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Effect of Size and Mouthful Amount of Foods on the Mastication Properties and Texture

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Seasoned *daikon* was used as a material in order to examine the effect of sample size and mouthful amount of foods on the properties. Five sample sizes and six mouthful amounts were chosen. A cube of 1 cm^3 was used and cut to prepare the five sizes, and the mouthful amounts were equivalent to 1–6 cubes of 1 cm^3. As the sample size decreased, the breaking properties decreased, the average masseter muscle activity and average chewing force decreased, the total number of chewing strokes increased, and there was no significant difference in the while sensory softness. Evaluations of ease of chewing, shape-keeping ability, and ease of eating were lower when the sample size was small. As the mouthful amount was increased, the breaking properties increased, and the chewing duration and total number of chewing strokes increased. Softness and shape-keeping ability did not depend on the mouthful amount. Evaluations of the ease of chewing and ease of eating became higher as the mouthful amount was increased. The effect of size and mouthful amount was plotted two-dimensionally by using a principal component analysis. The ease of eating decreased as the cube of 1 cm^3 was cut smaller. As the mouthful amount increased, the chewing duration and total number of chewing strokes increased, although the ease of eating tended to improve.

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INTRODUCTION

The rapidly aging population has created a strong demand for foods for senior citizens, nursing care foods, and thickening materials, and many are now on the market.[1)2)] These foods have to be easy to chew and difficult to get into the lungs. The foods already on the market and cooked in nursing care homes are often softened, reconstituted, or minced for people who have difficulty in chewing.[3)4)]

The particle size of minced foods varies among different nursing care homes,[3)4)] and it has been pointed out that minced foods tend to be broken into pieces in the mouth and are not easy to eat for senior citizens.[5)6)] The size and the shape of foods have been addressed in several studies, foods cut into certain shapes having been investigated for their toughness, size and shape just before swallowing.[7)-9)] The effect of thickeners on minced foods has been reported,[10)-12)] and some investigations have employed masticatory electromyographic measurement.[13)-17)]

Minced food which tends to be broken into pieces in the mouth may retain its shape if the volume in the mouth is adequate. The effect of a mouthful of food has received little attention, excepting a study on the number of chewing gum pieces in the mouth.[18)]

None of these studies mentioned has presented any systematic data on the size and amount of food in a mouthful. One or more types of food with different physical properties were sliced, shredded, or minced in a way for common use.

The effect of the degree of mincing and the amount of food in a mouthful on the activity of the masseter muscles were investigated by using seasoned *daikon*, and a sensory evaluation was conducted on the ease of eating. The effect of seasoning was also examined by a similar investigation with unseasoned *daikon*.

MATERIALS AND METHODS

Preparation of the materials and samples

Daikon was chosen as the test material and was obtained from a supermarket on the day of measurement. One fifth at the root end and one fifth at the leaf end were removed from the *daikon*, and about 5 mm was peeled off from the remaining vegetable. After removing the core of approximately 1 cm in diameter,

the *daikon* was cut into cubes of 1 cm^3. A 200-g amount of the *daikon* cubes was boiled in 2 *l* of distilled water for 10 min, and 7% soy sauce (1% salt, *honjozo* soy sauce, Kikkoman), 5% sugar (*spoon jirushi* white sugar, Mitsuiseito) and 0.5% *umami* seasoning (*honndashi, katsuodashi*, Ajinomoto) were then added. The calculated weight of each seasoning was based on the weight of the water before boiling. The seasoned *daikon* was boiled for another 10 min, and distilled water used to make up the water that had evaporated. The cooking process was conducted with a K2-PH1 1400-W IH cooker (National). The seasoned *daikon* was kept in a refrigerator for one night before measurement.

Five sample sizes of the seasoned *daikon* were tested: a cube of 1 cm^3, half a cube (called half), a quarter of a cube (called quarter), one eighth of a cube (called one eighth), and one eighth minced ten times (called minced). For measurement, samples of the five sizes were reformed into a size similar to the original cube of 1 cm^3. Each of the five sample sizes was tested in six mouthful amounts equivalent to 1–6 cubes of 1 cm^3. Therefore, 30 (5×6) samples were used for the subsequent measurements.

Breaking examination

Measurements were carried out with an RE-3305 high-resolution Rheoner measuring instrument (Yamaden). The measuring conditions were as follows: constant compression at a compression velocity of 1 mm/s, a 200-N load cell, a breaking strain ratio of 90%, and a no. 2 circular shaped plunger 4 cm in diameter.

As already mentioned, a sample was put on the measuring plate in a form as close as possible to the original 1 cm^3 cube. When the sample was in more than one piece, the pieces were put on the plate as close to each other as possible, with the center of the plunger touching the center of the pieces.

The breaking load, breaking strain, and breaking energy were calculated from the recorded breaking curve by using software for a BAS-3305-LE automatic creep meter (Breaking Strength Analyzer Windows Ver. 1.0.(a); Yamaden). Each sample was subjected to 10 repeated measurements, and the average value was determined.

Masticatory electromyographic measurement

Among the muscles used for mastication, a pair of the right and left masseter muscles was selected and an electrode was attached to the surface of each. The active potential was measured with an MP100WS data acquisition and analysis system (an EMG100 amplifier for electromyography and AcqKnowledge software; Biopac System Co.). The measuring conditions were 500 Hz (LP), 100 Hz (HP), and 1,000 (gain).

Each sample was measured five times. The examinees were eight female students at the author's university each aged 21 or 22 years, and they gave informed consent after an explanation of the objective of the measurements.

A data analysis was conducted on the data obtained during the first five chewing movements from the beginning of mastication. The following values were calculated, the characteristic values for each food being the average values obtained from five repeated measurements by the eight examinees.

The analyzed values were (i) average masseter muscle activity value, (ii) average chewing force, (iii) average duration of one biting movement, (iv) average duration of one chewing movement, (v) chewing duration, and (vi) total number of chewing strokes, which were the same as in the study of Imai and Sato.[19]

Sensory evaluation

A sensory evaluation was conducted on the softness, ease of chewing, shape-keeping ability, and overall ease of eating by scoring in 7 steps (−3 to +3): ±3; very, ±2; quite, ±1; fairy, 0; not distinguishable: − and + showed the evaluation of "hard" *vs.* "soft," "difficult to chew" *vs.* "easy to chew," "keeping shape poorly" *vs.* "keeping shape well," and "difficult to eat" *vs.* "easy to eat." Each sensory evaluation was made on an absolute basis by presenting one sample at a time. The evaluation panel was made up of the 8 female students who participated in the masticatory electromyographic measurements. The sensory evaluation took place in a cooking training room at a temperature of 23±2℃ during the test period of 13:30–17:00. The average of the values scored by the 8 panelists was taken as the final result.

Statistical analysis

A two-factor analysis of variance was conducted to examine the effect on each property of the size and mouthful amount of the sample, and a correlation analysis was conducted to examine the relationship between each property. A principal component analysis was also carried out to examine the relationship between the size and mouthful amount of each sample. The principal component analysis was started from the correlation analysis with an eigenvalue of 1 or more. The two-factor analysis of variance, correlation analysis, and principal component analysis were done by using SPSS statistical analysis software

Table 1. Main effect on two-way ANOVA of each property value for boiled and seasoned *daikon*

	Main effect	
	Sample size	Mouthful amount
Breaking load	***	***
Breaking strain	***	***
Breaking energy	***	***
Average masseter muscle activity value	**	n.s.
Average chewing force	**	n.s.
Average duration of one chewing movement	n.s.	n.s.
Average duration of one biting movement	n.s.	n.s.
Chewing duration	n.s.	***
Total number of chewing strokes	**	***
Ease of chewing	**	***
Softness	n.s.	n.s.
Shape-keeping ability	***	n.s.
Overall ease of eating	***	**

*$0.01 \leqq p < 0.05$, **$0.001 \leqq p < 0.01$, ***$p < 0.001$, n.s. not significant.

(11.0J for Windows; SPSS Japan).

RESULTS

Table 1 shows the results of the two-factor analysis of variance, which tested for the difference of the main effect, for all the properties.

Breaking properties of the seasoned *daikon*

The breaking properties are shown in Fig. 1. The breaking load significantly decreased with decreasing sample size, the breaking load of "one eighth" being smaller than that of a cube of 1 cm^3, "half" and "quarter." "Minced" had an even smaller value than "one eighth." The breaking load significantly increased with increasing mouthful amount, although "minced" had a markedly small value irrespective of the mouthful amount.

The breaking strain varied significantly with sample size, "minced" in particular having a much smaller value than the other sizes. The breaking strain significantly increased with increasing mouthful amount. In particular, the breaking strain increased markedly as the mouthful amount increased from one to three in a cube of 1 cm^3, "quarter," and "one eighth," while the breaking strain of the "half" increased gradually as the mouthful amount increased from one to six.

The breaking energy also varied significantly among the sizes, tending to decrease with decreasing

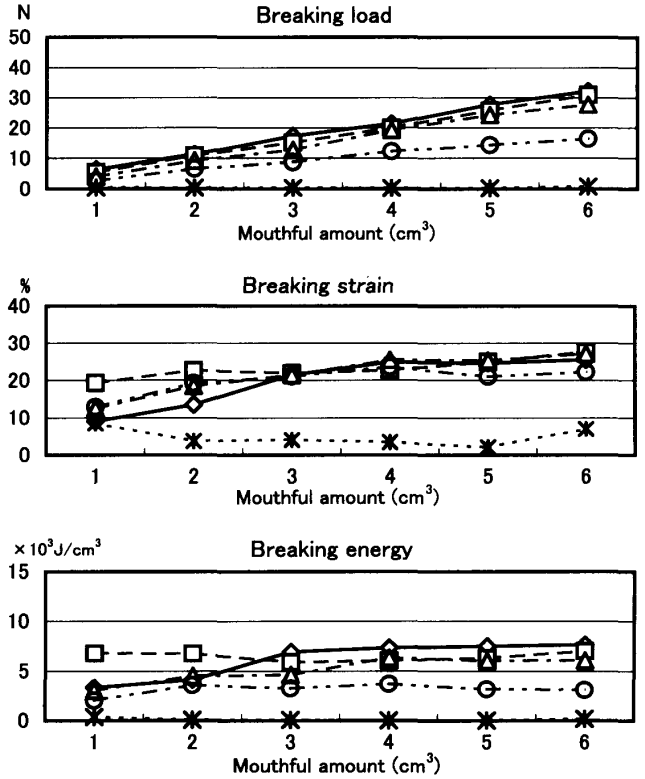

Fig. 1. Results of breaking examination of boiled and seasoned *daikon*

——◇—— a cube of 1 cm^3, — — □ — — half, —-△-— quarter, —--○--— one eighth, ···· * ···· minced.

sample size. The breaking energy was particularly low for "minced." The breaking energy varied significantly with mouthful amount as well. The breaking energy tended to increase with increasing mouthful amount in a cube of 1 cm^3, "quarter," and "one eighth" in the range from one to three mouthful amount.

Masticatory electromyographic properties of seasoned *daikon*

The masticatory electromyographic properties are shown in Fig. 2. The profiles of the average masseter muscle activity and average chewing force were similar to each other. Only the sample size created a significant difference, with "quarter" and "minced" having smaller values than the other three sizes.

The average duration of one chewing movement and of one biting movement were not significantly different for sample size and mouthful amount. The chewing duration significantly increased with increasing mouthful amount, and the total number of chewing strokes significantly increased with decreasing sample size and increasing mouthful amount.

Sensory evaluation of seasoned *daikon*

The sensory properties are shown in Fig. 3. Ease of chewing was significantly different according to sample size and mouthful amount. "Quarter" was evaluated as the easiest to chew, while "one-eighth" and "minced" were evaluated as difficult to chew. In the mouthful amount range of 1–4 cubes, with the exception of minced," ease of chewing increased with increasing mouthful amount. However, a mouthful amount equivalent to 5–6 cubes was no easier to chew than a mouthful amount equivalent to 4 cubes. The ease of chewing for a mouthful amount equivalent to 3 and 4 cubes depended mainly on sample size, unlike other mouthful amounts.

The sample size and mouthful amount had no significant effect on softness, while the shape-keeping ability was significantly different among the sample sizes, irrespective of the mouthful amount. The shape-keeping ability was greatest for a cube of 1 cm^3, this being followed in order by "quarter," "half," "one-eighth," and "minced."

The overall ease of eating was significantly different according to sample size and mouthful, the results being similar to those for ease of chewing.

Correlation among the properties of seasoned *daikon*

The correlation coefficients for the breaking properties, masticatory electromyographic properties and sensory properties are shown in Table 2.

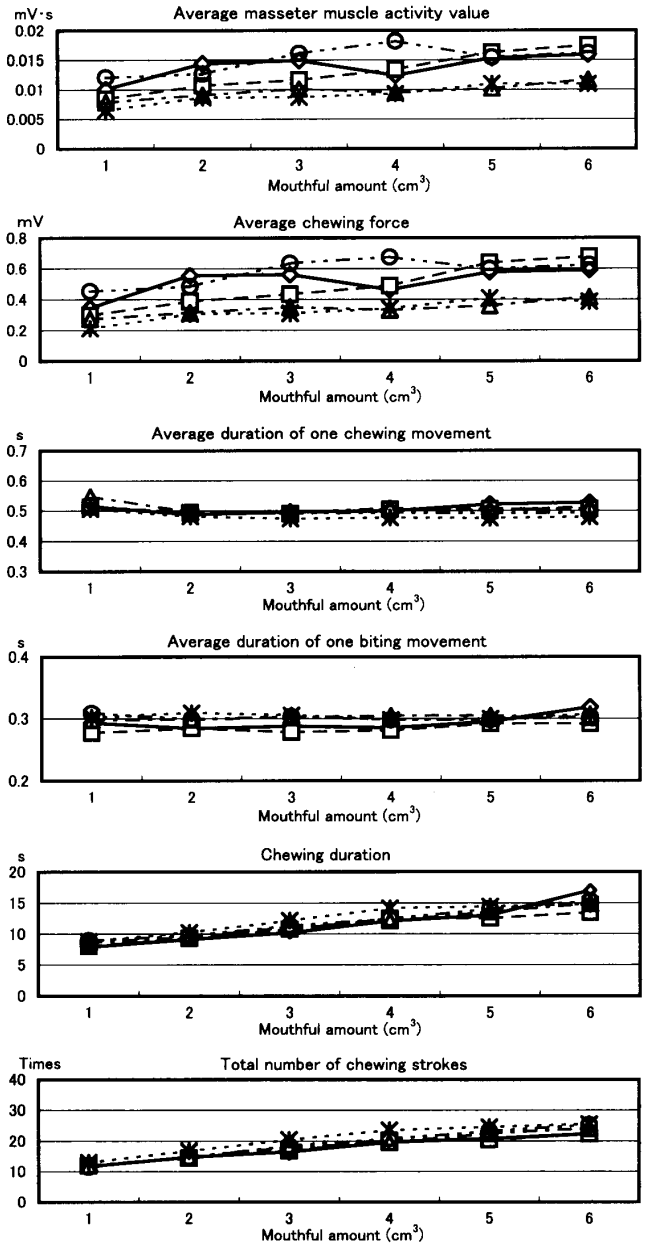

Fig. 2. Results of electromyographic measurement of boiled and seasoned *daikon*

——◇—— a cube of 1 cm^3, — — □ — — half, —-△-— quarter, —--○--— one eighth, ···· ＊ ···· minced.

The three breaking properties showed high positive correlation among each other. Among the masticatory electromyographic properties, markedly high correlation was seen between the average value for masseter muscle activity and average chewing force, and between the total number of chewing strokes and the chewing duration. The former two properties had a positive correlation with the latter two properties. The chewing duration had a positive correlation with the average duration of one biting

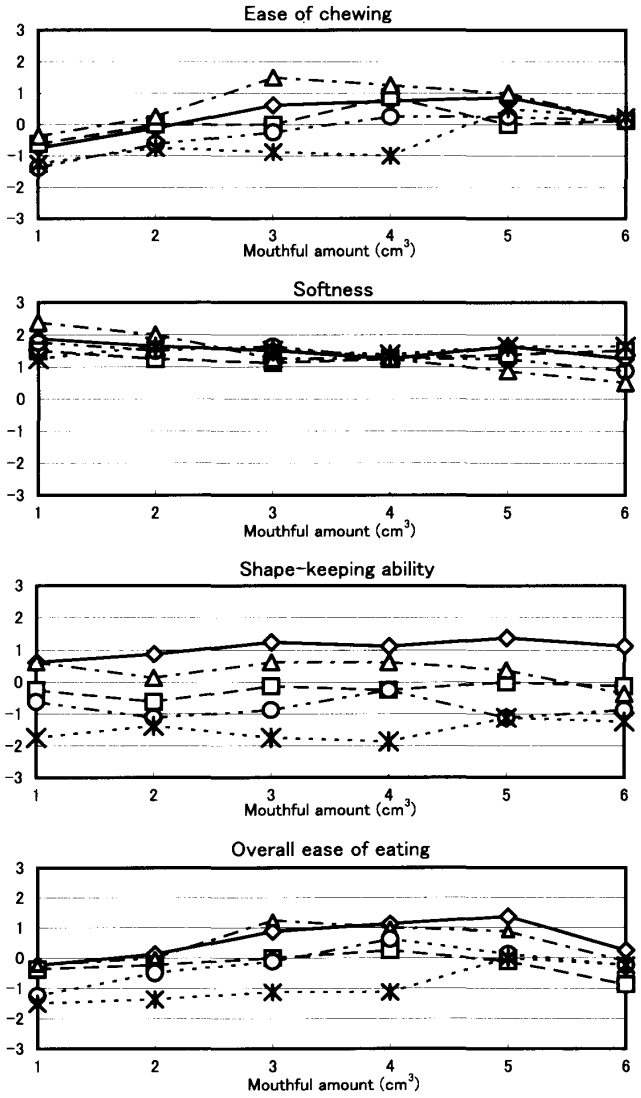

Fig. 3. Results of sensory evaluation of boiled and seasoned *daikon*

——◇—— a cube of 1 cm³, – – □ – – half, —·△·— quarter, —··○··— one eighth, ····＊···· minced.

movement, while the average duration of one chewing movement had no correlation with any of the other masticatory electromyographic properties.

Between the masticatory electromyographic properties and breaking properties, the value for the average masseter muscle activity, average chewing force, and average duration of one chewing movement each had a positive correlation with the three breaking properties. The total number of chewing strokes and the chewing duration both had a positive correlation with the breaking load.

Among the sensory properties, the ease of chewing, shape-keeping ability, and ease of eating had positive correlations with each other. Softness, on the other hand, had no correlation with the other three properties. Between the sensory and other properties, the ease of chewing, shape-keeping ability, and ease of eating each had a positive correlation with the breaking properties, while the softness had a negative correlation with the breaking properties. The shape-keeping ability only had a positive correlation with the average duration of one chewing movement. The chewing duration and total number of chewing strokes were negatively correlated with softness and positively correlated with ease of chewing.

Categorization of the seasoned *daikon* samples by a principal component analysis

A principal component analysis was carried out by using all the breaking properties, masticatory electromyographic properties, and sensory properties. Table 3 shows the factor loadings, and Fig. 4 plots the principal component scores on a two-dimensional graph, using the first and second principal components.

The first, second, third, and fourth principal components were extracted. The accumulated proportion was 63% for the first and second principal components combined, and 83% for the first, second, third, and fourth principal components combined.

On the plotted graph of the principal component scores, the first principal component was distributed in the negative direction as the size decreased, although "half" and "quarter" were almost the same in the graph. As the mouthful amount increased, the first and second principal components were distributed in the positive direction.

DISCUSSION

Effect of sample size on the properties of seasoned *daikon*

In order to compare the results from masticatory electromyographic measurement and the sensory evaluation, the load required to break the same amount was used (*i.e.*, equivalent to a mouthful amount of 1–6 cubes). The breaking load increased with increasing mouthful amount. When calculated as the breaking stress, a cube of 1 cm³ required 6.4×10^4 N/m², two cubes of 1 cm³ required 5.5×10^4 N/m², and 3–6 cubes required less than 5×10^4 N/m². The Ministry of Health, Labour and Welfare has indicated "less than 5×10^4 N/m²" as the standard for foods for senior citizens.[20] Although our measurement methods are different from those used in the standard, our samples are thought to have represented a hardness which can be consumed by peo-

Table 2. Correlation matrix of property values for boiled and seasoned *daikon*

	1	2	3	4	5	6	7	8	9	10	11	12
1 Breaking load												
2 Breaking strain	0.87***											
3 Breaking energy	0.84***	0.89***										
4 Average masseter muscle activity value	0.60***	0.56**	0.40*									
5 Average chewing force	0.57**	0.54**	0.38*	0.99***								
6 Average duration of one chewing movement	0.41*	0.41*	0.50**	0.02	0.00							
7 Average duration of one biting movement	−0.10	−0.24	−0.43*	−0.07	−0.08	0.00						
8 Chewing duration	0.48**	0.22	0.05	0.44*	0.43*	−0.18	0.41*					
9 Total number of chewing strokes	0.38*	0.15	−0.03	0.41*	0.40*	−0.36	0.31	0.96***				
10 Ease of chewing	0.59**	0.58**	0.55**	0.29	0.25	0.02	−0.11	0.40	0.45*			
11 Softness	−0.48**	−0.47**	−0.29	−0.22	−0.20	0.20	−0.01	−0.53**	−0.53**	−0.31		
12 Shape-keeping ability	0.62***	0.57**	0.76***	0.27	0.24	0.57**	−0.24	−0.08	−0.17	0.57**	0.09	
13 Overall ease of eating	0.56**	0.60***	0.63***	0.33	0.29	0.18	−0.19	0.22	0.23	0.89***	−0.20	0.76***

*$0.01 \leqq p < 0.05$, **$0.001 \leqq p < 0.01$, ***$p < 0.001$.

Table 3. Principal component, eigenvalue and proportion calculated from a principal component analysis of boiled and seasoned *daikon*

	Factor 1	Factor 2	Factor 3	Factor 4
Breaking load	**0.91**	0.14	−0.01	0.12
Breaking strain	**0.90**	−0.24	−0.15	−0.05
Breaking energy	**0.80**	−0.43	−0.10	−0.08
Shape-keeping ability	**0.78**	−0.43	0.27	0.22
Overall ease of eating	**0.78**	−0.03	0.47	−0.13
Ease of chewing	**0.71**	0.18	0.53	−0.22
Total number of chewing strokes	0.25	**0.90**	0.15	−0.06
Chewing duration	0.10	**0.73**	0.19	0.37
Softness	−0.35	**−0.51**	−0.08	0.39
Average masseter muscle activity value	0.68	0.37	**−0.57**	0.12
Average chewing force	0.65	0.37	**−0.60**	0.11
Average duration of one chewing movement	0.34	−0.51	0.10	**0.64**
Average duration of one biting movement	−0.28	0.49	0.25	**0.61**
Eigenvalue	5.3	2.9	1.4	1.3
% of total variance explained	40.6	22.1	11.0	9.6
Accumulated % of total variance explained	40.6	62.7	73.7	83.3

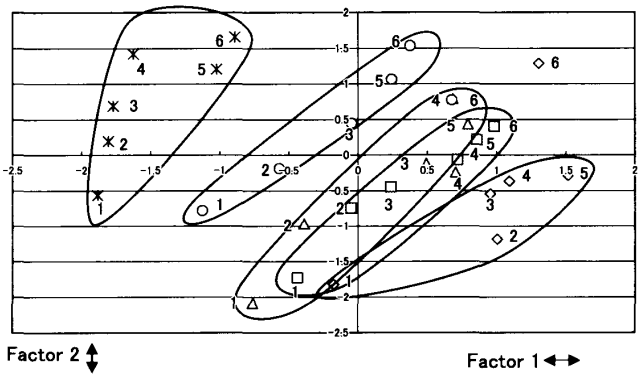

Fig. 4. Plot of principal component scores for each sample

◇ a cube of 1 cm^3, □ half, △ quarter, ○ one eighth, * minced. Numbers in figure show the mouthful amount of food (cm^3).

ple with difficulty in chewing and swallowing.

The breaking properties were similar for cube sizes of 1 cm^3, half, and quarter, while a cube of one eighth showed about half the breaking load and breaking energy of a cube of 1 cm^3. The one eighth cube size is thought to have needed a smaller breaking load because it had already been cut into pieces, so that little load was required to separate the pieces. On the other hand, the minced sample failed to show a distinct breaking point, this being different from the other sample sizes. In the range of small breaking strain, however, the minced sample seemed to show a distinct breaking point. The resulting breaking load was much smaller than with the other sample sizes and had no relationship with the mouthful amount.

The measured values for breaking stress and hardness in texture are generally considered to be related to the sensory hardness (or softness).[21)-23)] In this present study, the breaking stress (calculated from the breaking load) depended significantly on the sample size, although no significant difference was apparent in the softness from the sensory evaluation. Our samples were prepared from the same material and cooked in the same way, and most of them had a small enough breaking stress to meet the standard for foods for senior citizens.[20)] This would have caused the panelists to consider every sample as soft in the sensory evaluation. In addition, seasoning would have influenced the tastiness evaluated by the panelists, and this point will be discussed later.

Features of each sample size can be summarized as follows:

A cube of 1 cm^3 was evaluated to be easiest to eat overall, because it was not divided into pieces in the mouth and was easy to chew when compared with the other sample sizes. Due to its larger undivided size, however, the need for using the masseter muscles resulted in greater average masseter muscle ac-

tivity and average chewing force.

"Half" was evaluated as less easy to eat overall than a cube of 1 cm^3, because it had more pieces than the undivided cube which made it easily broken into pieces and less easy to chew. However, its average masseter muscle activity and average chewing force were less than those for the cube of 1 cm^3.

"Quarter," like the cube of 1 cm^3, had the highest evaluation for overall ease of eating among all the sample sizes. It was rated as easiest to chew among all the sample sizes and recognized as second only to the cube of 1 cm^3 in its shape-keeping ability in the mouth. The average masseter muscle activity and average chewing force were similar to those of "minced" as the smallest values among all sample sizes. The size of the "quarter" sample was $0.5 \times 0.5 \times 1$ cm. Since the number of pieces was four times that in a cube of 1 cm^3, the shape-keeping ability of "quarter" was less than that of the 1 cm^3 cube. However, "quarter" was evaluated as the easiest to eat among all the sample sizes. This high evaluation may have partly been due to the small activity of the masseter muscles, although further investigation will be necessary in this respect.

"One eighth" required no less average masseter muscle activity or average chewing force than the values for the cube of 1 cm^3, while it showed less breaking load than of the 1 cm^3 cube, "half," and "quarter" samples. "One eighth" was evaluated as second worst only to "minced" in terms of its ease of chewing and shape-keeping ability, which may have resulted in the high activity of the masseter muscles.

"Minced" like "one eighth" had the least shape-keeping ability and was the least easy to chew among all the sample sizes. However, "minced" was different from "one eighth" in that it showed the smallest average masseter muscle activity and average chewing force, and the largest total number of chewing strokes. The minced sample was already broken into pieces in the mouth and was not easy to chew, resulting in the largest total number of chewing strokes. Nevertheless, one chew did not need strong masseter musle activity which can be estimated from the extremely small breaking load.

Few studies have compared samples of different sizes in the same mouthful amounts. Yoshino and Kuwahara[8] have examined the ease of chewing for five kinds of food cut into three shapes, *i.e.*, chunks, strips, and slices. They concluded that chunks were the easiest to chew for all the foods except carrot which was easiest to chew as strips. Shiino[24] has pointed out that foods cut into shapes with a certain thickness such as a half-moon or rectangular prism were sometimes easier to chew than minced foods. This finding agrees with ours that large samples such as of the 1 cm^3 cube, "half" and "quarter" were easier to chew than "minced" and "one eighth."

Nakayama and Kohyama[17] cut the same weight of foods into different shapes and used them for masticatory electromyographic measurement of the masseter muscles. The results show that thin samples of carrot and cucumber (slices or strips) required a significantly larger total number of chewing strokes and chewing duration than thick samples. Thin samples of roasted pork and steamed fish paste, on the other hand, tended to require a smaller total number of chewing strokes and chewing duration than thick samples, although no significant difference was recognized. Kohyama *et al.*[16] compared samples of 10-mm-thick slices of cucumber with a pile of thin slices (*ca.* 1 mm) and reported that the thinly sliced sample required a larger chewing duration, total number of chewing strokes, and average masseter muscle activity. The same tendency was apparent in our study when the one eighth sample was compared with a cube of 1 cm^3.

The results of these studies suggest that the effect of the sample size of food on the masseter muscle activity could be entirely different from food to food. It will be worth examining in the future the effect of different physical properties of foods on the ease of eating and masseter muscle activity. Such an examination can be developed from the results of this study which has investigated the effect of the sample size and mouthful amount on the ease of eating and masseter muscle activity.

Effect of mouthful amount on the properties of seasoned *daikon*

The breaking load increased significantly with increasing mouthful amount, but no significant difference was recognized when calculated as the breaking stress.

Although the masseter muscle activity showed no significant difference in electromyographic parameters for each chew, the chewing duration and total number of chewing strokes increased with increasing mouthful amount. This result is in accordance with the study on rice porridge by Nakayama and Kohyama[25] and the study on retort-pouched rice by Shiozawa *et al.*[26] In a study comparing the same food shaped into cubes of different sizes,[15] the larger samples needed a significantly longer chewing duration

and greater total number of chewing strokes than the small samples, although the measurement conditions were different from those in our study. Shiga *et al.*[18] conducted masticatory electromyographic measurement using 1–4 pieces of chewing gum whose size and physical properties did not change during chewing. The results show that the average masseter muscle activity increased with increasing number of pieces of chewing gum. In our study, the average masseter muscle activity increased slightly with increasing mouthful amount, although no significant difference was recognized. This may be attributable to the difference in physical properties of the samples themselves.

The sensory evaluation of the shape-keeping ability and softness showed no significant difference among samples. Ease of chewing and ease of eating did have significant difference and were highly related with each other. Therefore, ease of chewing proved to have strong influence on the overall ease of eating for the samples used in our study. Ease of chewing and ease of eating were positively evaluated for 2–6 mouthful amounts of all samples except for "minced," the highest evaluation being given for the 4–5 mouthful amounts. Of our samples, 4–5 cm^2 proved to be the easiest to eat, with too little or too much food in the mouth not being easy to eat.

"Minced" was different from the other sample sizes in that a 1–4 mouthful amount of the minced sample had a low evaluation, while a 5 or 6 mouthful amount of the minced sample proved to be as easy to eat as the other sized samples. It is suggested that minced food is broken into pieces in the mouth when the amount is small, but that it becomes easy to eat when the amount is large enough to keep the pieces together in the mouth.

Effect of size and mouthful amount on the properties of seasoned *daikon*

Based on the variability of each principal component, it is considered that the first principal component was ease of eating, the second principal component was the time kept in the mouth, the third principal component was the masseter muscle activity, and the fourth principal component was the chewing cycle.

A graph plotted with the principal component scores shows that ease of eating decreased with decreasing sample size, although "half" and "quarter" were almost the same on the graph. As the mouthful amount increased, the time kept in the mouth increased and the *daikon* became easier to eat.

In respect of the seasoned *daikon* with a hardness that enables it to be used as food for senior citizens, ease of eating decreased as the cube of 1 cm^3 was cut into smaller pieces. As the mouthful amount of the sample increased, the chewing duration and total number of chewing strokes also increased, while the ease of eating improved.

CONCLUSION

Boiled and seasoned *daikon* was used as a material in order to examine the effect of sample size and mouthful amount of food on its properties. Five sample sizes and six mouthful amounts were chosen: the sizes were a cube of 1 cm^3, half of the cube ("half"), quarter of the cube ("quarter"), one eighth of the cube ("one eighth"), and the cube minced ("minced"). The mouthful amounts were equivalent to 1–6 cubes of 1 cm^3. The properties were determined by a breaking examination, masticatory electromyographic measurement, and sensory evaluation.

The samples had a hardness effectively meeting the standard for foods for senior citizens presented by the Ministry of Health, Labour and Welfare.

As the sample size decreased, the breaking properties decreased, the average masseter muscle activity and average chewing force decreased, the total number of chewing strokes increased, and the evaluated ease of chewing, shape-keeping ability and ease of eating tended to decrease. "Quarter," however, had the highest evaluation for ease of chewing and ease of eating, being comparable to a cube of 1 cm^3. "Quarter" also had the smallest average masseter muscle activity and average chewing force, being comparable to "minced."

As the mouthful amount increased, the breaking properties increased, the chewing duration and total number of chewing strokes increased, and the ease of chewing and ease of eating significantly increased. However, 5 and 6 mouthful amounts had a low evaluation for certain samples sizes in the ease of chewing and ease of eating, while only "minced" had a low evaluation for 1–4 mouthful amounts and a high evaluation for 5 and 6 mouthful amounts. The softness and shape-keeping ability did not depend on the mouthful amount.

A principal component analysis was conducted to examine the effect of sample size and mouthful amount on the properties of the samples, the results being plotted on a two-dimensional graph. As the size decreased, the ease of eating also decreased, and as the mouthful amount increased, the chewing duration

and total number of chewing strokes increased, although the ease of eating tended to improve.

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咀嚼特性とテクスチャーに及ぼす食物の大きさと一口量の影響

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食べ物の大きさと一口量の影響を知るために，味付け大根を試料として検討を行った．大きさは1 cm角を基本に，それを切断した5種類，一口量は，1 cm角1個～6個分までの6種類とした．測定は，破断試験，咀嚼筋筋電位測定および官能評価を行った．その結果，大きさの影響は，小さくなるほど破断特性値は低下し，筋活動量平均および咬合力平均も低下して，咀嚼回数は増加したが，官能的軟らかさには有意差がなかった．また，噛みやすさ，まとまりやすさ，食べやすさの評価は小さいほうが低くなった．ただし，大きさの影響は，一概に大きさの順でないかもしれないことも示唆された．一口量の影響は，増加するほど破断特性値は増加し，咀嚼時間および咀嚼回数が増加した．軟らかさおよびまとまりやすさは一口量の影響がなかった．噛みやすさおよび食べやすさは有意差があり，多いほうが評価が高い傾向があったが，5または6個分で評価が下がった．なお刻みだけは，5および6個分の評価がもっとも高かった．主成分分析により大きさおよび一口量の影響を2次元に表したところ，1 cm角から小さく切るほど食べ難くなり，一口量が多くなるほど咀嚼時間・回数が増加するが，食べやすさは向上する傾向があることが示唆された．

キーワード：食物の大きさ，一口量，官能評価，筋電位測定，破断試験．