±0.10^{a}	-0.17±0.18^{b}
Springiness	0.91±0.07^{a}	0.90±0.02^{a}	0.85±0.12^{a}
Cohesiveness	0.85±0.03^{a}	0.81±0.01^{b}	0.81±0.02^{ab}
Chewiness(N)	11.09±1.47^{b}	13.35±1.03^{b}	16.65±1.48^{a}
1.0mm/s 30%			
Hardness(N)	28.18±2.72^{a}	29.66±1.43^{a}	31.46±3.01^{a}
Adhesiveness(N.sec)	-0.25±0.13^{a}	-0.39±0.17^{a}	-1.01±0.66^{a}
Springiness	0.82±0.04^{a}	0.78±0.04^{ab}	0.75±0.04^{b}
Cohesiveness	0.74±0.04^{a}	0.68±0.01^{b}	0.68±0.03^{b}
Chewiness(N)	15.82±1.43^{a}	15.00±0.98^{a}	16.02±1.58^{a}
2.0mm/s 30%			
Hardness(N)	32.35±3.35^{a}	27.10±1.34^{b}	35.12±1.17^{a}
Adhesiveness(N.sec)	-0.47±0.32^{ab}	-0.22±0.16^{b}	-0.72±0.37^{a}
Springiness	0.85±0.05^{a}	0.78±0.03^{a}	0.80±0.04^{a}
Cohesiveness	0.74±0.04^{a}	0.71±0.03^{b}	0.68±0.01^{b}
Chewiness(N)	16.79±2.23^{ab}	15.33±1.21^{b}	18.52±0.53^{a}
5.0mm/s 30%			
Hardness(N)	31.66±2.16^{b}	31.36±3.01^{b}	35.66±1.71^{a}
Adhesiveness(N.sec)	-0.49±0.27^{a}	-0.23±0.09^{a}	-0.50±0.29^{a}
Springiness	0.84±0.08^{a}	0.83±0.04^{a}	0.82±0.04^{a}
Cohesiveness	0.77±0.04^{a}	0.69±0.02^{b}	0.67±0.02^{b}
Chewiness(N)	20.88±1.21^{a}	17.27±1.74^{b}	20.44±2.55^{ab}

(b) different particle size

Test conditions[1)]	Red ginseng marc sausage samples		
	Control[1)]	P1	P2
1.0mm/s 20%			
Hardness(N)	16.11±1.55[2)a]	17.56±3.22[a]	14.47±2.05[a]
Adhesiveness(N.sec)	-0.67±0.46[a]	-0.52±0.50[a]	-0.91±0.39[a]
Springiness	0.86±0.05[a]	0.84±0.06[a]	0.90±0.04[a]
Cohesiveness	0.79±0.01[b]	0.79±0.01[b]	0.87±0.04[a]
Chewiness(N)	9.48±1.68[a]	11.70±1.97[a]	11.29±0.49[a]
2.0mm/s 20%			
Hardness(N)	16.20±2.02[a]	17.32±0.22[a]	13.19±2.22[a]
Adhesiveness(N.sec)	-0.74±0.08[a]	-0.75±0.01[a]	-0.36±0.36[a]
Springiness	0.91±0.03[a]	0.87±0.01[a]	0.90±0.05[a]
Cohesiveness	0.85±0.03[a]	0.85±0.04[a]	0.87±0.02[a]
Chewiness(N)	10.97±1.54[a]	12.92±1.01[a]	10.97±0.92[a]
5.0mm/s 20%			
Hardness(N)	15.20±2.83[b]	19.50±0.24[a]	17.67±1.95[ab]
Adhesiveness(N.sec)	-0.42±0.02[b]	-0.68±0.02[a]	-0.72±0.01[a]
Springiness	0.91±0.06[a]	0.87±0.04[a]	0.91±0.04[a]
Cohesiveness	0.85±0.03[a]	0.83±0.01[a]	0.88±0.03[a]
Chewiness(N)	11.09±1.47[b]	14.05±0.50[a]	13.98±1.65[a]
1.0mm/s 30%			
Hardness(N)	28.18±2.72[ab]	33.22±3.07[a]	26.79±3.49[b]
Adhesiveness(N.sec)	-0.25±0.13[a]	-1.25±0.07[a]	-1.18±0.51[a]
Springiness	0.82±0.04[a]	0.84±0.01[a]	0.83±0.03[a]
Cohesiveness	0.74±0.04[a]	0.74±0.03[a]	0.78±0.03[a]
Chewiness(N)	15.82±1.43[b]	20.64±1.18[a]	17.21±1.78[b]
2.0mm/s 30%			
Hardness(N)	32.35±3.35[a]	34.39±5.28[a]	29.16±4.55[a]
Adhesiveness(N.sec)	-0.47±0.32[a]	-0.46±0.32[a]	-0.42±0.40[a]
Springiness	0.85±0.05[a]	0.85±0.03[a]	0.89±0.04[a]
Cohesiveness	0.74±0.04[b]	0.77±0.06[ab]	0.84±0.03[a]
Chewiness(N)	16.79±.2.23[a]	22.39±3.76[a]	21.88±3.93[a]
5.0mm/s 30%			
Hardness(N)	31.66±2.16[a]	34.95±3.11[a]	31.21±3.56[a]
Adhesiveness(N.sec)	-0.49±0.27[a]	-0.49±0.34[a]	-0.52±0.26[a]
Springiness	0.84±0.07[a]	0.91±0.07[a]	0.89±0.05[a]
Cohesiveness	0.77±0.03[a]	0.79±0.05[a]	0.84±0.05[a]
Chewiness(N)	20.88±1.21[a]	23.79±5.65[a]	23.68±5.14[a]

[1)] Control, no red ginseng marc added; T1, red ginseng marc 1.5% (w/w); T2, red ginseng marc 3.0% (w/w); P1, red ginseng marc powder samples (300 ㎛ ≤ particle size ≤ 710 ㎛); P2, red ginseng marc powder samples (particle size ≤ 300 ㎛).

[2)] Mean±SD.

[a-d] Mean in the same row with different letters are significantly different ($p<0.05$).

Figure legends

Fig. 1. Frequency sweep test of chicken breast sausage with different amounts (T1, T2) and particle sizes (P1, P2) of red ginseng marc powder.

Fig. 2. Temperature sweep test of chicken breast sausage with different amounts (T1, T2) and particle sizes (P1, P2) of red ginseng marc powder at 5 Pa shear stress and 1 Hz frequency, from 25 to 75℃.

Fig. 3. Mean values of texture parameters of chicken breast sausage with different amounts and particle sizes of red ginseng marc powder obtained from TPA tests at various strain ratio (top) and cross-head speed (bottom).

Fig. 4. Mean values of texture parameters of chicken breast sausage with different amounts (top) and particle sizes (bottom) of red ginseng marc powder obtained from all TPA tests (different strain ratio & cross-head speed).

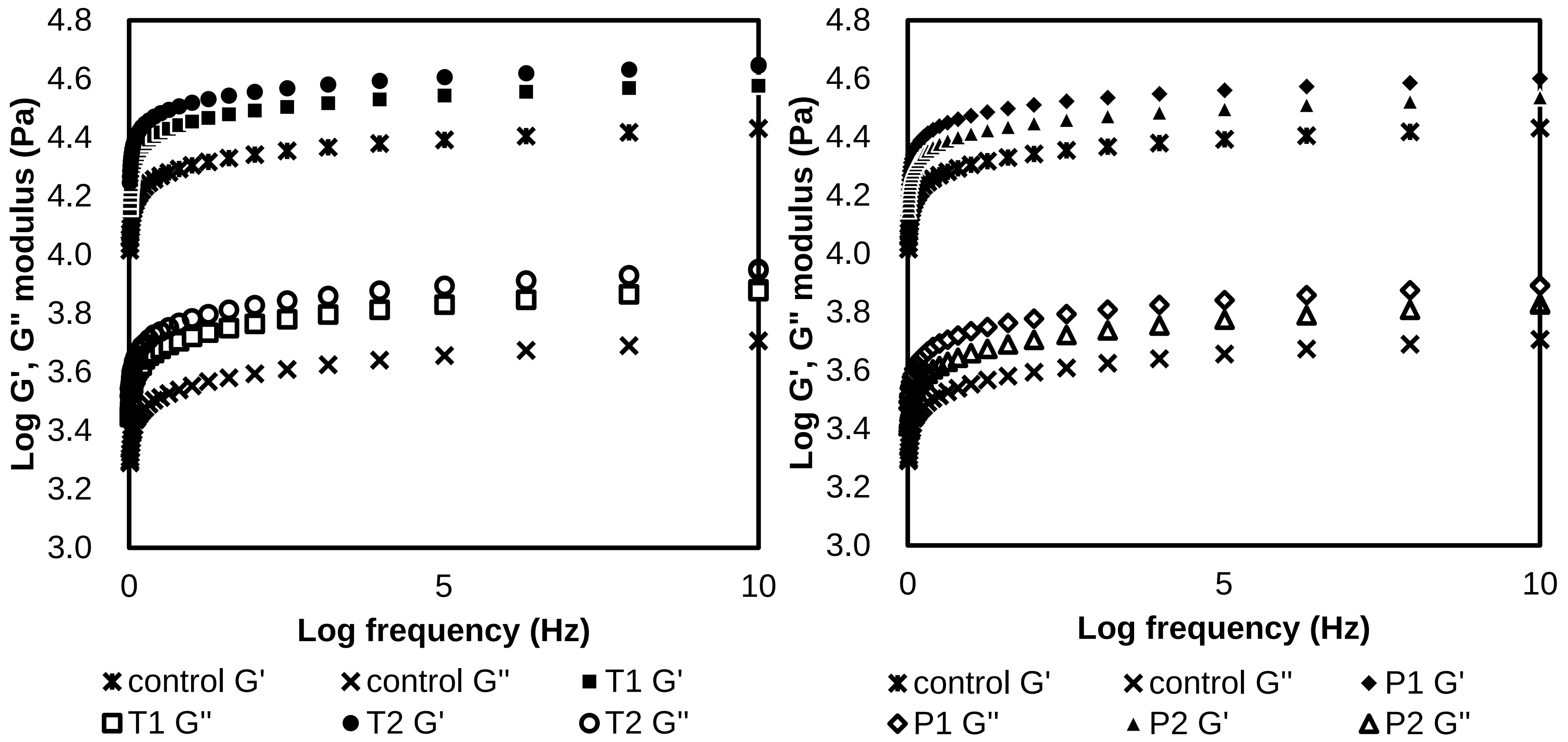

4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
Log G', G" modulus (Pa)
0
5
10
Log frequency (Hz)
control G'
control G"
T1 G'
T1 G"
T2 G'
T2 G"
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
Log G', G" modulus (Pa)
0
5
10
Log frequency (Hz)
control G'
control G"
P1 G'
P1 G"
P2 G'
P2 G"

Fig. 1.

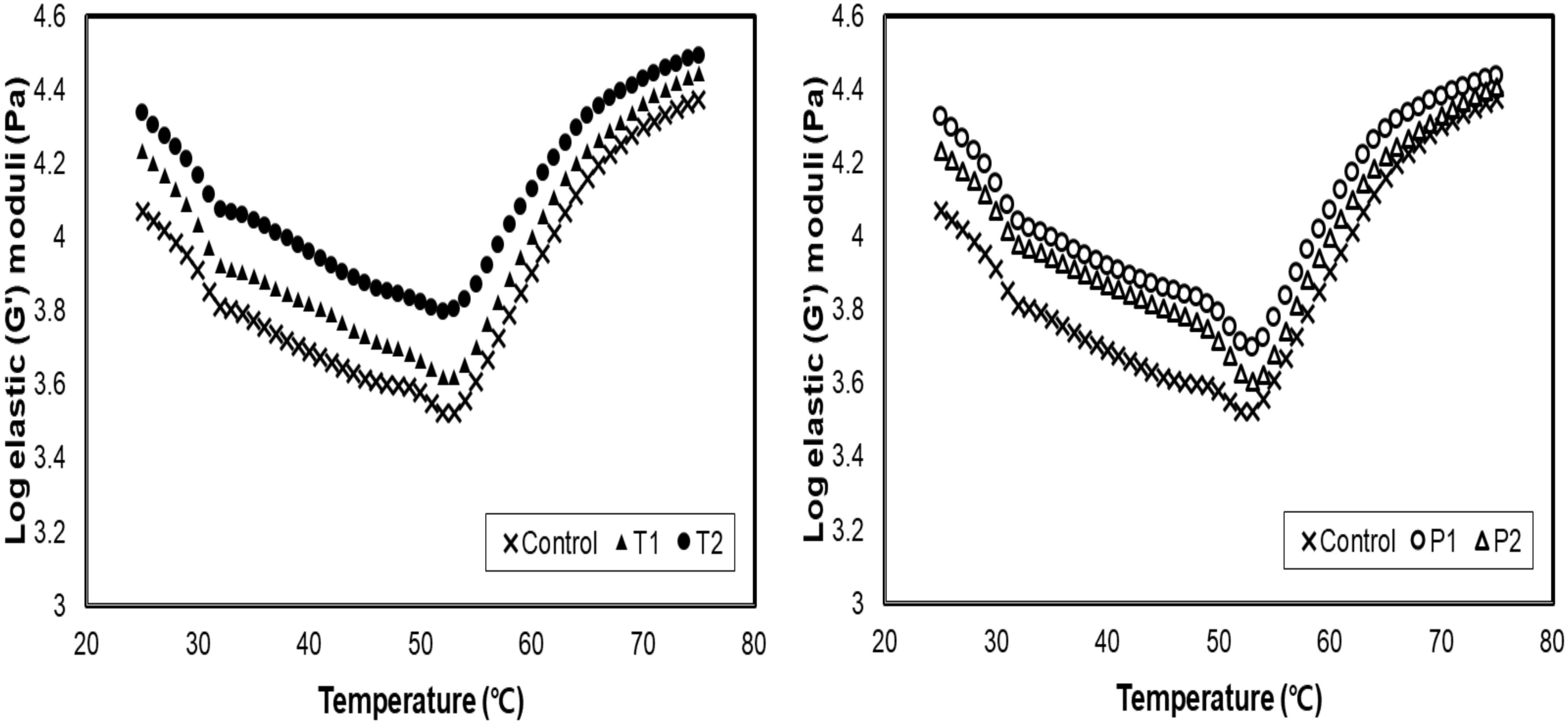
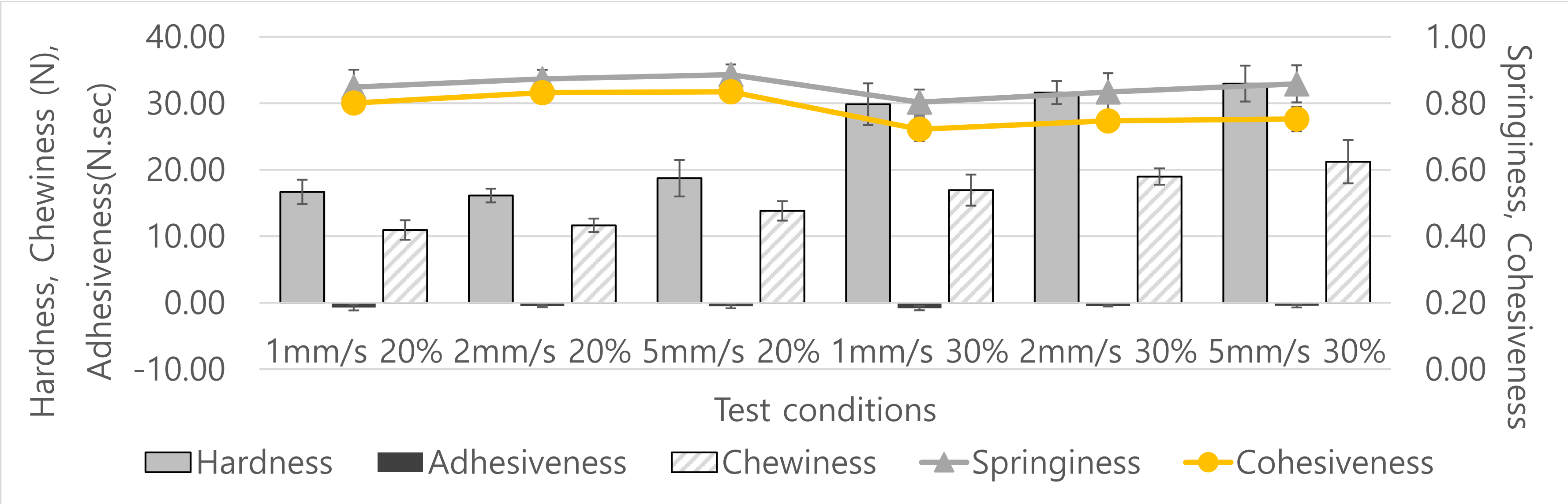
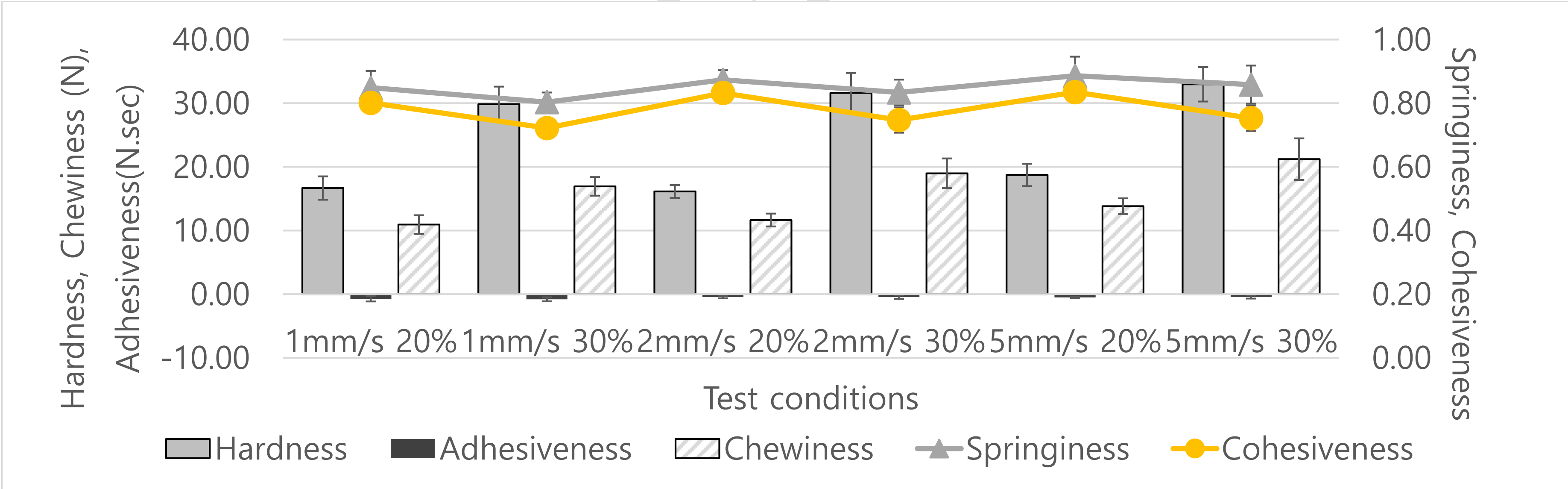

Log elastic (G') moduli (Pa)
Temperature (℃)
Control
T1
T2
Log elastic (G') moduli (Pa)
Temperature (℃)
Control
P1
P2

Fig. 2.



Hardness, Chewiness (N), Adhesiveness(N.sec)
40.00
30.00
20.00
10.00
0.00
-10.00
1.00
0.80
0.60
0.40
0.20
0.00
Springiness, Cohesiveness
1mm/s 20%
2mm/s 20%
5mm/s 20%
1mm/s 30%
2mm/s 30%
5mm/s 30%
Test conditions
Hardness
Adhesiveness
Chewiness
Springiness
Cohesiveness



Hardness, Chewiness (N), Adhesiveness(N.sec)
40.00
30.00
20.00
10.00
0.00
-10.00
1.00
0.80
0.60
0.40
0.20
0.00
Springiness, Cohesiveness
1mm/s 20%
1mm/s 30%
2mm/s 20%
2mm/s 30%
5mm/s 20%
5mm/s 30%
Test conditions
Hardness
Adhesiveness
Chewiness
Springiness
Cohesiveness

Fig. 3.

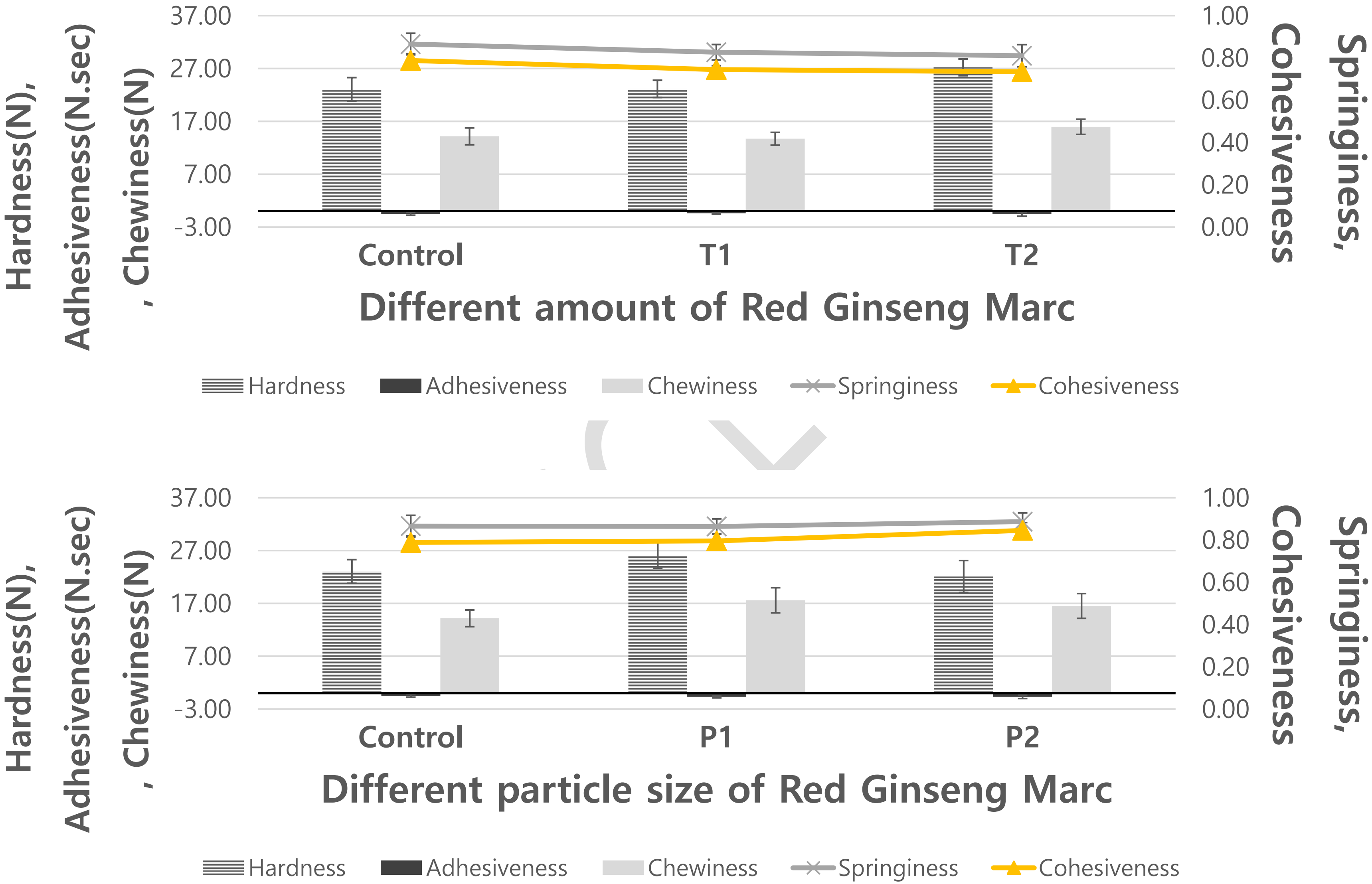

37.00
27.00
17.00
7.00
-3.00
1.00
0.80
0.60
0.40
0.20
0.00
Hardness(N), Adhesiveness(N.sec), Chewiness(N)
Springiness, Cohesiveness
Control
T1
T2
Different amount of Red Ginseng Marc
Hardness
Adhesiveness
Chewiness
Springiness
Cohesiveness
37.00
27.00
17.00
7.00
-3.00
1.00
0.80
0.60
0.40
0.20
0.00
Hardness(N), Adhesiveness(N.sec), Chewiness(N)
Springiness, Cohesiveness
Control
P1
P2
Different particle size of Red Ginseng Marc
Hardness
Adhesiveness
Chewiness
Springiness
Cohesiveness

Fig. 4.