Relationship between Oral Condition and Preference for Cooked Rice in Elderly and Young People

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To determine preferred texture of cooked rice, sensory analysis and measurements were conducted using 116 elderly and 81 young individuals. Six types of cooked rice with a significant difference in texture were prepared by cooking rice with a weight of water 1.1 - 2.6 times the weight of rice. Seven factors of oral condition, including the number of remaining teeth, occlusal supporting area and occlusal force in dental prescale, were examined. Significant differences in oral condition were observed between the elderly and young individuals. Furthermore, the elderly individuals preferred the texture of rice cooked with 1.9 times the weight of water, while the young preferred the texture of rice cooked with 1.5 times the weight of water. Using these data, the panelists were divided into five groups using a neural network method. The measurements within these stratified groups revealed that oral condition was not necessarily correlated with the preference for cooked rice, which is likely the result of the particular preference among Japanese people for the texture of flavorful cooked rice.

Keywords: elderly, cooked rice, oral condition, neural network

Introduction

According to the Bureau of Statistics in the Japanese Prime Minister’s Office, the proportion of the elderly to the total population in Japan was 20.8% in 2006. Improving the quality of life of the elderly is currently a major concern.

The physical changes due to aging are experienced to a different extent for each individual. Even those who do not require nursing care can experience some changes in the oral cavity. These include decreased saliva secretion (Sreebny and Schwartz, 1986; Shigetomi et al., 1995), swallowing dysfunction (Furukawa, 1984), jaw joint disorders and difficulty with movement of lower jaw (Nishi, 1999), or loss of teeth.

These malfunctions, as well as other diseases, lead to difficulty with food mastication and ingestion. Several reports have shown that the number of remaining teeth is related to the efficiency of mastication (Mumma and Quinton, 1970; Chen and Lowenstein, 1984; Ando et al., 2000; Suzuki et al., 1993; Maeda et al., 1996). The loss of teeth leads to decreased food intake, particularly the intake of dietary fiber and vitamin C (Sheiham and Steel, 2001), due to difficulty with mastication and swallowing.

Roininen et al. (2004) classified the fruits and vegetables into “easy” to eat or “hard” to eat categories according to the ease with which the elderly can eat them. Especially for the elderly, the adequate food intake is thus important not only for the enjoyment in life but also for supplying nutrients to keep good health.

It is not desirable for the elderly who have problematic oral conditions to consume predominantly soft foods. Such individuals need to improve mastication, which increases blood flow and activates the brain (Ishiyama, 2001; Nagata et al., 2001; Shiga et al., 2004; Shiga et al., 2005).

Our research group has reported that sensitivity to the graininess of small particles and the number of cycles and

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the duration of mastication differed between elderly and young individuals (Hatae et al., 2001). The most frequently consumed food in Japan is rice, a staple of the Japanese diet. Serving cooked rice at the preferred texture would satisfy the elderly and improve their quality of life.

We previously reported that elderly individuals preferred the texture of rice cooked with a weight of water 1.8 times the weight of rice, while young individuals preferred rice cooked with a weight of water 1.5 times the weight of rice (Onitsuka et al., 2003). However, this previous study employed only 10 elderly and 10 young panelists. In general, it is known that the elderly like softer foods than young people, and the findings of our previous report supported this knowledge. However, for Japanese people, as rice is consumed daily, they pay particular attention to the texture of cooked rice. Therefore, we aimed to elucidate the relationship between preference for cooked rice and oral condition among the elderly. Using a large number of panelists, we also attempted to group individuals using a neural network combining oral condition, preference for cooked rice texture, duration of mastication time and number of chews.

A statistical method for categorizing a large volume of data is Principal Component Analysis (PCA), which calculates similarity based on each data point. This method selects the factor vector that maximizes the variation from the data, then decreases the dimension by minimizing the margin of error. There is no guarantee that the result is the best factor; however, as the PCA method is easy to conduct using computer software, it is often used for categorizing data.

For a large volume of data, to the process of gathering data in the order of their similarity and establishing the best category, is easier to conduct due to the improved performance of modern computers. A neural network is a method in which the cognitive processes of the human brain are modeled. In this paper, we used a neural networking technique called self-organizing maps (SOM). This method was proposed by Kohonen (1995) in the 1980s and has been widely used in recent research. This method classifies instances in the data on the basis of the similarity of their repeated pattern vectors, and leads to better categories. Since it is possible to obtain better categorizing than PCA, this network is effective for practical use.

Materials and Methods

**Cooked rice samples** Wash-free Koshihikari rice samples harvested in Tochigi in 2001, 2003 and 2006 were used. Samples were stored at 4°C until used for the measurement of physical properties and sensory analysis. Six types of cooked rice with different textures were prepared using different weights of water, 1.1, 1.4, 1.7, 2.0, 2.3 and 2.6 times (w/w) the raw rice, as in the previous study (Onitsuka et al., 2003). Five types of rice cooked with weights of water 1.4 ~ 2.6 times the weight of rice were served to elderly individuals while those cooked with weights of water 1.1 ~ 2.3 times the weight of rice were served to the young individuals.

**Physical properties of cooked rice samples** The hardness, cohesiveness and stickiness of a single grain of rice were measured using a texture analyzer (TA.XT.plus, Eiko Seiki Co., Ltd., Tokyo, Japan). The testing conditions were as follows: test speed, 1.0 mm/s; plunger, 12 mm φ; test mode and compression of 80% deformation. From the curve observed, the following data were obtained: height of the first peak as hardness, ratio of the second peak area to the first peak area as cohesiveness, and peak area under the base line after the first peak as stickiness.

**Sensory panel** Participants were 116 elderly panelists (21 males, 95 females; age range, 66 to 91 years) from Uonuma-shi in Niigata, Bunkyo-ku in Tokyo, and Ichikawa-shi in Chiba. The age distribution of the participants was as follows: 65~69 for 30, 70~74 for 32, 75~79 for 30, 80~84 for 15, and over 85 for 9 panelists. All the elderly came to a local community hall by themselves, and had no difficulty with food mastication or swallowing. For young panelists, 40 male (mean age, 25.4 ± 2.2 SD) and 41 female (mean age, 21.8 ± 1.3) university students were recruited.

The samples used were in the form of a typical daily meal. Before the sensory analysis, panelists were oriented regarding the objective of the study, that their statistically analyzed data would be published without publishing any details of their personal data. Only panelists who provided consent participated in the sensory analysis.

**Oral conditions of the panel** The panelists were asked to confirm their names and ages. A dentist examined their oral cavity and dental condition. Normally, food is masticated primarily using the four sets of molar teeth; therefore, the absence of paired molar teeth could disturb full mastication. We thus consider the occlusal-supporting area from the remaining teeth. The molar teeth consist of two premolar and two true molar teeth. Two premolar teeth construct an upper-lower pair on the right and left sides of the mouth. Two true molar teeth also construct the two sets. Panelists who had 4 sets were assigned to level 4, and those with none were assigned to level 0. According to the Eichner classification, the dental condition was classified into 10 categories from 1, in which no teeth defects were detected, to 10, in which no teeth remained (Kober, 1982).

Occlusal area (mm²) and maximum occlusal force (N) were measured using the Dental Prescale (Fuji Film Co. Ltd., Tokyo, Japan) (Yamaguchi et al., 1995).

**Sensory analysis** Before the test, the samples were...
kept in a rice cooker at about 70°C in the rice cooker. Each panelist was given a spoonful (6 g) of cooked rice. The panelists ate the rice and then evaluated the rice as follows: a, too hard (not preferable); b, preferable; and c, too soft (not preferable). If a panelist indicated that the rice cooked with a weight of water 1.7 times the weight of rice was “too hard” and the rice cooked with a weight of water 2.0 times the weight of rice was “too soft”, then the preferable weight of water for rice for the panelist must fall between 1.7 times and 2.0 times. A linear correlation was observed between the weight of water and the hardness of the cooked rice for samples cooked with a weight of water 1.1 times to 2.3 times the weight of rice. Thus, we calculated that the panelist’s preferable cooked rice would be prepared using weight of water that is the arithmetic mean of 1.7 and 2.0, which is 1.85 times the weight of rice.

One of the three testers handed the rice and recorded the answer, and the other two, without notifying the panelists, recorded the duration of mastication and the number of chews until each panelist had swallowed the rice.

The order of presentation was done according to the amount of water used for cooking. The hardness of cooked rice samples were as follows: 4.12 N (2.6 times water addition), 5.10 N (2.3 times water addition), 6.37 N (2.0 times water addition), 7.75 N (1.7 times water addition), and 8.63 N (1.4 times water addition).

The duration of the test for each panelist was 20 to 30 min for the 5 samples. The sensory test was carried out in independent small rooms at a small local community hall from 10:00 to 11:00 and from 14:30 to 15:30 between 2002 and 2007.

The young panelists were first given 6 g of rice samples cooked with a weight of water 2.3 times, 2.0 times, 1.7 times, 1.4 times, and 1.1 times the weight of rice. The panelists evaluated the rice as (1) too hard, (2) preferable, or (3) too soft using a written form. The tester measured the duration of mastication and the number of chews. The sensory test was conducted in a quiet cooking practice room at the university. The room was equipped a window in the northern wall and contained one table for each panelist. The test was conducted from 2002 to 2006.

**Statistical analysis** Analyses of variance, Tukey’s multiple comparison, and t-test were conducted using SPSS ver.10 software. Neural networking using Self-Organizing Maps (SOM) was also performed. SOM is a neural network algorithm that does not require a teacher. It allows researchers to obtain a quasi-best categorization of data once the similarity between data points is defined. It gradually converges to the best solution by repetition of the training process as long as local minima points are carefully avoided. For the actual execution, we used pdp++Rel.3.0 developed by O’Reilly and Munakata (2000).

### Results and Discussion

**Physical properties of the cooked rice** Hardness, cohesiveness and stickiness as determined by a texture analyzer are shown in Table 1. The rice samples used were obtained in 2001, 2003 and 2006, and their physical properties were measured each time to confirm that the textures of the cooked rice were within a small range of variation.

The results showed the same tendency as in a previous report (Onitsuka et al., 2003). When more water was added to the rice, a lower hardness, smaller cohesiveness and larger stickiness of cooked rice was observed. The analysis of variance and the Tukey multiple comparison revealed that there were significant differences among six types of cooked rice in terms of hardness. With respect to cohesiveness and stickiness, the cooked rice samples were classified into three groups.

**Oral condition of the panelists** The mean and standard deviation of the panelists’ oral condition, the number of remaining teeth, occlusal-supporting area, Eichner classifica-

| Table 1. Physical properties of the cooked rice samples (Mean ± S.D.) |
|--------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                          | 1.1             | 1.4             | 1.7             | 2.0             | 2.3             | 2.6             |
| Hardness(N)              | 11.77±2.07a     | 8.63±1.67b      | 7.75±1.86c      | 6.37±1.47d      | 5.10±0.78e      | 4.12±0.69f      |
| Cohesiveness             | 0.46±0.03a      | 0.47±0.04a      | 0.46±0.04a      | 0.42±0.04b      | 0.38±0.04c      | 0.38±0.04f      |
| Stickiness(10^3 Nm)      | 0.37±0.09a      | 0.45±0.09a      | 0.62±0.20b      | 0.70±0.23b      | 0.91±0.21c      | 0.95±0.25f      |

a,b,c,d,e,f: Values with different letter(s) in the same row are significantly different (p < 0.05). (n = 8)
Table 2. Oral condition of the panelists.

<table>
<thead>
<tr>
<th></th>
<th>Elderly</th>
<th></th>
<th></th>
<th>Young</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
<td>Mean±S.D.</td>
<td>Maximum</td>
<td>Minimum</td>
<td>Mean±S.D.</td>
</tr>
<tr>
<td>Upper remaining teeth</td>
<td>14</td>
<td>0</td>
<td>6.7±5.9</td>
<td>14</td>
<td>12</td>
<td>13.8±2.1</td>
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<tr>
<td>Lower remaining teeth</td>
<td>14</td>
<td>0</td>
<td>7.9±5.6</td>
<td>14</td>
<td>12</td>
<td>13.8±2.1</td>
</tr>
<tr>
<td>Occlusal supporting area</td>
<td>4</td>
<td>0</td>
<td>1.6±1.8</td>
<td>4</td>
<td>4</td>
<td>4.0±0.0</td>
</tr>
<tr>
<td>Occlusal supporting area</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>including artificial teeth</td>
<td>4</td>
<td>0</td>
<td>3.6±1.1</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Eichner classification</td>
<td>10</td>
<td>1</td>
<td>5.9±3.3</td>
<td>2</td>
<td>1</td>
<td>1.0±0.2</td>
</tr>
<tr>
<td>Occlusal area (mm²)</td>
<td>89.9</td>
<td>1.9</td>
<td>18.5±15.0</td>
<td>108</td>
<td>8.8</td>
<td>37.6±2.0</td>
</tr>
<tr>
<td>Maximum occlusal force (N)</td>
<td>1614.3</td>
<td>11.3</td>
<td>402.9±330.4</td>
<td>1996.5</td>
<td>120.0</td>
<td>713.5±434.4</td>
</tr>
</tbody>
</table>

Asterisks show significant difference between the elderly (n = 116) and the young (n = 81). ***: p < 0.001, **: p < 0.01.
Maximum value and Minimum value mean the value of the panel members tested.

Table 3. Number of chews, mastication times and mastication cycle for the cooked rice samples by the elderly and the young.

<table>
<thead>
<tr>
<th></th>
<th>Ratio of water</th>
<th>Elderly</th>
<th></th>
<th>Young</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Mean±S.D.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>46.4±19.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>48.3±26.6</td>
<td>36.8±16.4</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>42.1±22.9</td>
<td>31.0±11.5</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of chews</td>
<td>2.0</td>
<td>37.4±17.4</td>
<td>26.2±10.2</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>31.8±14.3</td>
<td>21.9±9.6</td>
<td>***</td>
<td></td>
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<tr>
<td></td>
<td>2.6</td>
<td>28.4±13.3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mastication time(s)</td>
<td>1.1</td>
<td>33.3±19.1</td>
<td>24.1±9.9</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>29.6±15.5</td>
<td>19.9±8.0</td>
<td>***</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>26.4±11.9</td>
<td>17.9±7.9</td>
<td>***</td>
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<tr>
<td></td>
<td>2.0</td>
<td>23.2±9.4</td>
<td>15.9±7.3</td>
<td>***</td>
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<tr>
<td></td>
<td>2.3</td>
<td>21.3±8.9</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mastication cycle(s)</td>
<td>1.1</td>
<td>0.73±0.25</td>
<td>0.67±0.14</td>
<td>n.s.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(time/number of chews)</td>
<td>1.4</td>
<td>0.73±0.22</td>
<td>0.66±0.13</td>
<td>**</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>1.7</td>
<td>0.74±0.21</td>
<td>0.70±0.15</td>
<td>**</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2.0</td>
<td>0.75±0.21</td>
<td>0.74±0.14</td>
<td>n.s.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>2.3</td>
<td>0.78±0.23</td>
<td></td>
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<tr>
<td></td>
<td>2.6</td>
<td></td>
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</tbody>
</table>

a,b,c,d: Values with different letter(s) within the column show significant difference (p<0.05). ***, **: Values in the same line show significant difference between the elderly (n=116) and the young (n=81). ***: p<0.001, **: p<0.01, n.s.: not significant.
tion and the values obtained from the dental prescale for the elderly and the young panelists are shown in Table 2. All the items for the elderly varied widely. Some had almost all of their teeth, while some had none, almost independent of their age. The correlation coefficient of age and the number of remaining teeth was 0.45, with Eichner at 0.31. Almost all the young panelists had all of their teeth except for three panelists. Maximum occlusal force was significantly ($p < 0.05$) different between male (824.5 ± 463.6 N) and female (597.6 ± 389.0 N). This tendency was in agreement with that reported by Uchida (1990) although Uchida’s report focused on 145 panelists who were mostly elderly and full denture wearers. For the elderly, only 21 males participated; therefore, no sex-dependent differences were obtained. All items were significantly different ($p < 0.001$) between the elderly and the young panelists. Even elderly panelists who had all of their teeth had lower occlusal force than the young panelists, indicating that occlusal force may be reduced due to age.

Preference for the texture of the cooked rice The rice cooked with a weight of water 1.9 ± 0.4 times the weight of rice was preferred by most of the elderly panelists. No significant differences were observed according to the age of the elderly panelists. The rice cooked with 1.5 ± 0.2 times water added was mostly preferred by the young. There was a significant difference ($p < 0.001$) between the elderly and the young. For young panelists, no significant sex-dependent difference was observed. The elderly preferred the rice samples with 7.06 N hardness, 0.44 cohesiveness and $0.66 \times 10^{-3}$ Nm stickiness, while the young preferred those with 8.14 N hardness, 0.46 cohesiveness and $0.54 \times 10^{-3}$ Nm stickiness. The results of the duration of mastication and number of chews for the six types of cooked rice are shown in Table 3. The duration of mastication and number of cycles and for different rice textures differed between the elderly and the young panelists.

The duration of mastication and the number of chews for each cooked rice sample significantly differed between the elderly and the young panelists. This tendency is similar to the findings of Mioche et al. (2004) who reported that the elderly increased the number of chews to compensate for the decreased activity of the muscles required for mastication. Kohyama et al. (2004) compared the chewing patterns for six types of food measured with jaw kinetics and electromyography (EMG) in 10 elderly and 10 young people, and found that the elderly showed smaller muscle activity and longer EMG duration. Kohyama et al. (2002) reported that there was no significant difference between the elderly and the young in terms of the number of chews when eating rice, although this finding does not agree with our results. The mastication cycle was almost constant in the elderly, while in the young, their mastication cycle was larger when harder rice samples were served.

Categorizing of panel members using SOM As input pattern-vector components, we chose the sex, age, and oral condition parameters of the panelists as well as their preferences for cooked rice. Feed forward 3-layer network consists of input, hidden, and output layers. The number of neuron nodes in the input layer was set at 17 according to the length of the input pattern vector, whereas the number of the other layers was fixed at 10. The weights were initialized to random numbers. The size of the input vector components was

![Fig. 1. Age distribution of the panelists in five groups. The error bars shown in the figures indicate the standard deviation by the square root of the number of panelists belonging to the group, namely the error associated with the average if Gaussian distribution is assumed.](image1)

![Fig. 2. Distribution of the occlusal area of the panelists in five groups. Error bars are the same as in Fig. 1.](image2)
normalized to \([0,1]\) in order to facilitate the monitoring of the convergence. First, we performed 1000 training sessions. Then, several sessions were conducted starting with different sets of random weights. Subsequently, the consistency was compared between the results. Finally, we combined the categories nearest to each other and made into 5 categories.

Among the five groups, Group 1 consisted of 37 young panelists, including 25 males, and 15 elderly panelists (aged 35 ± 19) (Fig. 1). They had all of their teeth, and had the largest occlusal area (Fig. 2) and strongest occlusal force (Fig. 3) among the five groups. They preferred rice cooked with a volume of water 1.5 ± 0.2 times the weight of rice (Fig. 4).

Group 2 consisted of 24 elderly and 15 young panelists (aged 54 ± 25), but their teeth defect was negligible (average 2). As their teeth were in comparably good condition, the occlusal supporting area was 3.5. However, the occlusal force was lower than in group 1. They preferred rice cooked with a weight of water 1.8 ± 0.4 times the weight of rice.

Group 3 comprised 12 elderly and 29 young panelists (aged 37 ± 23) including 25 females. This group was similar to group 1, but with slight teeth defect (average 2), and an occlusal supporting area of 3.8 (Fig. 5). The occlusal force was lower than in group 1. The number of chews for the rice cooked with a weight of water 1.7 times the weight of rice was higher than in group 1 (Fig. 6). Their preference for cooked rice was similar to that of group 2, preferring rice cooked with a weight of water 1.7 ± 0.3 times the weight of rice.

Group 4 comprised elderly panelists (aged 68 ± 11). They had a large number of defects and had only 12 teeth;
therefore, the occlusal supporting area was less than 1, and the occlusal force was low. They preferred rice cooked with a weight of water 1.8 ± 0.2 times the weight of rice, which is the same as group 2 although their oral condition was different.

Group 5 consisted of elderly panelists (aged 78 ± 6) with almost no remaining teeth, and an occlusal supporting area of almost zero. The occlusal force was as low as that observed in group 4. Many panelists had full dentures. The duration of mastication and the number of chews for all samples were the largest in this group. They preferred rice cooked with a weight of water 2.0 ± 0.4 times the weight of rice.

Using SOM for not only oral condition, but also preference and mastication data, we successfully categorized the panelists. Panelists who had a lower oral condition tended to prefer soft cooked rice, but even when the oral condition was not the same, their preference for the cooked rice samples was almost the same. For example, groups 4 and 2 had different oral conditions (lower in group 4 than group 2), but the preference for cooked rice was almost the same, with both groups indicating a preference for rice cooked with a weight of water 1.8 times the weight of rice. In the neural network categorization, we were able to confirm that oral condition is not necessarily correlated with the preference for cooked rice.

As Japanese people eat cooked rice every day as a staple food, they have a particular sensitivity to the texture of cooked rice. The elderly may still have a particular preference through their dietary habits, even though their oral condition has deteriorated. Cooked rice has a stickiness that allows the rice to be formed into a shape that is easy to eat. This fact has been observed by one of our authors during her work with elderly people with dysphagia.

Sato et al. (1988) and Imai (1998) classified several foods and made cooked rice that was classified as “easy to eat”. The present findings indicate that among the elderly, the preferred texture of cooked rice may not necessarily relate to oral condition. Information of the texture of cooked rice for the elderly should reflect their oral condition while considering their preferences.

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