Electromyographic Measurement of Eating Behaviors for Buckwheat Noodles

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The objective of this study was to analyze human eating behaviors in chewing and slurping buckwheat noodles. We used electromyography to measure the activity of the jaw-closing, jaw-opening, and lip-closing muscles while healthy adults ate one mouthful of buckwheat noodles. Slurping the noodles required a longer mastication period but smaller muscle activity per movement than chewing the same samples. Total muscle activity was greater in slurping. Slurping also showed a longer average cycle time but greater variances in the cycle time than rhythmical chewing. The mechanical properties of buckwheat noodles significantly differed between the noodle types (half-raw and dry), but the human mastication variables for the two types of noodles were not significantly changed within a subject. Both types of noodles kept for 10 min at 23°C after being cooked could be consumed with less mastication effort than those immediately served, and this observation corresponded to softening of the noodles during the standing time.

Key words: buckwheat noodles; texture; mastication; electromyography; dietary education

Modern Japanese don’t masticate food well and this can cause undesirable effects on health because many mastication effects promote health status. Enhancement of saliva secretion to protect gastroesophageal mucosa and to inhibit the activities of carcinogenic compounds in food, increases in the blood stream to activate a wider area of the brain, elevating arousal levels, preventing obesity and diabetes, normalization in posture by activation of mastication muscles, decreases in the antigenicity of food and prevention of allergens, and acceleration in bone metabolism to reduce osteoporosis risk are evidence-based findings.1) Considering these mastication effects, fast eating with incomplete chewing is not recommended in terms of health.

Cooked buckwheat noodles (soba or soba-kiri in the old days) have been popular food among ordinary Japanese people since the 17th century (the Edo Era), and are known as a Japanese-origin fast food.2) Food connoisseurs enjoy the soba texture in the throat.2) The texture is called nodogoshi, and appears to be felt more strongly when people swallow it without chewing at all. People may consume it very quickly when they slurp up noodles with a sauce called tsuyu, which is flavored with soy sauce (shoyu).2) Though the texture of the noodles is soft,3) slurping up the noodles is difficult without mixing with a thin-liquid sauce that can reduce the surface adhesiveness of the noodles. To slurp up noodles using chopsticks is unique to Japanese, Korean, and Chinese people. Besides noodles, the slurping habit is also found in eating mixtures of solid and liquid foods, for example, rice-based foods such as ochadsuke and topped rice with side dishes in a bowl (donburi-mono), and soup-type foods such as misoshiru. These are very common and important dishes in the Japanese dietary life, consumed almost every day.

This study aimed to determine objectively the effects of mastication using electromyography (EMG). As EMG of the masticatory muscles represents the eating behavior of a human subject, it does not give a direct measure of the physical properties of the food. However, some of EMG variables relate to food properties that modify human mastication, as reported below. The masseter muscles are the same as the temporal muscles, known as the jaw-closing muscles, and they work more when a hard food is chewed.4) The EMG amplitude from the masseter muscles therefore becomes greater and the sum of muscle activity until swallowing represents chewing effort.4–6) In contrast, the suprahyoid musculature, which includes the anterior belly of the digastric, mylohyoid, and geniohyoid muscles, is the jaw-opening muscles, and sometimes is called the submental muscles.4) Besides the functions to open the jaw and to reflect the tongue movement,4–6,8) the suprahyoid musculature also elevates the hyoid at the early stage of swallowing.9,10) The orbicularis oris muscles surround the mouth and act to close and move the lips,10–12) EMG activities from the orbicularis oris muscles have been recorded as humans drank liquid, and they became stronger in swallowing more viscous liquids or greater volumes of liquid.11) The upper and lower, left and right side orbicularis oris muscles acted in time with lip movement, and activity became greater when the subjects took liquid through a straw than using a spoon and a cup.11)

The functions of the orbicularis oris muscles while humans eat food have not yet been reported. We found no description of slurping of food in the literature. In this study, the EMG variables were taken from the masseter muscles that close the jaw, the submental muscles that open the jaw and reflect tongue movement, and the orbicularis oris muscles. As the lip movement in slurping

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somewhat resembles drinking through a straw, the EMG measurement of orbicularis oris muscles that may exhibit some slurping characteristics was investigated. We compared chewing and slurping one mouthful of buckwheat noodles to analyze different human behaviors. As samples, we tested two types of commercial buckwheat noodles, one of them a half-raw-type and the other a dry type. As cooked noodle texture greatly change with time, we compared two different periods after being cooked (immediately and 10 min). Short-cut noodles are recommended for elderly people. This can change mastication variables as measured by the EMG technique as reported for finely cut apples and other foodstuffs, thus we also tested short-cut noodles.

Materials and Methods

Samples. Buckwheat noodles (Honbu Shinshu Soba (dry type, sample K) and Shinshu Namusobu (half-raw type, sample N)) were purchased from Karakida Seifun (Nagano, Japan). Sauce for noodles (Mentsuyu, Yamaki, Ehime, Japan) was diluted with twice the volume of water according to the recipe on the label. Each one portion (14 g for sample K and 13 g for sample N) was kept for 10 min at room temperature (23 °C), it was covered with plastic film to prevent drying. Short-cut noodles were prepared by cutting them 3 cm in length with a knife. Just before chewing or slurping the sample. The subjects raised their right hand to inform the experimenter. They were instructed before each trial as to whether they would chew or slurp the sample. The subjects were not informed which sample they were given. They were passed a bowl containing a sample of noodles put in a stainless basket was cooked in boiling water (6 liters) for 5.0 min (sample K) or 3.5 min (sample N) according to standard cooking methods described by the manufacturer. The cooked samples were cooled with tap water and then subjected to a mechanical compression test or mastication measurement immediately or after 10 min. A mouthful of sample (15 g) was poured into a plastic bowl, and if it was kept for 10 min at room temperature (23 °C), it was covered with plastic film to prevent drying. Short-cut noodles were prepared by cutting them 3 cm in length with a knife. Just before chewing or slurping the sample. The moisture content of the cooked noodles was calculated as weight loss by heating a sample (3 g) in an aluminum cup at 135 °C for 2 h.

Instrumental measurement. A compression test of cooked noodles was performed using a food rheometer (RE-33005, Yamaden, Tokyo) equipped a load cell of 1.96 N. A wedge-shaped plunger (No. 49, Yamaden) that had a wedge angle of 30 °, a bottom width of 1 mm, and a length of 30 mm was attached. A piece of noodle (about 4 cm in length) was placed on the stage of the rheometer, and the height and width were measured for each sample. The plunger cut the sample in half crosswise at a constant speed of 0.5 mm/s, and final sample deformation was set at 98% of the original height. Twelve measurements were repeated for each sample. Stresses were calculated as load divided by the initial contact area of sample and plunger (i.e., sample width × plunger width), and compressive strain was defined as the ratio of the deformation to the initial height of sample in %. The breaking point was determined by the first reduction in load, and if appropriate, the local minimum point was set as the first increase in load after the breaking point in the load-time curve.

Subjects. Thirteen volunteers (8 females and 5 males, aged 24 to 43 years) who were free from buckwheat allergy and functional mastication problems, and required no dental treatments participated in the mastication measurements. All the subjects were right-handed. Nine of the subjects were measured for orbicularis oris muscle activity. They gave their informed consent prior to the experiment.

Masticatory EMG measurements. Ten samples of cooked buckwheat noodles were randomly served to the subjects after two trials (chewing and slurping) for practice. The subjects were not informed which sample they were given. They were passed a bowl containing a sample noodle with the sauce, and wooden chopsticks, and started to eat the noodles by themselves according to a cue given by an experimenter. They were instructed before each trial as to whether chew or slurp the sample. The subjects raised their right hand immediately when they had finished eating. They freely rinsed their mouths with water or drink water before or between the trials. The recording session lasted for about 30 min.

EMG activities were recorded from both the left and right masseter muscles (LM and RM, Ms), suprahyoid musculature (SH), and one side of the inferior orbicularis oris muscles (OOI) using bipolar surface electrodes (NE-155A, Nihon Kohden, Tokyo) and an MEG-6108 amplifier with four AB-610J units (Nihon Kohden). Figure 1 shows the positions of the electrodes placed on the left masseters, suprahyoid musculature, and left inferior orbicularis oris muscles. A ground electrode was placed on the left wrist.

Data analysis. The four EMG signals were stored in a Windows computer using an MP150 program (Biopac Systems, Goleta, CA), at 1,000 Hz for further analysis, using wave-analysis software (AcqKnowledge®, ver. 3.8.2, Biopac Systems®). Figure 2A shows an example of the EMG record. The signals from both masseter muscles appeared almost simultaneously as the subjects freely changed chewing sides during mastication; therefore, the EMG data from LM and RM were averaged. The EMG activities from the masseters and suprahyoid musculature appeared alternately. From the Ms EMGs, the number of chewing strokes, mastication time, and mean chewing cycle time were derived. Since OOI showed different numbers and timing from the above three muscles (Fig 2A), the number of bursts and the cycle time for OOI were also taken. For each burst of each muscle, the amplitude or maximum voltage, burst duration, and muscle activity estimated as the time-integral of the EMG voltages were read, as shown in Fig. 2B. The cycle time for OOI was also taken. The values of amplitude, duration, muscle activity, and cycle time for each muscle were averaged for all cycles. Masseter muscle activities were summed for total muscle activity, and we defined this value as mastication effort. The end of the mastication period was determined by the closest EMG activity to the hand sign from each subject.

Statistics. Statistical analyses were performed using an SPSS (ver. 14.0J for Windows®) package (SPSS, Chicago, IL) with statistical significance set at p < 0.05. A t-test was conducted on the mechanical parameters, and the Wilcoxon signed-ranks test was applied on human recording variables for each effect.

Results and Discussion

Mechanical properties of buckwheat noodles. Figure 3 depicts the compression curves of the buckwheat samples. When the strain was small, the differences among the samples were small. Sample K exhibited a firmer texture than sample N at a similar

Fig. 1. Setting of EMG Electrodes.

Surface electrodes (10 mm in diameter) are placed on both sides of the masseter muscles (only left side, LM, can be seen), the left inferior orbicularis oris muscles (OOI), and the suprahyoid musculature (SH), using double-sided adhesive tape.
standing time; it was indicated by the stress values at a similar strain of greater than 40%. Newly cooked buckwheat noodles did not show a clear breaking point, and the curve shape was concave or convex downward, while both samples after 10 min exhibited a breaking point and the curve was slightly convex upward before breaking. The breaking point was determined as the local maximal point in stress or as the point where the stress did not increase but was constant, but sample N immediately after being cooked exhibited continuously increasing stress, which indicated not being broken in the compression test. For the stored samples, the depression in stress after breaking was significant in sample K, but that for sample N was detected for half the cases (6 trials over 12 measurements).

The cross-sectional area of cooked noodles K differed from that of sample N (thickness and width in Table 1). Since the breaking point was not always observed and the curve shape differed, we calculated the stress values at a fixed strain before breaking. Table 1 presents the results of statistical analysis. The mechanical properties of the four samples differed significantly. This suggests that buckwheat noodles rapidly decrease in mechanical resistance and break easily. This textural change is unfavorable one that may be said as loss of hagotae and koshi. The significant change within 10 min indicates that their texture is likely different between the early and late stages in consuming one portion of buckwheat noodles. Therefore the samples used in the mechanical test and mastication recordings were cooked for each trial, and adjusted as to the standing period after being cooked.

**Analyses of mastication parameters**

We evaluated the mastication variables, as shown in Table 2. The mastication manner of each subject differed greatly, though the reproducibility for a subject and a sample was high. For example, mastication time for newly cooked sample N ranged from 6.0 to 29.6 s. Several-fold differences were found for some other mastication variables. Since intersubject-differences were generally greater than the differences among samples, we compared pairwise mastication variables within a subject for each condition, i.e., sample type (K or N), standing time effect (0 or 10 min), eating manner (chewing or slurping), and noodle length (standard or short).
Standing for 10 min

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample K</th>
<th>Sample N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (mm)</td>
<td>1.68 ± 0.03</td>
<td>1.85 ± 0.02***</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>2.34 ± 0.02</td>
<td>2.56 ± 0.02***</td>
</tr>
<tr>
<td>Stress at 10% strain (kPa)</td>
<td>17.4 ± 0.5</td>
<td>16.6 ± 0.7</td>
</tr>
<tr>
<td>Stress at 20% strain (kPa)</td>
<td>41.0 ± 1.0</td>
<td>38.5 ± 1.3</td>
</tr>
<tr>
<td>Stress at 30% strain (kPa)</td>
<td>70.9 ± 1.7</td>
<td>65.8 ± 1.9</td>
</tr>
<tr>
<td>Stress at 40% strain (kPa)</td>
<td>107 ± 3</td>
<td>98 ± 3</td>
</tr>
<tr>
<td>Stress at 50% strain (kPa)</td>
<td>148 ± 12</td>
<td>135 ± 12*</td>
</tr>
<tr>
<td>Stress at 60% strain (kPa)</td>
<td>196 ± 5</td>
<td>177 ± 4*</td>
</tr>
<tr>
<td>Breaking stress (kPa)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Breaking strain (%)</td>
<td>81.1 ± 1.5</td>
<td>—</td>
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<tr>
<td>Local minimal stress (kPa)</td>
<td>—</td>
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</table>

Effects of sample type

There were essentially no significant differences between Sample K and Sample N at the same time after cooking. Only the cycle time for the orbicularis oris muscles of sample K (0.747 s, the average value of the two standing conditions) was significantly greater than that of sample N (0.625 s), but the probability of 0.036 indicated a very weak effect. As shown in Fig. 1 and Table 1, noodle piece size and mechanical properties for the two samples differed significantly, but these factors did not significantly influence the mastication variables. Texture is defined as all the mechanical, geometrical, and surface attributes of a product perceptible by means of mechanical, tactile and, where appropriate, visual and auditory receptors by the ISO. Therefore, mechanical properties not perceptible by human organs are not involved in texture. The observed EMG variables indicated that the two buckwheat noodle samples used in this study were close in texture whether the standing time was 0 or 10 min, and standard as the cooked product size or short-cut.

Effects of standing time

Table 2 shows mastication variables that changed significantly with standing time. The paired mastication variables based on a standing time of 0 or 10 min at
as discussed above, and the amplitude and duration of the OOI muscle became greater while swallowing higher consistency food.\(^{12}\) The decrease in Ms and OOI muscle activity per burst suggests that slurping of noodles requires less muscle work and is a easy movement of the jaw and lips. However, greater numbers of bursts for OOI resulted in greater total muscle work of OOI for slurping all the samples. The total muscle work of OOI can be estimated by the product of muscle activity per burst and the number of bursts. The values were 0.930 mV·s for chewing and 1.253 mV·s for slurping. Slurping required evidently greater lip work, the same as the total muscle activity of the masseters.

<table>
<thead>
<tr>
<th>Condition</th>
<th>EMG variables</th>
<th>Sample K</th>
<th>Sample N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chewing immediately</td>
<td>Mastication time (s)</td>
<td>13.7 ± 1.5</td>
<td>15.0 ± 1.8</td>
</tr>
<tr>
<td></td>
<td>Masseter muscles (average of both sides, Ms)</td>
<td>22.1 ± 2.6</td>
<td>24.2 ± 2.8</td>
</tr>
<tr>
<td></td>
<td>Number of chewing strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amplitude (mV)</td>
<td>0.752 ± 0.121</td>
<td>0.770 ± 0.131</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.139 ± 0.013</td>
<td>0.136 ± 0.009</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0147 ± 0.0021</td>
<td>0.0147 ± 0.0024</td>
</tr>
<tr>
<td></td>
<td>Chewing cycle (s)</td>
<td>0.844 ± 0.186</td>
<td>0.665 ± 0.033</td>
</tr>
<tr>
<td></td>
<td>Total muscle activity (mVs)</td>
<td>0.330 ± 0.056</td>
<td>0.368 ± 0.070</td>
</tr>
<tr>
<td>Suprayroid musculature (SH)</td>
<td>Amplitude (mV)</td>
<td>0.450 ± 0.045</td>
<td>0.461 ± 0.043</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.178 ± 0.023</td>
<td>0.196 ± 0.027</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0137 ± 0.0015</td>
<td>0.0150 ± 0.0018</td>
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<tr>
<td></td>
<td>Cycle time (s)</td>
<td>0.785 ± 0.081</td>
<td>0.666 ± 0.026</td>
</tr>
<tr>
<td>Chewing standing for 10 min</td>
<td>Mastication time (s)</td>
<td>13.8 ± 1.5</td>
<td>13.8 ± 1.5</td>
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<tr>
<td></td>
<td>Masseter muscles (average of both sides, Ms)</td>
<td>21.9 ± 2.3</td>
<td>21.4 ± 2.2</td>
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<tr>
<td></td>
<td>Number of chewing strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amplitude (mV)</td>
<td>0.653 ± 0.105</td>
<td>0.643 ± 0.090</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.117 ± 0.009</td>
<td>0.113 ± 0.011</td>
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<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0120 ± 0.00018</td>
<td>0.0114 ± 0.00015</td>
</tr>
<tr>
<td></td>
<td>Chewing cycle (s)</td>
<td>0.690 ± 0.031</td>
<td>0.683 ± 0.035</td>
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<tr>
<td></td>
<td>Total muscle activity (mVs)</td>
<td>0.245 ± 0.046</td>
<td>0.255 ± 0.047</td>
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<tr>
<td>Suprayroid musculature (SH)</td>
<td>Amplitude (mV)</td>
<td>0.455 ± 0.041</td>
<td>0.449 ± 0.038</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.158 ± 0.019</td>
<td>0.180 ± 0.021</td>
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<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0126 ± 0.00015</td>
<td>0.0136 ± 0.00016</td>
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<tr>
<td></td>
<td>Inferior orbicularis oris (OOI) muscles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of bursts</td>
<td>24.1 ± 3.1</td>
<td>25.4 ± 3.4</td>
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<tr>
<td></td>
<td>Amplitude (mV)</td>
<td>0.973 ± 0.160</td>
<td>0.948 ± 0.160</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.227 ± 0.051</td>
<td>0.189 ± 0.034</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0375 ± 0.00092</td>
<td>0.0348 ± 0.00089</td>
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<tr>
<td></td>
<td>Cycle time (s)</td>
<td>0.725 ± 0.057</td>
<td>0.619 ± 0.031</td>
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<tr>
<td>Slurping immediately</td>
<td>Mastication time (s)</td>
<td>31.4 ± 5.0</td>
<td>28.8 ± 3.7</td>
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<td></td>
<td>Masseter muscles (average of both sides, Ms)</td>
<td>39.2 ± 5.9</td>
<td>36.1 ± 5.3</td>
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<tr>
<td></td>
<td>Number of chewing strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amplitude (mV)</td>
<td>0.584 ± 0.112</td>
<td>0.543 ± 0.087</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.109 ± 0.007</td>
<td>0.104 ± 0.007</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0098 ± 0.00017</td>
<td>0.0093 ± 0.00015</td>
</tr>
<tr>
<td></td>
<td>Chewing cycle (s)</td>
<td>0.824 ± 0.049</td>
<td>0.861 ± 0.057</td>
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<tr>
<td></td>
<td>Total muscle activity (mVs)</td>
<td>0.380 ± 0.071</td>
<td>0.351 ± 0.066</td>
</tr>
</tbody>
</table>

Table 2. Results of Mastication Measurements for Buckwheat Noodles

<table>
<thead>
<tr>
<th>Condition</th>
<th>EMG variables</th>
<th>Sample K</th>
<th>Sample N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprayroid musculature (SH)</td>
<td>Amplitude (mV)</td>
<td>0.443 ± 0.035</td>
<td>0.430 ± 0.036</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.180 ± 0.026</td>
<td>0.180 ± 0.025</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0132 ± 0.0011</td>
<td>0.0128 ± 0.0013</td>
</tr>
<tr>
<td></td>
<td>Cycle time (s)</td>
<td>0.840 ± 0.060</td>
<td>0.798 ± 0.060</td>
</tr>
<tr>
<td>Inferior orbicularis oris (OOI) muscles</td>
<td>Number of bursts</td>
<td>46.0 ± 17.5</td>
<td>46.4 ± 10.1</td>
</tr>
<tr>
<td></td>
<td>Amplitude (mV)</td>
<td>0.827 ± 0.084</td>
<td>0.763 ± 0.101</td>
</tr>
<tr>
<td></td>
<td>Duration (s)</td>
<td>0.240 ± 0.033</td>
<td>0.178 ± 0.037</td>
</tr>
<tr>
<td></td>
<td>Muscle activity (mV)</td>
<td>0.0320 ± 0.00048</td>
<td>0.0240 ± 0.00057</td>
</tr>
<tr>
<td></td>
<td>Cycle time (s)</td>
<td>0.813 ± 0.060</td>
<td>0.787 ± 0.081</td>
</tr>
</tbody>
</table>

Mean and standard error values for 13 (Ms), 12 (SH) and 7 subjects (OOI).
Not only the average value but also the standard deviation of Ms and OOI cycle times was significantly greater in slurping than in chewing. These findings suggest that chewing is performed rhythmically because the central pattern generator in the brain stem controls it, while slurping food is not repeated in a similar rhythm.

Sample size effects
To compare with the short-cut sample and the standard long noodle, former showed a slightly but significantly smaller number of chews and lower total muscle activity of masseters, as shown in Table 5. The amplitudes of the masseter and inferior orbicularis oris muscles decreased, but the chewing cycle for both muscles increased when the samples were cut. Mastication effort of normal noodles was slightly greater than that of short noodles. Cutting hard foods such as raw carrot, and soft but difficult to cut foods such as pork meat, did not decrease mastication effort, while smaller pieces of easy to eat food such as minced meat ball reduced it, as discovered previously. Buckwheat noodle is categorized as a soft food consumed with less mastication effort.

As reported for cut foods, cut sample size involving a mouthful food with a fixed mass influenced mastication behavior. Cutting noodles decreased the number of chewing strokes, the duration, and the amplitude per chew, but increased muscle activity per chew and cycle time. In terms of mastication effort, short noodles were effective in reducing it. We did not instruct the subjects about eating manner, but predicted that they did not slurp the short samples. As expected, the mastication behaviors for short noodles were more close to chewing than slurping the long noodles. The short duration of masseter activities and longer chewing cycle observed for the mastication behavior suggests that the short noodles were easier to chew.

Besides breaking the food particle size by chewing, mastication has another function. According to Hieemae,23) mastication is a two-step process in the oral cavity, first to break down the food by the back teeth and second to make the bolus ready to swallow. It can be also explained by the oral process model presented by Hutchings and Lillford,23) where the structure of the food must be sufficiently broken down and the surface of the bolus must be well lubricated for swallowing. The longer EMG cycle time for the masseters and OOI for short cut noodles suggests that buckwheat noodles require mastication mainly in forming a bolus with a smooth surface by mixing with saliva in the mouth rather than in breaking down the structure. A significantly smaller number of chews in the short-cut noodles than the standard noodles but not a significantly different mastication time was found (Table 5). The number of chewing strokes and mastication time correlated to very high significance, and this exception for short-cut noodles may be due to the difficulty in making a bolus.

Conclusion
To analyze human eating behaviors in chewing and slurping buckwheat noodles, electromyography measurement during eating one mouthful of buckwheat noodles was conducted. Though the mechanical properties of the samples differed significantly between the noodle types, the mastication variables were not significantly changed for a subject. Standing time after cooking made noodles softer and less springy, and the change decreased the activity of the jaw-closing muscles. Slurping required a longer mastication period but a smaller EMG amplitude, where the movement showed a longer and less rhythmical cycle time, than chewing.

### Table 3. Effects of Standing Time of Buckwheat Noodles on Mastication Variables

<table>
<thead>
<tr>
<th>EMG variables</th>
<th>p</th>
<th>0 min</th>
<th>10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masseter amplitude (mV)</td>
<td>***</td>
<td>0.662 ± 0.057</td>
<td>0.585 ± 0.048</td>
</tr>
<tr>
<td>Masseter duration (s)</td>
<td>**</td>
<td>0.122 ± 0.005</td>
<td>0.110 ± 0.004</td>
</tr>
<tr>
<td>Muscle activity of masseters (mV/s)</td>
<td>0.0122 ± 0.0010</td>
<td>0.0104 ± 0.0008</td>
<td></td>
</tr>
<tr>
<td>Total muscle activity of masseters (mV/s)</td>
<td>***</td>
<td>0.357 ± 0.032</td>
<td>0.302 ± 0.031</td>
</tr>
</tbody>
</table>

Mean and standard error values for 52 trials. Variables differing significantly by Wilcoxon signed-ranks test are shown; ***, p < 0.01 and ***, p < 0.001.

### Table 4. Effects of Eating Manner on Mastication Variables

<table>
<thead>
<tr>
<th>Mastication Variables</th>
<th>p</th>
<th>Chewing</th>
<th>Slurping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastication time (s)</td>
<td>***</td>
<td>14.1 ± 0.8</td>
<td>30.3 ± 2.1</td>
</tr>
<tr>
<td>Number of chewing strokes</td>
<td>***</td>
<td>22.3 ± 1.2</td>
<td>38.6 ± 2.9</td>
</tr>
<tr>
<td>Masseter amplitude (mV)</td>
<td>***</td>
<td>0.705 ± 0.055</td>
<td>0.543 ± 0.048</td>
</tr>
<tr>
<td>Masseter duration (s)</td>
<td>***</td>
<td>0.126 ± 0.005</td>
<td>0.106 ± 0.003</td>
</tr>
<tr>
<td>Muscle activity of masseters (mV/s)</td>
<td>***</td>
<td>0.0132 ± 0.0010</td>
<td>0.0093 ± 0.0008</td>
</tr>
<tr>
<td>Chewing cycle of masseters (s)</td>
<td>***</td>
<td>0.720 ± 0.048</td>
<td>0.833 ± 0.027</td>
</tr>
<tr>
<td>Standard deviation of chewing cycles (s)</td>
<td>***</td>
<td>0.433 ± 0.195</td>
<td>0.576 ± 0.049</td>
</tr>
<tr>
<td>Total muscle activity of masseters (mV/s)</td>
<td>**</td>
<td>0.299 ± 0.028</td>
<td>0.359 ± 0.035</td>
</tr>
<tr>
<td>Number of bursts of OOI</td>
<td>***</td>
<td>24.6 ± 1.9</td>
<td>46.4 ± 6.0</td>
</tr>
<tr>
<td>Amplitude of OOI (mV)</td>
<td>***</td>
<td>0.994 ± 0.078</td>
<td>0.771 ± 0.052</td>
</tr>
<tr>
<td>Muscle activity of OOI (s)</td>
<td>***</td>
<td>0.0379 ± 0.0047</td>
<td>0.0270 ± 0.0028</td>
</tr>
<tr>
<td>Cycle time of OOI (s)</td>
<td>**</td>
<td>0.700 ± 0.030</td>
<td>0.824 ± 0.030</td>
</tr>
<tr>
<td>Standard deviation of OOI cycles (s)</td>
<td>***</td>
<td>0.365 ± 0.069</td>
<td>0.591 ± 0.050</td>
</tr>
</tbody>
</table>

Mean and standard error values for 26 (masseters) and 26 (orbicularis oris, OOI) trials. Variables that differ significantly by Wilcoxon signed-ranks test are shown; *, p < 0.05 and ***, p < 0.01.
the same samples. Cutting the noodles short reduced the mastication effort, as generally found in easy-to-eat food.

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References