Food Sci. Technol. Res., **15** (1), 75 – 82, 2009

Technical paper

Time-intensity Analysis of Sourness of Commercially Produced Gummy Jellies Available in Japan

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Received March 12, 2008; Accepted September 13, 2008

The flavor release of commercial gummy jellies was studied. Time-intensity (T-I) assessments, electromyography (EMG) of the jaw-closing muscles, and mechanical tests were conducted to characterize the gummy jellies. After a preliminary sensory test and round-table discussion by expert panelists, six samples of gummy jelly were selected from 25 products to represent the various gummy jelly products produced in Japan. Six trained panelists participated in the T-I assessment coupled with EMG measurement. Sourness was perceived shortly after starting to chew; it reached a maximum intensity after sufficient mastication (18-32 chewing strokes) and lasted for a relatively long time (16.8-45.9 s) after the main chewing activity had finished. The results obtained from EMG measurements and T-I assessments showed that sourness was perceived mildly and late with very tough samples, strongly and early with tender and rubbery samples, and mildly and early with samples that were easy to chew. Thus, sourness and texture are closely related in the gummy jelly products commercially available in Japan.

Keywords: electromyography, gummy jelly, mastication, sensory evaluation, sourness, time-intensity

Introduction

The release of flavor compounds from food plays an important role in consumer acceptance. Flavor release is influenced by mechanical deformation, changes in temperature and mixing with saliva in the mouth during chewing, as well as by the chemical structure of the flavor compounds. The effect of texture on flavor release has been studied using gel systems as a food model (Muñoz, 1986; Guinard and Marty, 1995; Wilson and Brown, 1997; Clark, 2002; Bayarri *et al.*, 2007). These previous studies showed that flavor intensity generally decreased with increasing gel hardness.

Most of these results were obtained from a gel system that was easily broken down in the mouth after a short period of chewing. However, flavor release plays a more important role in consumer acceptance of hard jelly products than it does of soft jelly products. Few reports have been found regarding the effects of texture of hard jelly products on flavor perception.

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In recent years, gummy jellies have become very popular among Japanese consumers, and their market size has increased up to 180 million dollars a year (Tsukino, 2006). Gummy jellies have an elastic texture and are made mainly from sugar, gelatin, and starch syrup with various flavoring agents. They were first introduced to the Japanese market in the 1980s (Tsukino, 2006). Gummy jellies were initially regarded as cheap confectionery for only children; however, recent gummy jellies have also been accepted by adults and elderly people because of their wide variety of flavors and textures (Tsukino, 2006).

Currently, many types of gummy jellies are commercially available in Japan. In particular, gummy jellies with a sour taste are popular nationwide due to the good images of citric acid and ascorbic acid for health and beauty benefits. In addition, strong sourness seems to be a piquant taste for children and teenagers. The intensity of sourness and the rate of flavor release from products widely differ, and variation in the intensity of sourness during chewing is a very important sensory characteristic of gummy jellies.

Time-intensity (T-I) assessment is one of the descriptive techniques for sensory analysis and is effective for assessing the temporal aroma, taste, and texture (reviewed by Cliff and Heymann, 1993; Dijksterhuis and Piggott, 2001). This technique can be applied to evaluate the temporal sour perception of food like gummy jelly that is chewed for a long time.

Electromyography (EMG), which records the activities of the mastication muscles, has been applied for measuring the temporal texture as reviewed by Gonzalez *et al.* (2001). EMG activities of the masseter muscles, which are the jaw-closing muscles, are known to be correlated with biting force (Proeschel and Morneburg, 2002). Measuring EMG simultaneously with T-I assessment enables the relationship between the flavor release perception and temporal texture to be analyzed (Wilson and Brown, 1997; Sprunt *et al.*, 2002; Kohyama *et al.*, 2003).

The acceptance of a gummy jelly depends on the temporal sour perception and texture of the product during eating. However, the dynamic aspects of sour intensity and texture in a gummy jelly have not previously been studied. The aim of the present study is to characterize the temporal perception of sourness and texture in gummy jellies commercially available in Japan by T-I assessment coupled with EMG measurement.

Materials and Methods

Samples In the present study, the number of samples was six in consideration of fatigue of the assessors. Six commercial gummy jelly samples (Table 1) were selected from 25 products through a preliminary sensory test and round-table discussion by expert panelists, who have extensive experience in sensory evaluation and/or texture analysis of gel-type food. The selected samples had different textures and differences in sourness perception during chewing (Table 1) and represented the various gummy jelly products commercially available in Japan. Although the size of a sample affects its masticatory properties (Kohyama *et al.*, 2004; 2005a; Miyawaki *et al.*, 2001), we retained the original shape of each sample as the range of the sample sizes was small (Table 1). All samples were kept at room temperature (25°C). Other gummy jelly products were used for training sessions.

Water and an aqueous solution of 1.0% (w/v) citric acid (chemically pure for food use) were respectively used as references for "not present" and "very high". Commercially obtained mineral water (Asahi Soft Drinks, Japan) was used for preparing these two references and for rinsing the mouth between samples. The reference solutions were kept at 25°C for 1 h before evaluation.

Mechanical testing A mechanical compression test was performed on each sample using a universal testing machine (Model 5542; Instron, Canton, MA, USA) attached with a cylindrical probe (4.79 mm in diameter) rotated at a constant speed of 1 mm/s. As the probe was smaller than the samples, the stress was calculated as the detected load divided by the cross-sectional area of the probe (18.0 mm^2). Strain was calculated as the ratio of the vertical deformation to the initial height. Rupture of a sample was determined as the point at which the first reduction in stress was observed. Tests were replicated six times for each sample.

Apparatus A data collection system (MP150; Biopac Systems, Goleta, CA, USA) was used for the T-I assess-

Table 1. Size and features of the samples in this study.

Sample	Weight (g)	Height (mm)	Length[1] (mm)	Width[2] (mm)	Shape of underside	Features[3]
A	3.71	11.2	23.9	17.9	ellipsoid	easy to chew
B	3.92	8.9	30.2	14.7	ellipsoid	soft and rubbery texture, chewy, covered with sour powder
C	3.56	9.0	22.0	14.8	rectangle	tough, rubbery texture
D	3.43	10.3	24.0	17.0	ellipsoid	easy to chew, includes sweet and sour syrup in center
E	3.56	5.6	27.7	22.4	ellipsoid	soft and rubbery texture, chewy, covered with sweet and sour powder
F	5.05	15.4	19.0		circle	gummy, includes sweet and sour syrup in center

The numbers in the table are mean values for 6 replicates.

[1] Length of the underside of the sample.

[2] Width of the underside of the sample. In the case of the circle (F), the diameter is given.

[3] Comments from the expert panelists during selecting the samples.

ment coupled with EMG measurement. As the T-I indicator, a 100-mm linear sliding potentiometer (TSD115; Biopac Systems) was connected to the system. The output of the potentiometer ranged from 0 to 5 V according to the slide lever position that was graduated from 0 to 10 at equal intervals, 1 being "very weak" and 10 "very high". Each panelist adjusted the lever according to the perceived sourness intensity.

Synchronized EMG data was collected together with T-I assessment (Kohyama *et al.*, 2003). The EMG signals were generated by surface electrodes with a diameter of 10.0 mm (EL503; Biopac Systems) mounted on the left and right masseter muscles 20 mm apart. The signals were amplified 1000 fold, after eliminating electrical noise at 50 Hz and filtered between 1.0 to 500 Hz using EMG amplifier units (EMG100C; Biopac Systems) (Kohyama *et al.*, 2000; 2005b).

The T-I and EMG data were digitized at 1000 Hz and stored on a personal computer for further analysis using AcqKnowledge ver. 3.8.2 software (Biopac Systems).

Selection and training of panelists The study design was approved by the National Food Research Institute Ethics Committee. All panelists gave their informed consent before every session. The six panelists (female; mean age, 34.8 years old; range, 28-42 years old) were selected from the National Food Research Institute sensory panel and which had been selected trained according to ISO 8586-1. They had two years of experience in sensory evaluation, although none had been previously involved in T-I assessment. None suffered from any symptoms of masticatory dysfunction, pain during eating or wore dental prostheses.

As the panelists had no experience in T-I assessment, they participated in five training sessions. In the first session, they were given verbal instructions on the objectives of the study. In the second session, each panelist was given two reference solutions: water as a "not present" reference and a 1.0% citric acid solution as a "very high" reference. They were instructed to note the sourness levels at their most intense. The reference solutions were presented during further training sessions as well. After tasting each reference, each panelist evaluated the maximum sourness intensity of two gummy jelly products at their most intense as a preliminary test. At the end of the second session, the panelists discussed the sourness intensities that they had rated for each product and revised the rating as necessary.

In the third session, the panelists were trained to judge sourness at certain times during chewing and recorded the intensity on a score card. Two kinds of gummy jelly products different from those used in session 2 were evaluated. First, the panelists were given each of these two products and asked to rate the sourness 5, 10, and 20 s after placing the product on the tongue. Then, they evaluated the same two products to familiarize themselves with manipulating the T-I lever.

In the fourth session, the panelists were trained in T-I assessment by evaluating the six samples presented in random order.

In the fifth and final training session, the panelists were trained in the T-I assessment coupled with the EMG measurement. Again, they were given the six samples in random order and T-I was assessed, while measuring EMG.

Procedures for TI assessment and EMG measurement Data was collected for two sessions. The first session rated the sourness by T-I assessment alone and the second by T-I assessment coupled with EMG measurement. During each data collection session, each of the six panelists performed two replicates of the six samples.

The two references, water and an aqueous 1.0% citric acid solution respectively representing "not present" and "very high", were presented at the beginning of each session. The panelists were instructed to eat a cracker and rinse the mouth well with water between each measurement.

At the beginning of each measurement, the slide lever was placed at the lowest position of 0. Each panelist was asked to chew normally and move the lever to a position representing the sourness intensity. Data were recorded from the time that the panelist inserted each sample into the mouth until the lever was returned to position 0. The panelists were blind to their own T-I curves during training and the data collection sessions.

Data analysis The T-I signals were resampled at 1.25 Hz. An example of a T-I curve is shown in Fig. 1. The following parameters were extracted from the T-I curves: I_{max} (maximum intensity), T_{max} (time to I_{max}), T_{tot} (total time), and AUC (area under the T-I curve) (Cliff and Heymann, 1993).

The parameters from the EMG data illustrated in Fig. 1 were obtained as previously described (Kohyama *et al.*, 2005a). The number of chewing strokes and mastication time were determined directly from the chart. The burst duration, cycle time, amplitude, and muscle activity (or time-integrated EMG signal of each chewing stroke) were obtained for the left and right masseter muscles and averaged, as the signals from the two muscles appeared at almost the same time. The parameters were averaged for all the chewing cycles. The sum of the muscle activity before swallowing was also calculated.

The number of chewing strokes and the sum of the muscle activity before the first perception of sourness and before T_{max} were calculated from both T-I and EMG data. The T-I duration after finishing the main chewing activity was also obtained (Kohyama *et al.*, 2003).

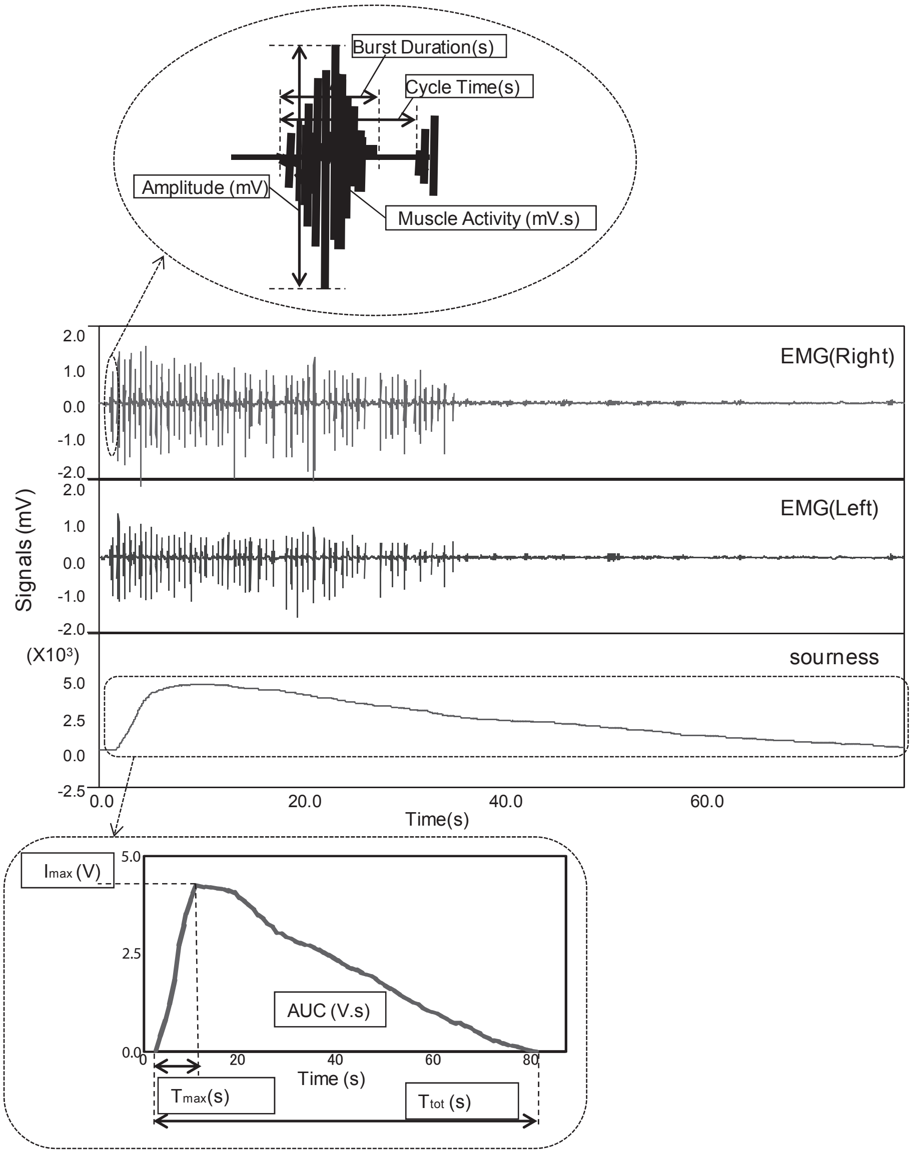

Fig. 1. Example of an electromyography (EMG) and time-intensity (T-I) assessment chart and parameters from an EMG and T-I curve.

The chart was recorded while a panelist was eating sample B. Data recording started when the panelist inserted the sample into the mouth. EMG signals of the right (top) and left (middle) masseter muscles and T-I assessment of sourness intensity (bottom). I_{max}, maximum intensity; T_{max}, time to I_{max}; T_{tot}, total time; AUC, area under the T-I curve.

A statistical analysis was performed with the SPSS package ver. 15.0J (SPSS, Chicago, IL, USA). The statistically significant differences among samples were determined by one-way analysis of variance (ANOVA) and Tukey's HSD test for the mechanical test data, and with repeated-measures ANOVA and paired *t*-test for the T-I and EMG data. Bonferroni's correction was used to reduce errors of the first kind. The T-I parameters were summarized by principal component analysis (PCA).

Results and Discussion

Mechanical testing The mechanical characteristics of the samples are shown in Table 2. The rupture stress was high for samples A and F. Although sample A exhibited a high stress value before rupture (at 0.3 strain), the stress values at 0.6 and 0.9 strains were not high after rupture. The texture of sample A was described as easy to chew at the round-table discussion by the panelists while selecting the samples (Table 1). The stress value of sample F was not as high as that of A at 0.3 strain. Moreover, stress values of sample F were low after rupture (at 0.6 and 0.9 strains); the texture was described as gummy by the expert panel (Table 1).

Although sample D showed a rupture point, the rupture stress was very low; the stress values were also low before and after rupture. The texture of sample D was described as easy to chew by the expert panel (Table 1).

Table 2. Mechanical characteristics of the samples.

Parameter		F-ratio		A		B		C		D		E		F	
Rupture stress	(MPa)	126	***	0.246	a	-		-		0.092	b	-		0.203	a
Rupture strain		20.8	***	0.525	b	-		-		0.398	c	-		0.578	a
Stress at 0.3 strain	(MPa)	15.5	***	0.168	a	0.032	c	0.135	ab	0.069	bc	0.171	a	0.079	bc
Stress at 0.6 strain	(MPa)	34.0	***	0.240	c	0.139	c	0.398	b	0.134	c	0.538	a	0.201	c
Stress at 0.9 strain	(MPa)	62.8	***	0.339	c	0.678	b	1.380	a	0.472	bc	1.106	a	0.237	c

Values are the means for 6 replicate samples. F-ratios and statistical probabilities were determined by ANOVA. Values followed by different alphabetical letters within a row indicate a significant differences (p<0.05). "-", not determined; ***p<0.001.

Table 3. Parameters obtained from electromyography (EMG) and time-intensity (T-I) measurement observed during mastication of the samples.

Parameters	F-ratio		A		B		C		D		E		F	
from EMG														
Number of chewing strokes	21.9	***	33.6	b	43.4	ab	66.4	a	30.9	b	41.8	ab	38.1	b
Mastication time (s)	22.7	***	26.4	bc	31.7	bc	51.8	a	24.9	c	35.6	ab	28.8	bc
Burst duration (s)	0.576	NS	0.4		0.4		0.3		0.4		0.4		0.3	
Cycle time (s)	0.750	NS	0.8		0.8		0.8		0.8		0.9		0.8	
Amplitude (mV)	4.75	**	1.72	a	1.74	a	2.04	a	1.40	a	1.74	a	1.33	a
Muscle activity per chew (mV.s)	17.3	***	0.022	ab	0.026	b	0.036	a	0.024	b	0.031	ab	0.023	b
Total muscle activity (mV.s)	18.1	***	0.750	ab	1.052	b	2.425	a	0.761	ab	1.299	ab	0.850	ab
from T-I														
Maximum intensity (I_{max}) (V)	45.5	***	1.82	c	4.16	a	1.89	c	1.98	c	3.27	b	1.90	c
Time to I_{max} (T_{max}) (s)	5.57	**	17.0	ab	14.0	ab	24.5	a	16.6	ab	15.7	b	16.0	ab
Total time (T_{tot}) (s)	23.3	***	50.1	bd	77.8	ab	68.6	a	47.0	cd	59.6	abc	46.3	d
Area under the T-I curve (AUC) (V.s)	33.2	***	50.6	bc	165.8	a	79.9	b	51.2	bc	102.6	b	51.5	c
from T-I and EMG														
Number of chewing strokes before onset of T-I	1.08	NS	2.1		1.8		2.3		2.3		2.1		2.4	
Time before onset of T-I (s)	1.07	NS	1.2		1.2		1.4		1.6		1.2		1.5	
Muscle activity before onset of T-I (mV.s)	2.24	NS	0.050		0.063		0.119		0.076		0.089		0.056	
Number of chewing strokes before I_{max}	6.14	***	21.3	a	20.3	a	32.4	a	21.6	a	17.9	a	22.7	a
Sum of muscle activity before I_{max} (mV.s)	11.9	**	0.487	a	0.626	a	1.452	a	0.571	a	0.776	a	0.573	a
T-I duration after ceasing main chewing activity	18.1	***	23.7	ab	45.9	a	16.8	b	22.1	b	24.0	b	17.5	b

Values are means of 6 subjects. F-ratios and statistical probabilities were determined by repeated-measure ANOVA. Values followed by different alphabetical letters within a row indicate significantl differences (p<0.05). NS, not significant; *p<0.05; **p<0.01; and ***p<0.001.

No clear rupture point was apparent for samples B, C and E; the textures of these samples were described as rubber-like by the experts (Table 1).

Mastication patterns Figure 1 shows typical data collected for sample B. Each channel shows the simultaneously recorded data for EMG measurements (top and middle) and T-I assessment (bottom). The masseter muscles are jaw-closing muscles and exhibit their activities while clenching the teeth. In this case, the number of chewing strokes was 55, and the main chewing activity finished in 35.3 s. A low level of EMG activity continued after chewing finished due to the muscle movements associated with cleaning food debris from the mouth and swallowing.

The average values for the EMG and T-I parameters of the six samples are shown in Table 3. There were significant differences among the samples in the number of chewing strokes, mastication time, amplitude, muscle activity per chew, and total muscle activity. The number of chewing strokes has been reported to be higher and the mastication time to be longer for a firm gel (Wilson and Brown, 1997). A relatively large number of chewing strokes and long mastication time were observed for sample C, indicative of its tough texture. In contrast, samples A, D and F had fewer chewing strokes and shorter mastication time, suggesting that they were easy to chew. Samples B and E had intermediate characteristics between sample C and samples A, D and F.

The correlation coefficients between the mechanical and EMG parameters are shown in Table 4. The stress at 0.9 strain was significantly correlated with the number of chewing strokes, mastication time, amplitude, muscle activity per chew, and total muscle activity. The rupture stress, rupture strain, and stress values at 0.3 and 0.6 strains were not correlated with the masticatory parameters. Although the correlation coefficients were obtained from the data of only three or six samples, the results agree with our previous findings for eight solid foods with various physical properties (Kohyama *et al.*, 2008). We showed in the previous report that the stress value under a very large compressive strain is more influential on EMG parameters than the rupture properties and the stress value under lower strain (Kohyama *et al.*, 2008).

The burst duration and cycle time were not correlated with the mechanical parameters, suggesting that the chewing rhythm of the panelists was not affected by the mechanical characteristics of the samples (Nakazawa and Togashi, 2000).

Perceived sourness The comparison of the T-I parameters with and without EMG measurements showed no statistically significant effect at the 5% level. Thus, attaching electrodes to the left and right masseter muscles had no effect on T-I assessment by the panelists.

Figure 1 shows that the panelists started to perceive sourness shortly after starting to chew (at 2.1 s) and after 19 chewing strokes the maximum sourness intensity was reached (at 11.3 s). The main chewing activity finished in 35.3 s, and the sourness perception lasted for 82.4 s. Kohyama *et al.*, (2003) have studied the temporal sweetness and texture of *monaka* (bean jam in a rice cracker shell) and observed the same eating process, which the sweetness was perceived shortly after starting to chew (at 3.3-4.8 s), and it reached maximum intensity after sufficient mastication (14.3-20.4 chewing strokes; at 8.0-12.2 s) and lasted after finishing the main chewing activities.

In contrast, Wilson and Brown (1997) have reported that the peak of flavor intensity occurred close to the point of swallowing banana-flavored gelatin gel. They pointed out that swallowing was often associated with a marked increase in flavor perception because of the bolus location at the back of the throat and the retronasal air flow. This was not found to be the case with the sourness from gummy jellies and the sweetness from *monaka* (Kohyama *et al.*, 2003) due to the differences in flavor compounds. Both sourness and sweetness are perceived when an aqueous tastant is mixed with saliva and stimulates receptors in the taste buds on the tongue, while the banana flavor is perceived as a retronasal aroma from the volatile compounds.

Average T-I curves for six samples are presented in Fig. 2 and the average values for each T-I parameter of the six samples are shown in Table 3. The T-I curves started to rise shortly after starting to chew (1.8-2.4 s); during this initial period, every panelist chewed one to three times. There was no significant difference between samples for the number of chewing strokes before the onset of T-I, the time before the onset of T-I, and the muscle activity before the onset of T-I.

There were significant differences among samples in the I_{max}, T_{max}, T_{tot}, and AUC values (Table 3). Sample B had the highest I_{max}, followed by sample E. Sample B also showed a long T_{tot} and large AUC. In T-I assessment of anethole-flavored gel, Sprunt *et al.* (2002) have reported that at least one of the values of I_{max}, T_{tot} and AUC tend to increase with increasing anethole concentration. These parameters may be related to the overall intensity of flavor. In the present study, I_{max}, T_{tot} and AUC for sample B were the highest, indicating that sample B was the sourest of all the samples. The T-I duration after finishing the main chewing activity was also the longest for sample B (45.9 s) compared with the other samples (16.8-24.0 s). Thus, the sourness of sample B was

Table 4. Correlation between the mechanical and electromyography (EMG) parameters.

	Number of chewing strokes	Mastication time	Burst duration	Cycle time	Amplitude	Muscle activity per chew	Total muscle activity
Rupture stress	0.928	0.930	-0.804	-0.733	0.071	-0.683	0.651
Rupture strain	0.587	0.591	-0.364	-0.258	0.592	-0.967	0.147
Stress at 0.3 strain	0.159	0.287	0.234	0.705	0.435	0.293	0.277
Stress at 0.6 strain	0.481	0.613	0.266	0.534	0.556	0.713	0.583
Stress at 0.9 strain	0.831 *	0.896 *	0.182	0.091	0.817 *	0.983 ***	0.898 *

The correlation coefficients between rupture stress, rupture strain, and EMG parameters were calculated from 3 samples that exhibited a rupture point. The correlation coefficients between stress values at a fixed strain and EMG parameters were calculated from 6 samples. *p<0.05 and ***p<0.001.

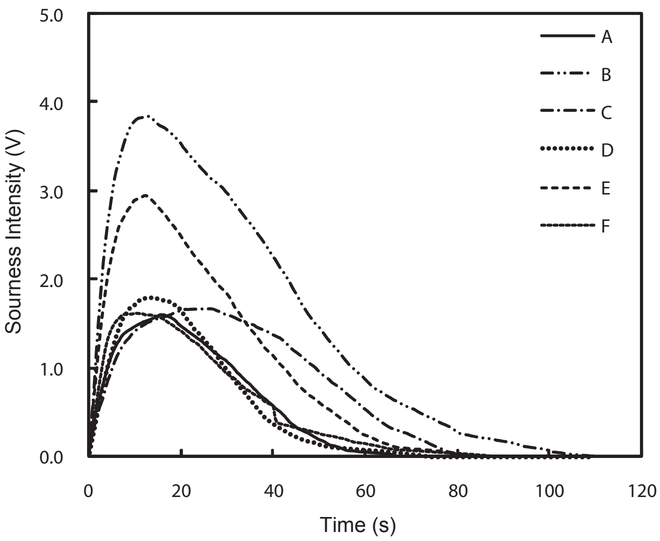

Fig. 2. Average time-intensity curves for gummy jellies.
The time-intensity curves for six gummy jellies (A-F) were calculated by averaging the intensity values of all panelists at given times, and connecting the mean values.

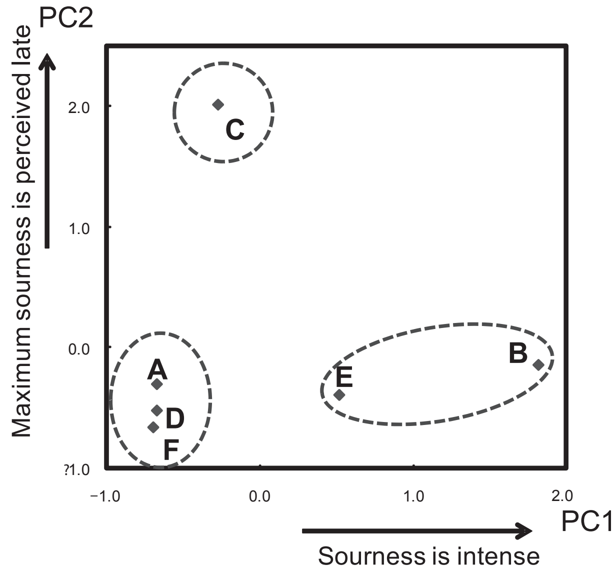

Fig. 3. Principal component space plot for gummy jellies.
The biplot shows the first principal component (PC 1) and second principal component (PC 2) scores from principal component analysis (PCA) using four time-intensity (T-I) parameters as variables and six gummy jellies as samples.

the strongest and lasted the longest.

T_{max} for sample C was the highest; that is, the maximum sourness occurred later than with any other samples. Sample C also resulted in the largest number of chewing strokes before I_{max} (32.4 strokes) when compared with the other samples (17.9-22.7 strokes).

The mean values for the T-I parameters from the panelists were summarized by PCA. Figure 3 shows the biplot of the first principal component (PC 1) and second principal component (PC 2) scores. The gummy jellies were categorized into three groups by PCA. The plots for samples A, D and F were similar with low scores for PC 1 and PC 2. The plots for samples B and E were relatively similar with high PC 1 scores and low PC 2 scores. On the other hand, the plot for sample C had a low PC 1 score and high PC 2 score.

The two dimensions of the biplot explained about 99.4% of the variance, 70.6% for PC 1 and 28.8% for PC 2. The factor loadings, eigenvalues and proportions for each principal component (PC) are shown in Table 5. The factor loadings for PC 1 were high for I_{max}, T_{tot} and AUC, and those for PC 2 were high for T_{max}. These factor loadings enabled PC 1 to be interpreted as the axis related to sourness intensity and PC 2 as the axis related to the timing of maximum sourness. The sample score plot (Fig. 3) clearly showed the characteristics of each sample in sourness perception. The sourness of samples A, D and F was low and was first perceived in a relatively short time. The sourness of samples B and E was high and was perceived early, while that of sample C was low and was perceived late.

Table 5. Factor loadings, eigenvalues and proportions of principal component analysis (PCA) using four time-intensity (T-I) parameters as variables and six gummy jellies as samples.

	PC1	PC2
Factor loadings		
Maximum intensity (I_{max})	0.977	-0.179
Time to I_{max} (T_{max})	-0.399	0.915
Total time (T_{tot})	0.849	0.523
Area under the T-I curve (AUC)	0.995	0.096
Eigenvalue	2.824	1.151
Proportion	0.706	0.288

Characterization of the samples by mechanical, EMG, and T-I parameters As already described, samples A, D and F required fewer chewing strokes and shorter mastication time (Table 3), indicating that they were easy to chew. Their T-I perception of sourness were similar (Fig. 3). The sourness release was fast and its intensity was not particularly high. Thus, products requiring little chewing may be designed to have mild and early sourness perception.

The texture of samples B and E was described as soft and rubbery in discussion by the expert panel (Table 1), which was supported by the mechanical and EMG data (Tables 2 and 3). For these two samples, intense sourness was perceived as soon as the samples were placed on the tongue and decreased with chewing. The mastication times were relatively long because of their rubbery texture. As products categorized in this group are often covered with powder containing citric acid, sourness may be regarded as a piquant taste with this type of gummy jelly product.

In contrast, the sourness of sample C, which has a texture that is tough and rubber-like (Tables 1 and 3), was low and was perceived late. Thus, gummy jelly products like sample C can be chewed and perceived for a long period.

This study presents the characteristics of flavor release and masticatory properties of commercial gummy jellies. The results can provide useful information for designing gummy jelly products. Although only six samples were tested in this study, they were carefully selected to represent the various products commercially available in Japan and they possess various textures and sourness intensities. The gummy jellies produced in Japan can be categorized into the three groups identified in this study.

The gummy jelly samples in the present study are all commercially available in Japan. They have various shapes and contain various kinds of gelling agents, sweeteners and acidulants in various concentrations. Further studies using model gel are needed to clarify the factors affecting the temporal sourness in these gummy jellies.

Acknowledgements This work was supported in part by a Grant-in-Aid for Scientific Research (C) from the Japan Society for the Promotion of Science (No. 20500700) and by the Program for Promotion of Basic Research Activities for Innovative Biosciences (PROBRAIN).

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