Roasting Conditions of Sesame Seeds and Their Effect on the Mechanical Properties of Gomatoju (Sesame Tofu)

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The effect of the roasting conditions of sesame seeds on the mechanical properties of gomatoju was investigated. Gomatoju was prepared with Muki (hull-less) and Arai (white and black, with hull) seeds (unroasted and roasted at 160, 170, 180, 190 and 200°C) in an electric oven for 15 min. Surface structures and vertical sections of Arai and Muki seeds were observed by SEM. The fracture stress and strain for gomatoju were the smallest when the seeds were roasted at 170°C, and were the highest when the seeds were roasted at 190°C (p<0.01). The average particle size in the sesame milk of seeds roasted at 170°C (21.5–40.4 μm) were smaller than that at 190°C (86.4–110.3 μm). Thus, it was considered that the particle size of gomatoju which is prepared with seeds roasted at 190°C became smaller (2.0–6.0 μm) by mixing during preparing of gomatoju. The mouthfeel of gomatoju prepared with seeds roasted at 190°C was not smooth, as they had a slight bitterness or "Zaratuki." In terms of the total acceptance by Kramer's test, gomatoju made from Muki (p<0.01) and Arai (p<0.05) was determined to have best palatability when the seeds were roasted at 170°C.

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**Keywords: Arai and Muki sesame seed, roasting conditions, Gomatoju, SEM observation, fracture and texture properties, sensory evaluation.**

**INTRODUCTION**

Gomatoju (sesame tofu), a mixed gel consisting of kudzu starch and sesame seeds, possesses unique textural characteristics. Gomatoju is a dish in Chinese-style vegetarian cuisine (Fucha-cuisine) called "maifujii," mainly consisting starch and oil. It is a traditional Japanese health food and a typical vegetarian dish. Gomatoju and sesame seeds are believed to have pharmacological actions1) in gastrointestinal diseases and detoxification,1) reducing cholesterol and high blood pressure.2 Sato et al.3) investigated the effects of preparation conditions, mixing ratios and cooking times on the physical properties of gomatoju. SEM observations in previous papers3) indicated that Gomatoju samples prepared by mixing sesame milk and kudzu starch at 250 rpm for 25 min had a uniform network structure. It was also found that Gomatoju prepared with ingredients having a ratio of 40–50 g of kudzu starch to 40–60 g of sesame with 450 g of added water were palatable in softness, mouthfeel and springiness.3) The sesame contributed to stability of the kudzu starch gel, but a larger proportion of sesame contents decreased the cohesiveness7) due to the high level (55.9%) of lipids in sesame seeds. Previous papers3)5) determined samples of roasted Arai black and white gomatoju have the best palatability because of their superior springiness. Further, it was also found that favorable oil content was 3.4–6.4%10) in the gomatoju. In this study, the effects of roasting conditions of sesame seeds on the mechanical properties of gomatoju were investigated. According to empirical knowledge of cooks, heating of sesame seeds should be stopped when three seeds pop open. Overheating creates a burning smell, loss of flavor and undesirable changes in the sesame components. We conducted an experiment to investigate which roasting temperature for sesame seeds produced the most palatable texture of gomatoju.

**MATERIALS AND METHODS**

**Materials**

Highly pure (99.0%, 'Kokkii' kudzu (Pueraria lobata Willed) starch was purchased from Inoue-
tengyokudou (Nara, Yoshino, 2003). The three kinds of sesame (*Sesamum indicum* DC) materials were produced in China (2003). The white sesame seeds from which hulls had been removed physically which shed their hulls are called "Muki-goma" length (L), width (W), thickness (T): 3.1, 2.1, 0.8 mm. The white and black sesame seeds with hulls which are dried after washing, called "Arai-shiro-goma" [L, W, T: 3.2, 1.9, 0.8 mm] and "Arai-kuro-goma" [L, W, T: 2.9, 1.8, 1.4 mm]. were purchased from Kadoya Oil Co. (Tonosho, Kagawa). The contents of lipids, proteins, and carbohydrates of sesame materials were analyzed quantitatively by the Soxhlet extraction method,12 the Kjeldahl method of nitrogen determination,12,14 and the phenol sulfuric acid method,12,15 respectively. In the determination of carbohydrate content, the sample was completely hydrolyzed by heating in 1.0 M sulfuric acid at 100°C for 5 h. The hydrolyzed matter was neutralized by 1 M sodium hydroxide, and the sample was obtained by filtering. One milliliter of 5% phenol solution was added to 2 ml of the sample solution. Five milliliters of 96% sulfuric acid was added to each test tube so that the stream hit the liquid surface directly, and the sample was measured at 480–490 nm wavelengths quantitatively by colorimeter.

**Color measurement by CIE chromaticity diagram**

*Arai* (white seeds with hull) and *Muki* (white hull-less seeds) were roasted at 160, 170, 180, 190, 200°C and 210°C in an electric oven (Rinnai, Rick-7N) for 15 min. Changes in the color (hue: a*, b*, L* value, and color difference: ΔE (ab*) of sesame seeds at various roasting conditions were measured using a color difference instrument (ZE2000, Denshokukogyo Co., Japan). The frequency particle size measurement

**Frequency particle size measurement**

The frequency particle size of sesame particles that passed through a 50 mesh sieve (=297 μm) in *Arai* white and *Muki* sesame milk were measured by the laser diffraction particle size analyzer (L Dana 2100, Shimadzu Co., Japan). The method for the preparation of sesame milk is explained in Fig.1; briefly, 450 g of water was mixed with 40 g of unroasted sesame or sesame roasted (at 160, 170, 180 or 190°C) for two kinds of sesame (*Arai* white, *Muki*) for 3 min and filtered by sieve to obtain about 435 g of sesame milk. Forty milliliters of deionized water was put into a cell of the LDPA instrument, and 0.5 ml of sesame milk diluted to one tenth (1/10) was dropped in the cell and measured three times. The average particle size was determined by the laser diffraction dispersion method.

**Preparation of Gomatoju**

Preparation procedures for gomatoju and the experimental apparatus are shown in Fig. 1. Briefly, 40 g of roasted sesame and 450 g of water were mixed for 3 min and filtered using a sieve (50 mesh=297 μm) to obtain about 435 g of sesame milk and sesame residue. A suspension of sesame milk (435 g) and *kudzu* starch (40 g) was prepared by simmering for 25 min on an electric heater 450 W (National NK-082) while mixing at a rate of 250 rpm using a mixing instrument (DC-3RT, Tokyo Rika Co., Japan). The hot samples were immediately poured into a Teflon ring case (20 mm height×20 mm inner diameter) and were kept in a 10°C incubator (ASONE, PRI-301) for 24 h. Tests on the samples were performed at 20°C. Three kinds of samples are called *Muki* (hull-less) gomatoju, *Arai* white (hull) gomatoju and *Arai* black (hull) gomatoju hereafter.

**Rheological measurements of gomatoju**

A creep meter (Rheotester RE-3305, Yamaden Co., Ltd. Tokyo, Japan) set by a thermostat chamber connected to a water bath to maintain the measuring temperature (20°C), was used for the measurement of fracture and texture properties of gomatoju under uniaxial compression. The samples were compressed to 80% strain by a cylinder plunger (40 mm diameter, non-stick Teflon) at a compression speed of 1.0 mm/s using a 2 kg load cell. The cross sectional area of the cylinder plunger used was larger than the sample...
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Fig. 2. Changes in the hue, value and color difference of Arai white and Muki white sesame seeds with increase of roasting temperature

area (20 mm diameter). Texture measurements were carried out at the same conditions as fracture measurements, but the samples were compressed to 60% measurement strain. A method of the compression test by large deformation was the same as that described by Nishinari. Care was taken so that the contact state between the plunger and cylindrical sample was fixed. Both the top and bottom surfaces of cylindrical gel samples were lubricated with silicon oil to make the frictional force as small as possible. Culloli and Sherman showed that lubrication, or lack of lubrication, of the contact surface between the food and compressing platen affects the force required to reach a given degree of compression. Thus the samples were lubricated by silicon oil to ensure uniform deformation. The values of the fracture and texture measurements were obtained from the means and standard deviations of a series of 10 tests, and significant difference between samples were examined by t test. The reason for carrying out a compression test rather than a penetration test in this study was to more closely approximate the texture of the gomafu i.e., the sensation of crushing the gomafu on the tongue.

Observation of the surface structure and vertical section of Muki white and Arai white sesame seeds by SEM

Scanning electron microscopy (Chilled Natural SEM-3500, Hitachi, Ltd.) observations were made at Niigata Water Works Bureau. Surface structures and vertical sections of Muki white and Arai white sesame seeds at different roasting temperatures were examined with an accelerating voltage of 20 kV. Vertical sections of unroasted or roasted sesame seeds were cut by a knife. As for gomafu (gel), about 5 mm squares of the samples without any chemical treatment were observed at temperatures ranging from 0 to −10°C. Air cell size (Heywood diameter) was analyzed by an Image Analyzer (LUZEX 500, Nireco, Co., Japan). The Heywood diameter equation used for the calculation was as follows:

\[
\text{H.D. (Heywood diameter)} = \sqrt{4/ \pi \times \text{area of air cell}}
\]

The sample was observed on a stand in its natural state, and was maintained at a low vacuum using a cool stage. It was possible to observe for long time by chilled SEM, even if the sample was susceptible to heat. The finer particles dispersed in the gomafu were calculated according to the scale of SEM photographs (Fig. 10).

Sensory evaluation

Sensory evaluations of the texture of gomafu made from two kinds of seeds (Muki and white Arai) and prepared at five kinds of roasting temperatures (unroasted, 160°C, 170°C, 180°C, 190°C) were performed by ranking methods, sample numbers, 5 panel, number 24 for each test. The panel was composed of students and teachers of Niigata Women's College. For each kind of gomafu (Muki, Arai) for hardness, springiness, and mouthfeel by discrimination test and total acceptance by palatable test were compared according to five samples; an order rating of 1, 2, 3, 4 or 5 was given to each sample, with 1 being
the most or best, 2 being the second-most/best, etc. The total sums of order were analyzed by means of Kramer's test, and further examined according to Newell & MacFarlane's test to detect significant difference between samples. Kendall's agreement coefficient of concordance, sample numbers 24, 0≤W≤1 was also used to judge the degree of agreement of the panel.

RESULTS AND DISCUSSION

Changes in the hue (a*, b*), value (L*) and color difference (ΔE ab*) of Arai white and Muki white sesame seeds with an increase of roasting temperature

The hue (a*: red, b*: yellow), the value (L*) and the color difference (ΔE ab*) of Arai white and Muki white sesame seeds with an increase of roasting temperature are shown in Fig. 2. The hue (+a*: red, +b*: yellow) of both Arai white and Muki white sesame seeds decreased at 180°C (yellow gradually became weaker at 200°C, 210°C), though the changes of Muki sesame seeds were more remarkable. The value (L*) of both sesame seeds decreased with an increase of roasting temperature; L* of Muki sesame seeds became higher than that of Arai up to 170°C, and both of them fell at temperature higher than 180°C, 200°C and 210°C. The color difference of Muki sesame seeds was larger than that of Arai white at all roasting temperatures. The changes in the hue and the color difference of Muki sesame seeds were larger than that of Arai white. It was considered that Muki sesame seeds had greater direct effects from roasting because they do not have a hull.

Chilled SEM observation of surface structure and vertical section

Fig. 3. Changes in the surface structure of Arai white and Muki white (hull-less) sesame seed with increase of roasting temperature.

O: Calcium oxalate crystallization.
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Cotyledon and endosperm tissue became more obvious with increase of roasting temperature. In the unroasted sesame, there was dosperm tissue inside the hull, and oil droplets were apparently jam-packed closely in the cotyledon cell tissue which were observed in the central inner part of the Muki white sesame seed; however, the turtle-shell-shape hull of the Arai white sesame when the Arai white sesame seeds expanded with roasting at 170°C. About 85% above of calcium contained in Arai sesame seeds 100 g weight is included in the hull. But the highest roasting temperature (200°C) damaged the Arai white sesame. On the other hand, the surface of the Muki (hull-less) white sesame were even, and were observed because of the lack of the turtle-shell-shape structure. Drops of oil from the Muki white sesame oozed out and became lumps, leading to their stronger color with an increase of roasting temperature. Changes in the vertical sections of Arai white and Muki white sesame seeds with increase of roasting temperature are shown in Fig. 4. The upper two parts show photographs of Arai white at different magnifications. Spherical calcium oxalate crystallizations were present under the hull at 170°C and became more obvious with increase of roasting temperature. In the unroasted sesame, there was endosperm tissue inside the hull tissue, and oil droplets were apparently jam-packed closely in the cotyledon cell tissue, which were observed in the central inner part. In the lower part of the Muki white sesame seed, there was a flow of oil droplets from the cotyledon cells of sesame seeds roasted at 200°C, and then that developed an irregular structure.

**The chemical components of sesame seed, sesame residue and sesame milk for Arai white and Muki white sesame seed**

The chemical components of sesame seeds: sesame residue (upper figure) and sesame milk (lower figure) with an increase of roasting temperature are shown in Fig. 5. Sesame milk was obtained by mixing 40 g...
Changes in the components of sesame seed, sesame residue (upper figure) and sesame milk (lower figure) with increase of roasting temperature

Sesame seed materials and 450 g of water for 3 min and then filtering. About 60–75% of the composition of sesame materials enters in the sesame milk. The chemical compositions of unroasted sesame seeds were obtained for 'Arai' white (water 5.0%, lipid 54.8%, protein 19.5%, carbohydrate 20.4%) and 'Muki' (water 4.0%, lipid 59.8%, protein 20.1%, carbohydrate 17.0%), respectively. The amount of carbohydrate in Muki (hull-less) sesame seeds were lower than that in Arai white because the soluble fiber content of sesame seeds with hulls (Arai) is about 1.5 times higher than that of hull-less seeds. Takeda et al. found that the lipid levels of sesame seeds did not change, that of protein constituents decreased and carbohydrate contents increased with an increase of roasting temperature. In this study, it can probably be considered that the increase in carbohydrates with increases in roasting temperature of sesame seeds was due to the generation of brown substances produced by the amino-carbonyl reaction, yielding indigestible enzyme products by the denaturation of the protein. The sesame residue decreased, and the particles passed through a sieve (297 μm) moved into the sesame milk with an increase of roasting temperature. Consequently, it is expected that the concentration of sesame milk components became higher. The amount of lipids in Muki sesame milk was greater than that of Arai sesame milk as reported in previous papers, and the amount of lipids did not change with an increase of roasting temperature; however, the amount of protein in the sesame milk decreased up to 170°C and increased at 180°C. Namely, when the sesame seeds were roasted at 170°C, the level of protein in the sesame milk was slightly lower than that observed at other treatments. The carbohydrate contents in the Muki sesame milk were larger than that of Arai, and that of both kinds of sesame milk increased with an increase of roasting temperature.

**Frequency particle size measurement**

Changes in the frequency of particle size with
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Fig. 6. Changes in the frequency particle size in Arai and Muki sesame milk with an increase of roasting temperature for sesame seeds.

Forty milliliters of deionized water was put into a cell of the (LDDA) instrument, and 0.5 ml of sesame milk diluted to one tenth (1/10) was dropped in the cell and measured three times.

Increasing of roasting temperature for Arai and Muki sesame milk are shown in Fig. 6. An average value for three particle sizes of each sample was shown in Fig. 6. The average particle size increased remarkably with an increase in roasting temperature for both kinds of sesame seeds, ranging from 9.8 to 21.5 μm for Arai and from 27.8 to 40.4 μm for Muki when the temperature was equal to or lower than 170°C, whereas ranging from 85.9 to 86.4 μm for Arai and from 96.7 to 110.3 μm for Muki when the temperature was 180 or 190°C. The average particle size in the Muki sesame milk was larger than that of Arai for
when compared at the same temperature. The frequency of particle size in the sesame milk of unroasted Arai had peaks at 2.4 μm, 8.3 μm, 29.0 μm and 153.0 μm, but that of the samples roasted at 170 °C, 180°C and 190°C had two peaks at 29.0 μm and 153.0 μm. On the other hand, the frequency particle size in all the samples of Muki sesame milk showed only two peaks at 29.0 μm and 153.0-233 μm. The X-ray diffraction of both Arai and Muki sesame seeds roasted at 180°C and 190°C and passed through a sieve (297 μm) were most heavily concentrated in the range of 0.100-0.300 μm.

Fracture properties of Muki (white) and Arai (white and black) gomatofu prepared at various roasting temperatures

Typical stress-strain curves of Muki gomatofu made from sesame seeds roasted at various temperatures are shown in Fig. 7. Fracture properties of three kinds of gomatofu prepared using various roasting temperatures of sesame seeds are shown in Fig. 8. Gomatofu showed a ductile fracture, after passing through a plastic domain. The fracture stress of three kinds of gomatofu was the lowest when seeds were roasted at 170°C, and the highest when seeds were roasted at 190°C. There were significant differences (p<0.01) in fracture stress between gomatofu prepared using seeds roasted at 170°C and those roasted at 180°C for all three kinds (Muki, black Arai, white Arai) of gomatofu. As for fracture strain in Muki gomatofu, there were no significant differences between gomatofu prepared using seeds roasted at 160°C and those roasted at 170°C, or between those roasted at 180°C and 190°C by t test. As for Arai black and Arai white gomatofu, there were significant differences (p<0.05) between those roasted at 160°C and
170°C. It is clear that gomatofu prepared using sesame seeds roasted at 190°C have higher fracture stress because their fracture stress and the fracture strain values (71–75%) were higher than those of the other samples. It was considered that the values of fracture stress and strain of the gomatofu prepared using seeds roasted at 170°C were the smallest.

**Texture properties of Arai white and Muki gomatofu**

Culloli and Sherman mentioned that texture is the composite of those properties (attributes) which arise from the structural elements of food and the manner in which it registers with the physiological senses. In this study, the average values (with standard deviation bars) of the ten measurements for each of three texture parameters (hardness, cohesiveness, and adhesiveness) of Arai white and Muki gomatofu made from seeds at various roasting temperatures are shown in Fig. 9. The significant difference was examined against the lowest mean value by t-test. The magnitude of the hardness H for Muki gomatofu was highest in order from H190°C (p<0.01) > H180°C (p<0.05) > H170°C (p<0.05) > Huunroasted for Arai gomatofu, the order starting with the highest was Huunroasted (p<0.05) > H190°C (p<0.05) > H180°C (p<0.05) > H170°C (p<0.05) > Huunroasted. For cohesiveness C, the order starting with the highest for Arai and Muki gomatofu was C190°C (p<0.05) > C180°C (p<0.05) > C170°C > C160°C > Cunroasted. For both kinds of gomatofu, the roasting temperature of 170°C produced the lowest hardness but the highest (p<0.01) cohesiveness. The cohesiveness of Arai gomatofu was higher than that of Muki. As for adhesiveness A, the magnitude for both gomatofu was highest in order from Aunroasted (p<0.05) > A160°C (p<0.01) > A170°C (p<0.05) > A180°C (p=n.s) = A190°C.

**Chilled SEM observations of Arai white and Muki gomatofu**

Figure 10 presents SEM photographs of the air cell size and vertical sections of structure for gomatofu with roasting conditions. SEM observation revealed that air cell sizes (H.D.) in both Arai white and Muki gomatofu were smaller and the cell number was higher against the lowest mean value respectively. n.s: no significant difference.
"Arai" white gomatofu

Unroasted 170°C 190°C 20 μm
H.D.: 13.70±4.3μm 18.45±5.3μm 16.30±5.4μm

"Muki" white gomatofu (hull-less sesame)

Unroasted 170°C 190°C 20 μm
H.D.: 15.73±4.8μm 22.94±7.6μm 16.86±4.9μm

Fig. 10. Chilled-SEM observation of structure of Arai white and Muki gomatofu with increase of roasting temperature (×1,500)

O mark: The finer particles of sesame seeds.

Sensory evaluation of Arai white and Muki gomatofu

Results of the ranking method are shown in Fig. 11. The number shows the total sum of order. Ranking of the hardness by sensory evaluation Hs for both Arai and Muki were highest in order beginning with sample HsA. 190°C (hard). HsB, 180°C > HsC, 170°C > HsD, 160°C > HsE, 150°C (Muki, p<0.01). These findings indicated that both gomatofu had the least hardness (i.e., maximum softness) when prepared with sesame seeds roasted at 170°C. But panels had difficulty judging the difference between Arai and Muki, the Kendall coefficient was low: W = 0.14, indicating no significant difference. Ranking of the springiness S for Arai white was, in order from highest to lowest, sample Sb, 190°C (hard) > Sa, unroasted > Sd, 180°C > Sc, 170°C > Sa, 160°C (Muki, p<0.01). As for the ranking of the mouthfeel M, there was significant difference (p<0.01) between Muki e, 170°C (p<0.01) (which was large because of the lack of hull and light taste) and Muki e, 190°C (p<0.01) (which was small). Ranking of the total acceptance TA for Arai was highest starting with TAe, 190°C > TAB, 180°C > TAc, 170°C > TAb, 160°C > TAd, 150°C (p<0.01). For Muki, total acceptance TA was highest in order from TAe, 190°C > TAb, 180°C > TAc, 170°C > TAB, 160°C > TAe, 150°C (p<0.01). Namely, the sample of Muki e, 170°C (p<0.01) was also evaluated to have the best palatability, respectively. For both Arai and Muki, ranking of total acceptance was lowest for the sample e, or the sample roasted at 190°C (p<0.01). Muki e, 190°C (p<0.01), had the lowest allerow evaluation of the Muki because of its unpleasant mouthfeel, and Arai e, 190°C (p<0.01) had the lowest overall evaluation among the Arai because of having slight bitterness or "Zarataki" and powdery. In the parameters of springiness (p<0.01), mouthfeel (p<0.01), and total acceptance (p<0.01), the judgment of the panel showed high agreement based on Kendall's coefficient (W); the exception was hardness.
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(Arai white gomatofu)

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(Muki gomatofu)

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Fig. 11. Sensory evaluation of Arai white gomatofu and Muki gomatofu prepared at various roasting temperatures by ranking method.

Sample a, unroasted gomatofu; b, 160°C gomatofu; c, 170°C gomatofu; d, 180°C gomatofu; e, 190°C gomatofu. The number in Fig. 11 showed the total sum of order. Sample number: 5, panel member: n = 24. Total order sum were examined according to Kramer's test: A: p < 0.01, B: p < 0.05. Significant difference between samples was examined according to Newell & MacFarlane's test: *p < 0.05, **p < 0.01, Kendall's coefficient of agreement: W*: p < 0.05, W**: p < 0.01. W*: no significant difference, 0 ≤ W ≤ 1.

CONCLUSION

It was reported in previous papers that gomatofu follows a phase-separation model having networks of kudzu starch and sesame components. Sesame seeds are usually roasted until the hull is burst by internal vapor pressure; in this study, sesame seeds started popping at 170°C. SEM of vertical sections of sesame seeds revealed that roasting sesame at 170°C created distinct spaces between the residual endosperm tissue and the cotyledon tissue. The changes in the color of Muki white sesame seeds by roasting were particularly intense, because they do not have a hull. The difference in the physical properties of sesame due to roasting greatly affected the color, sesame components and texture of the seeds, and the ease of grinding. Arai white sesame roasted at 170°C were structurally well expanded, became thicker, and were easily broken by roasting. Arai white sesame seeds were more suitable for roasted gomatofu than Muki white sesame seeds. Muki gomatofu prepared with unroasted seeds was sticky and softer and creamier than Arai gomatofu due to the latter’s elastic, slightly firm, and minutely structured hull. Gomatofu prepared using seeds roasted at 170°C had appropriate color and a lower level of protein; a smaller average particle size (Arai, 21.5 μm; Muki, 40.4 μm) and peak of relative particle content in sesame milk (Arai, 7.8%; Muki, 8.2%) than those using seeds roasted at 190°C (Arai, 86.4 μm and 11.6%; Muki, 110.3 μm and 14.3%). The values of the fracture stress and strain (Fig. 8) and hardness (Fig. 9) for Arai white and Muki gomatofu were lowest for 170°C (softness), the magnitude of cohesiveness were large. The magnitude of adhesiveness for gomatofu decreased with roasting temperatures; it was guessed that this trend was due to the influence of the particle size. The particle size of gomatofu became smaller (2.0–6.0 μm) by mixing during preparing of gomatofu according to calculations, using the scale in Fig. 10, though average particle size of sesame roasted at 190°C in the sesame milk was very large. It was guessed that most of the finer sesame particles (comparatively soft) were dispersed in the network of the gomatofu by mixing the suspension of sesame milk and kudzu starch. The fracture stress increased at
higher roasting temperatures because these fine particles of sesame have a filling effect, and they increased the elastic modulus of the gel. Sensory evaluation showed that gomatofu prepared with seeds roasted at 170°C had best palatability (Arari gomatofu, p < 0.05, Muki gomatofu, p < 0.01) due to their softness and mouthfeel. It was found that good mouthfeel is characterized by smoothness, and is an important parameter in the texture of gomatofu. But Arari and Muki gomatofu prepared with seeds roasted at 190°C became hard and burnt taste, and those of mouthfeel was rated the worst (p < 0.01) because it was not smooth. It was considered that oral perception of grittiness was influenced not only by average particle size and the density of the dispersion particles but also by the physical properties of the starch gel and the variety of starch. In addition, it was difficult for panel to detect grittiness when the particle size was small and soft, and the viscosity of the dispersion medium was high. Oral perception of grittiness for gomatofu was slightly strong and was evaluated as “Zarauki” and powdery in this study, though the sesame particle size in gomatofu roasted at a high temperature (190°C) was not so large, and those particles which were observed in Fig. 10 were comparatively hard.

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Roasting Conditions of Sesame Seeds and Their Effect on the Mechanical Properties of Gomatofu (Sesame Tofu)


ゴマ豆腐の力学特性に及ぼすゴマ種子の焙煎条件の影響
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ゴマ豆腐の力学特性に及ぼすゴマの焙煎条件の影響について検討した。ゴマ豆腐は、皮むき白ゴマ、皮付き洗いゴマ（白、黒）を未加熱及び 160℃、170℃、180℃、190℃、200℃の温度で、電気オーブンにより 15 分間焙煎した。洗い白ゴマとむき白ゴマの表面構造と水平面（断面）構造は、チルド SEM により観察された。ゴマ豆腐の破断点，破断歪みは、ゴマ種子が170℃で焙煎された時，最も低く，190℃で焙煎された時が最も高かった（p<0.01）。170℃で焙煎されたゴマから得られたゴマ乳の平均粒子径（洗い 21.5 ～むき 40.4 μm）は，190℃ゴマ乳の平均粒子径（洗い 86.4 ～むき 110.3 μm）よりも小さかった。しかし，SEM 観察の結果から，190℃で焙煎されたゴマ種子で調製されたゴマ豆腐の粒子径（2.0 ～6.0 μm）はゴマ豆の調製中に混ざって，より小さくなった。190℃で焙煎されたゴマ種子で調製されたゴマ豆腐の口ざわりは，わずかに苦みやざらつき感があり，なめらかではなかった。クラマーの検査による総合評価において，皮むきゴマ豆腐（p<0.01），洗いゴマ豆腐（p<0.05）は 170℃焙煎ゴマで調製された時に最も高く評価された。

キーワード：皮むき白ゴマと洗い白ゴマ，焙煎温度，ゴマ豆腐，SEM 観察，力学特性（破断特性，テクスチャ），官能検査.

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