Application of Human Mastication Measurements on Food Texture Analysis

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Texture

- **All the mechanical, geometrical and surface attributes of a product perceptible by means of mechanical, tactile and, where appropriate, visual and auditory receptors.** ISO 11036

Texture = perceived physical properties

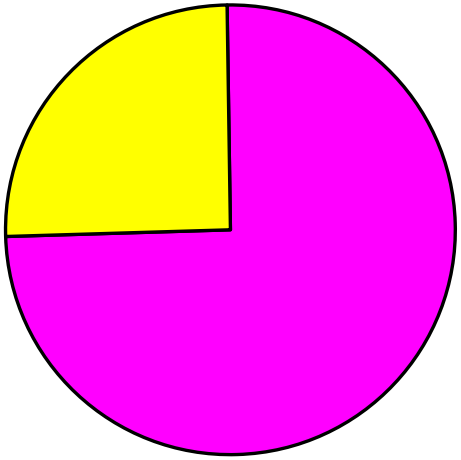
Greatest number (445) of texture terms in Japanese

Onomatopoeic expression

F. Hayakawa, *et al.* : Jpn. J. Food Sci. Technol. (in Japanese), **52**, 337-346 (2005), **53**, 327-336 (2006), **54**, 488-502 (2007)

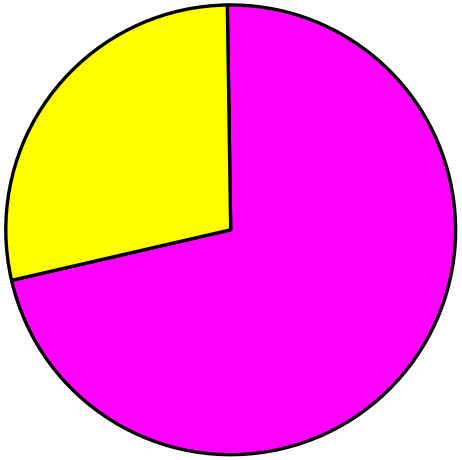
Contribution of Texture to Food Palatability

Cooked rice



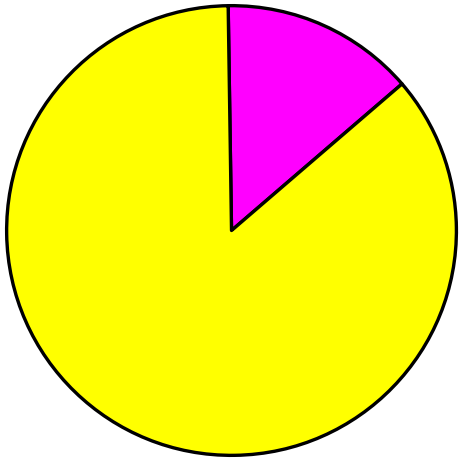
Dango

Rice cake with NG-R



Sake

Rice wine



Physical factors: texture, temperature, appearance, crushing sound

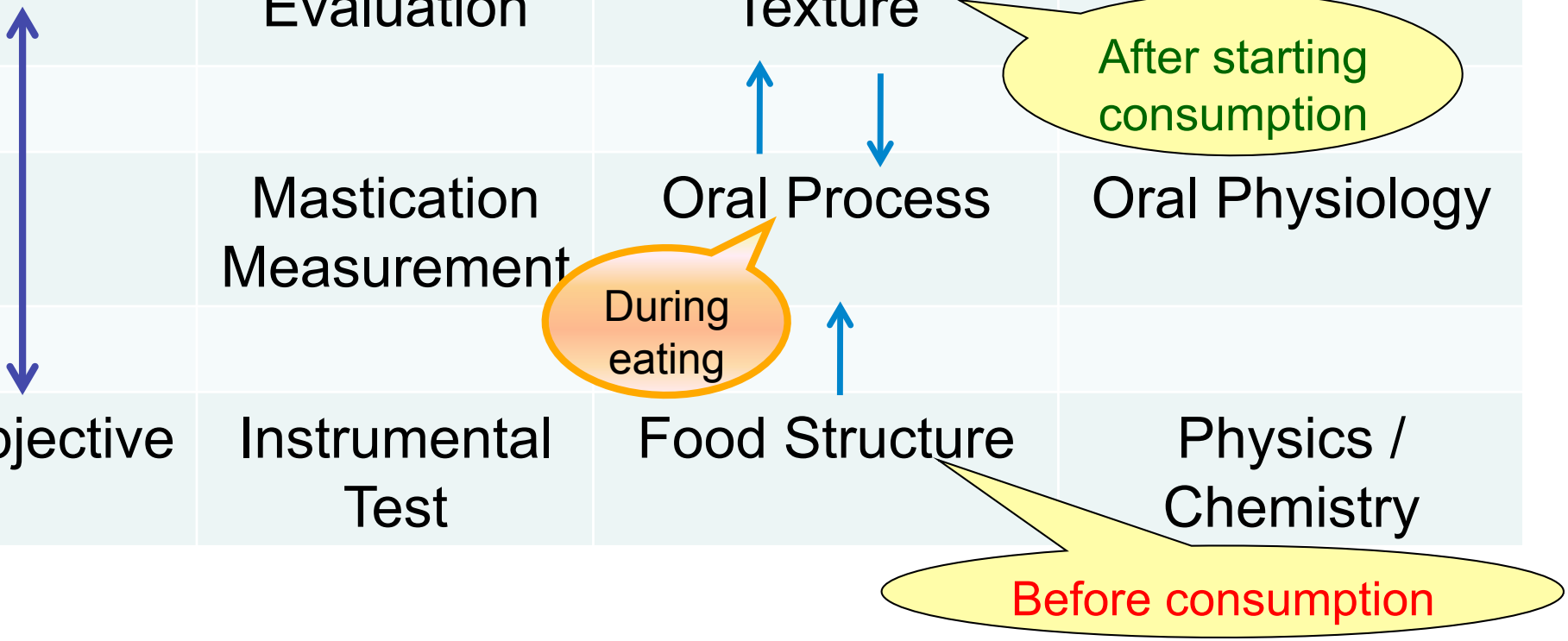
Chemical factors: taste, odor = flavor

In many solid food and gels, physical > chemical

N. Matsumoto & F. Matsumoto: *Chori Kagaku* (in Japanese), **10**, 97-101 (1977)

Methods in Food Texture Measurements

Characteristics	Method	Object	Field
Objective	Sensory Evaluation	Perceived Texture	Psychophysics
	Mastication Measurement	Oral Process	Oral Physiology
Subjective	Instrumental Test	Food Structure	Physics / Chemistry



C. Wilkinson *et al.*: Trends Food Sci. Technol., **11**, 442-450 (2000)

K. Kohyama: Chemistry and Biology (in Japanese), **47**, 133-137 (2009)

New approach

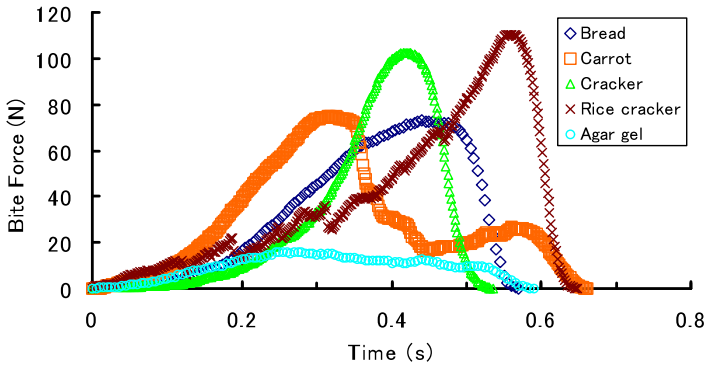
Direct measurements of oral process of food

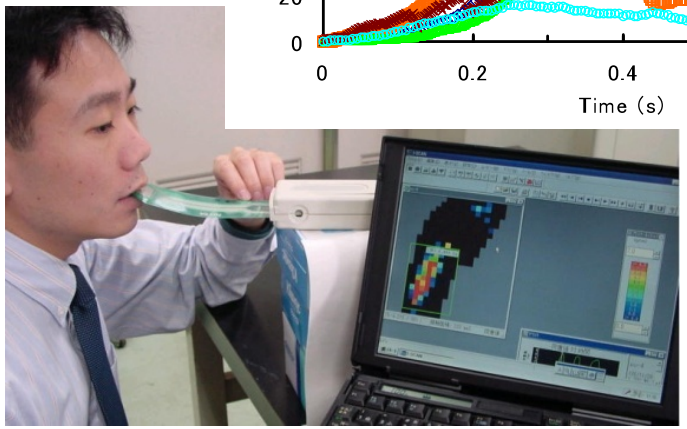
- Texture changes during mastication

  (food fracture, temperature, moisture, mixing with saliva, grinding…)
- Ease / difficulty in mastication or swallowing
- Effects of mouthful / serving size
- Link of the subjective (sensory) attributes with objective (instrumental) parameters
- Individual differences

Oral Measurement of Texture

Bite curves of various foods



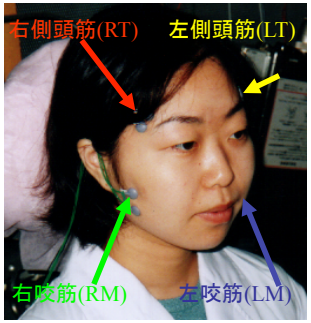


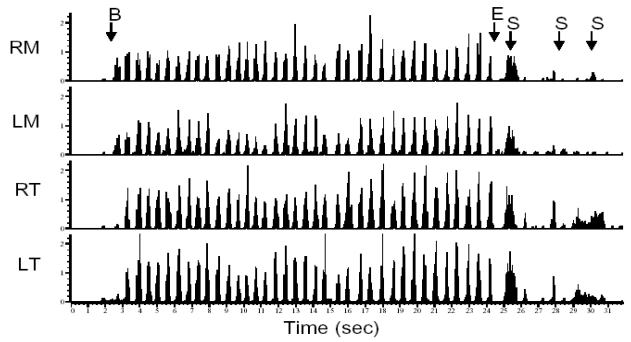
① Bite Force

Multiple-point sheet sensor

③ Mandibullar Kinematics

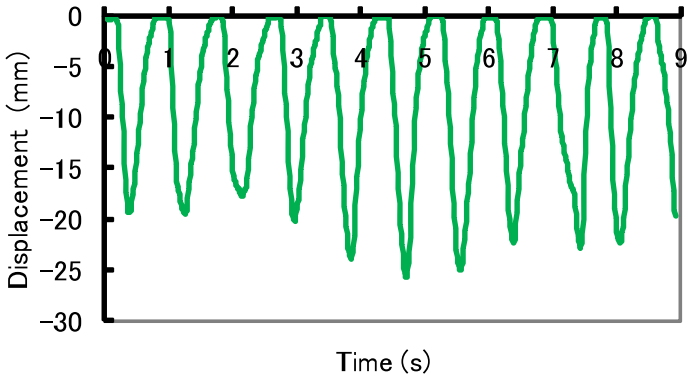
EMG of jaw closing muscles (5g beef)





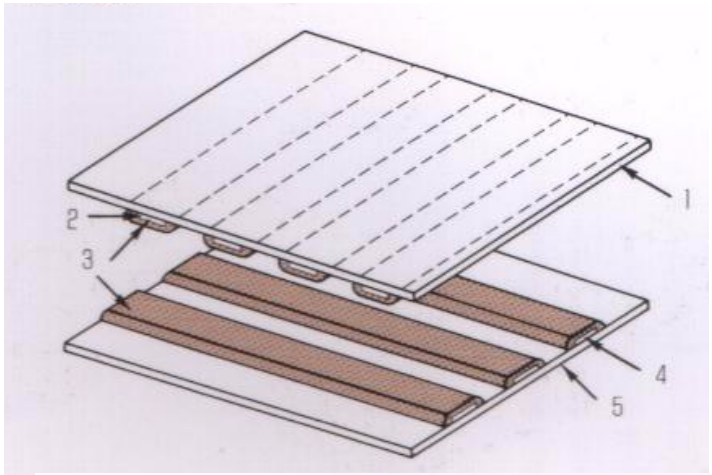
② Electromyography (EMG)

Jaw movement for chewing gum



Bite Measurement by a Multiple-point Sheet Sensor

Pressure distribution on the sensor plane can be measured at real time (~0.01s).

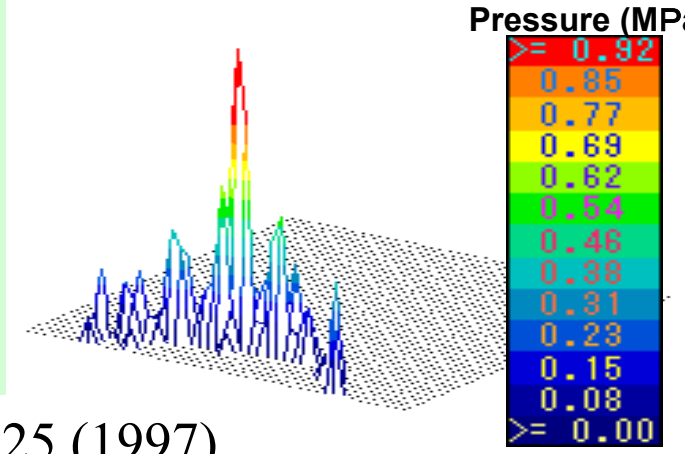


1, 5. PE-film

2. A row electrode

3. pressure-sensitive ink

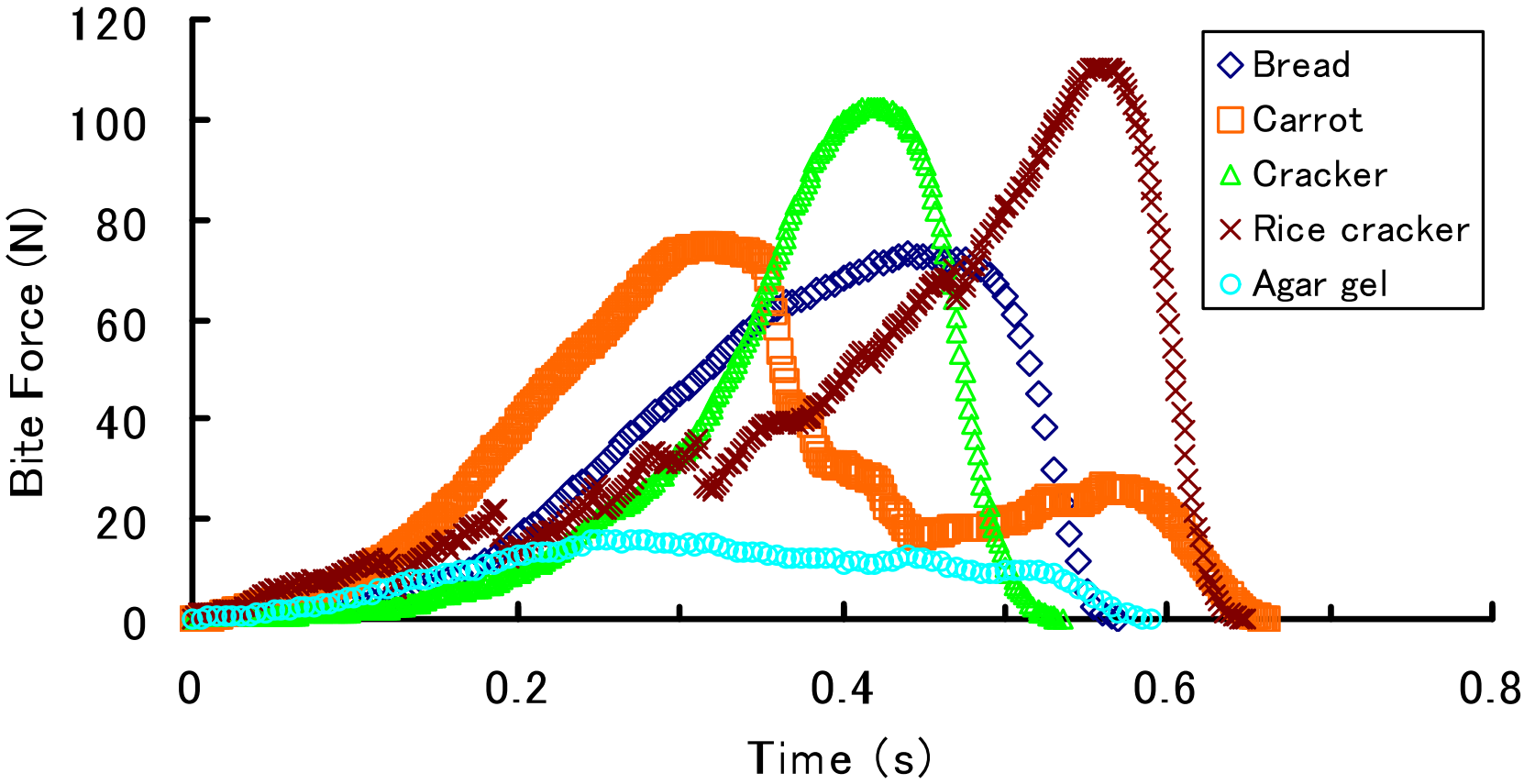
4. A column electrode



1) K. Kohyama, *et al.*: J. Food Sci., **62**, 922-925 (1997)

2) K. Kohyama & M. Nishi: J. Texture Studies, **28**, 605-617 (1997)

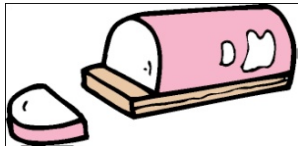
Bite Curves by Molars



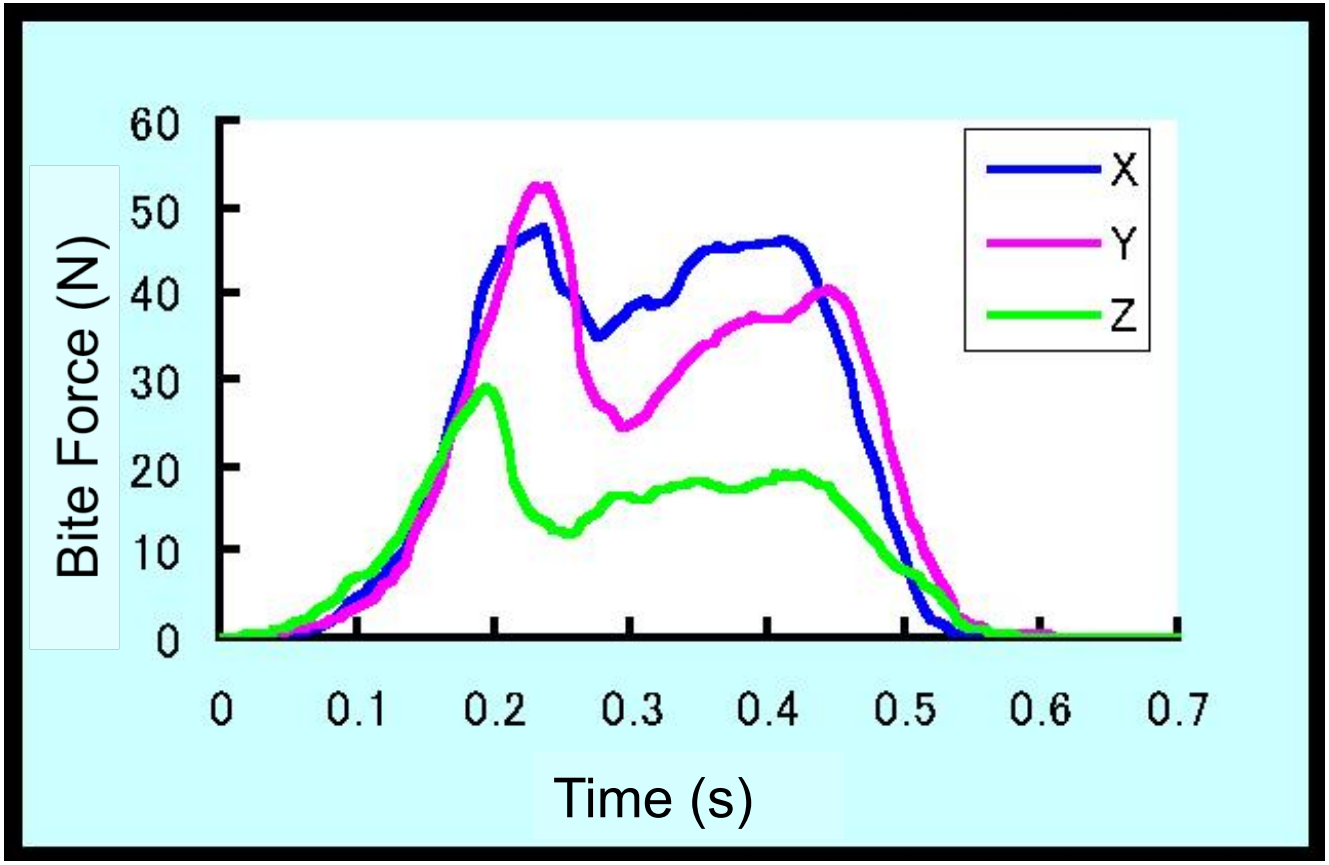
A young female bit solid food on the MSCAN2 sheet sensor

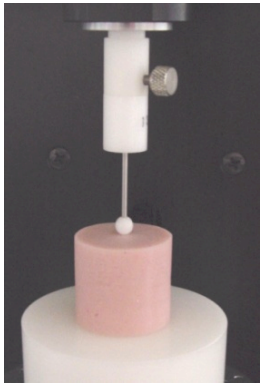
modulus → slope; breaking stress → first peak, not max. force

K. Kohyama *et al.*: Food Sci. Technol. Res., **7**, 290-296 (2001)



Bite Curves for *Surimi* gels





Gel Strength (N・mm)	
X	165
Y	187
Z	59

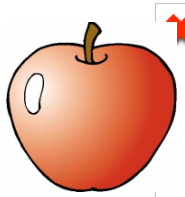
A young female bit a gel on the MSCAN2 sheet sensor

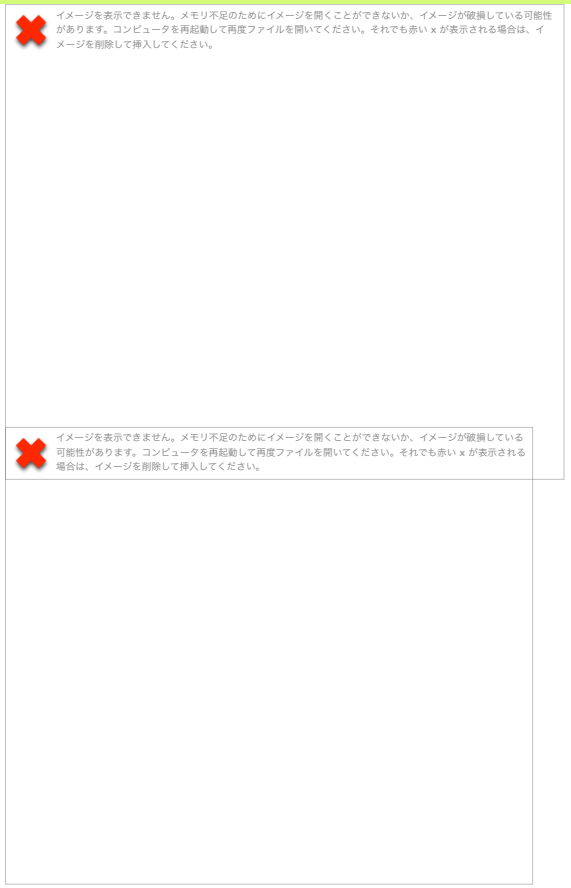
Gels shows two peaks

First peak related to the gel strength

K. Kohyama *et al.*: Biosci. Biotechnol. Biochem., **65**, 2597-2603 (2001)

Effects of sample thickness





Bite pressure

Apple

Raw carrot

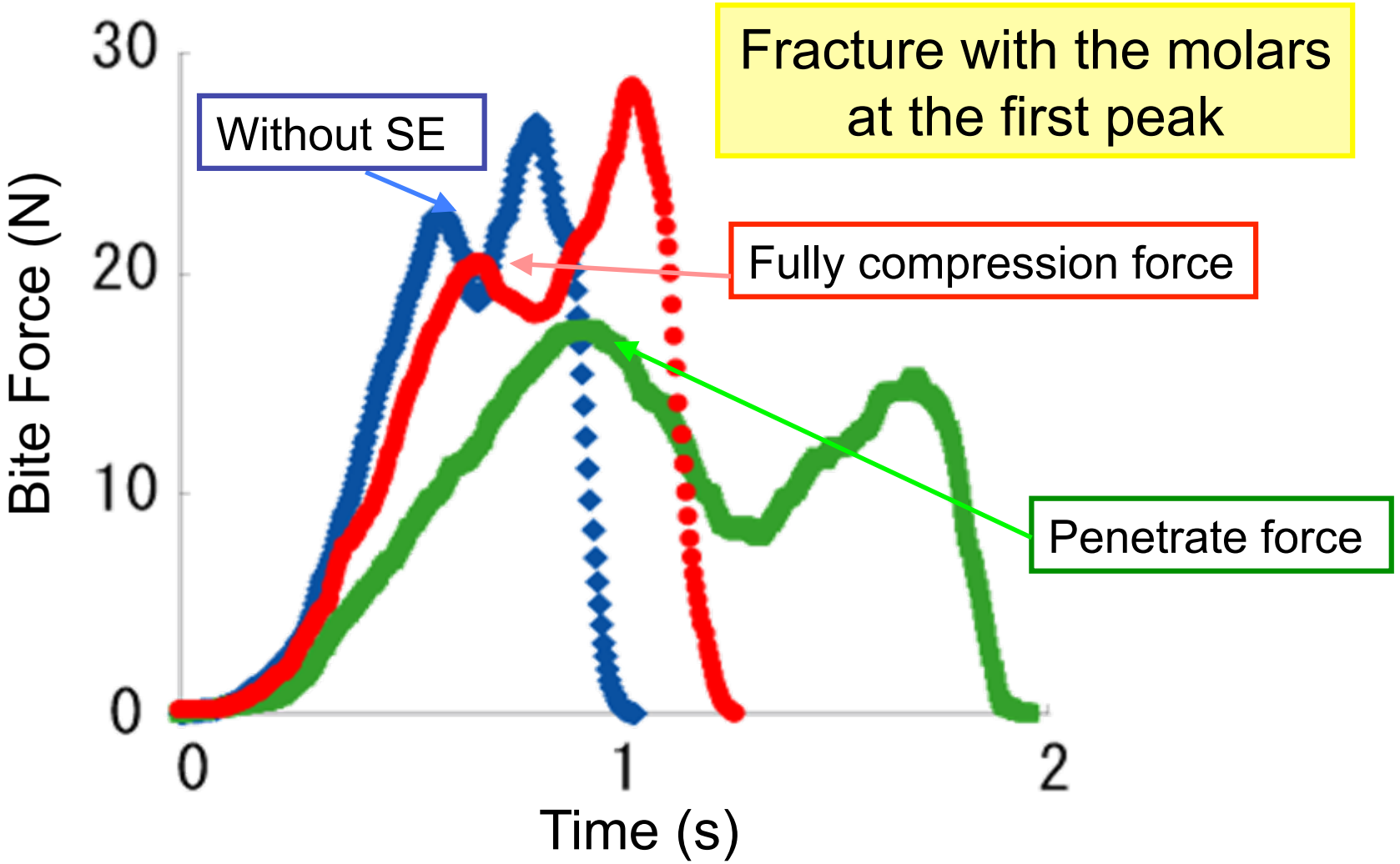
Surimi gel

Cheese

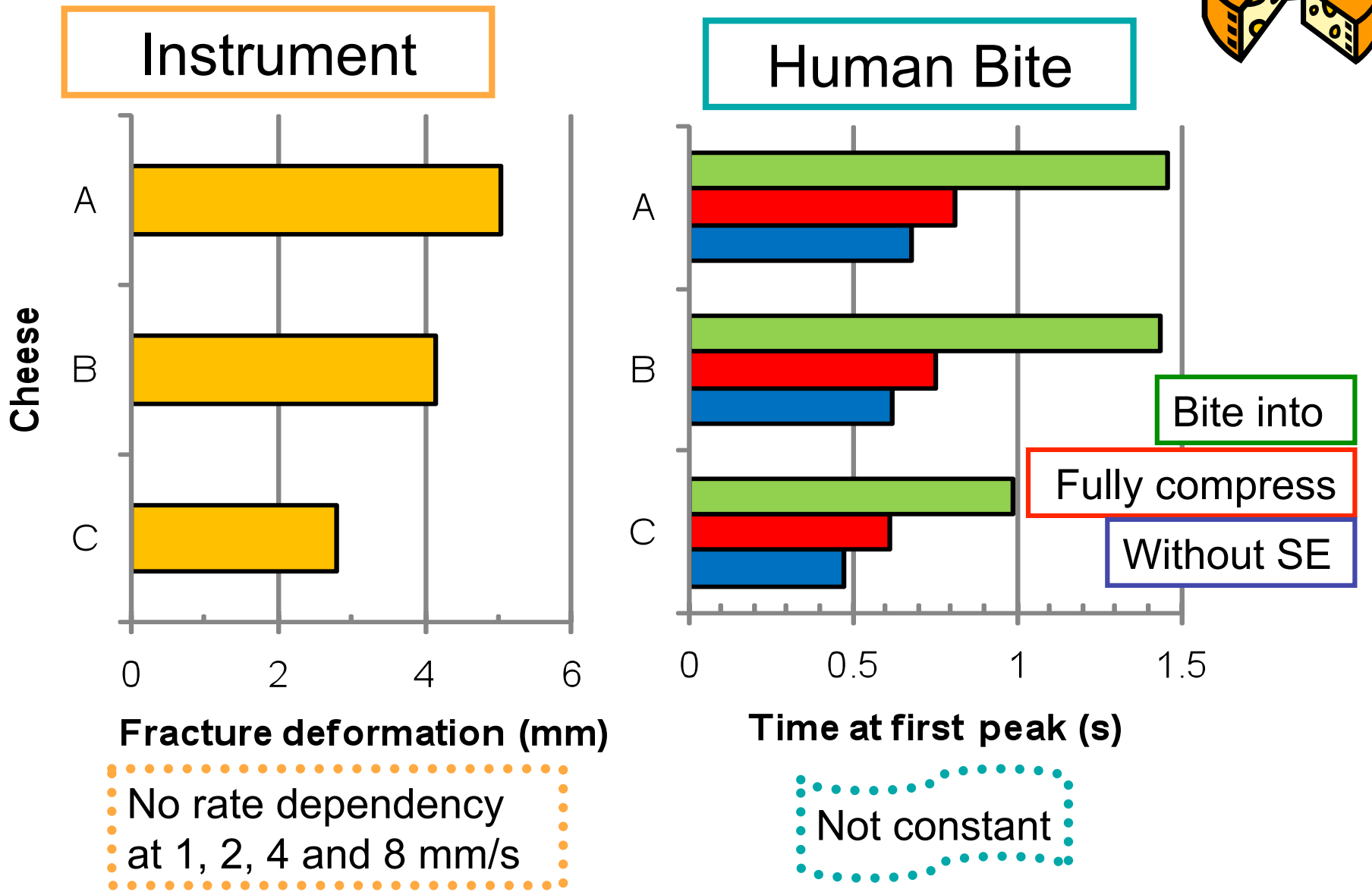
- Maximum bite force with the incisors increased with thickness of food
- Instrumental test showed a constant maximum load (>10 mm)
- Maximum bite pressure increased or constant with food thickness

H.Dan, H.Watanabe, & K.Kohyama: J. Texture Stud., **34**, 287-302 (2003)

Cheese Bite with Different Ways

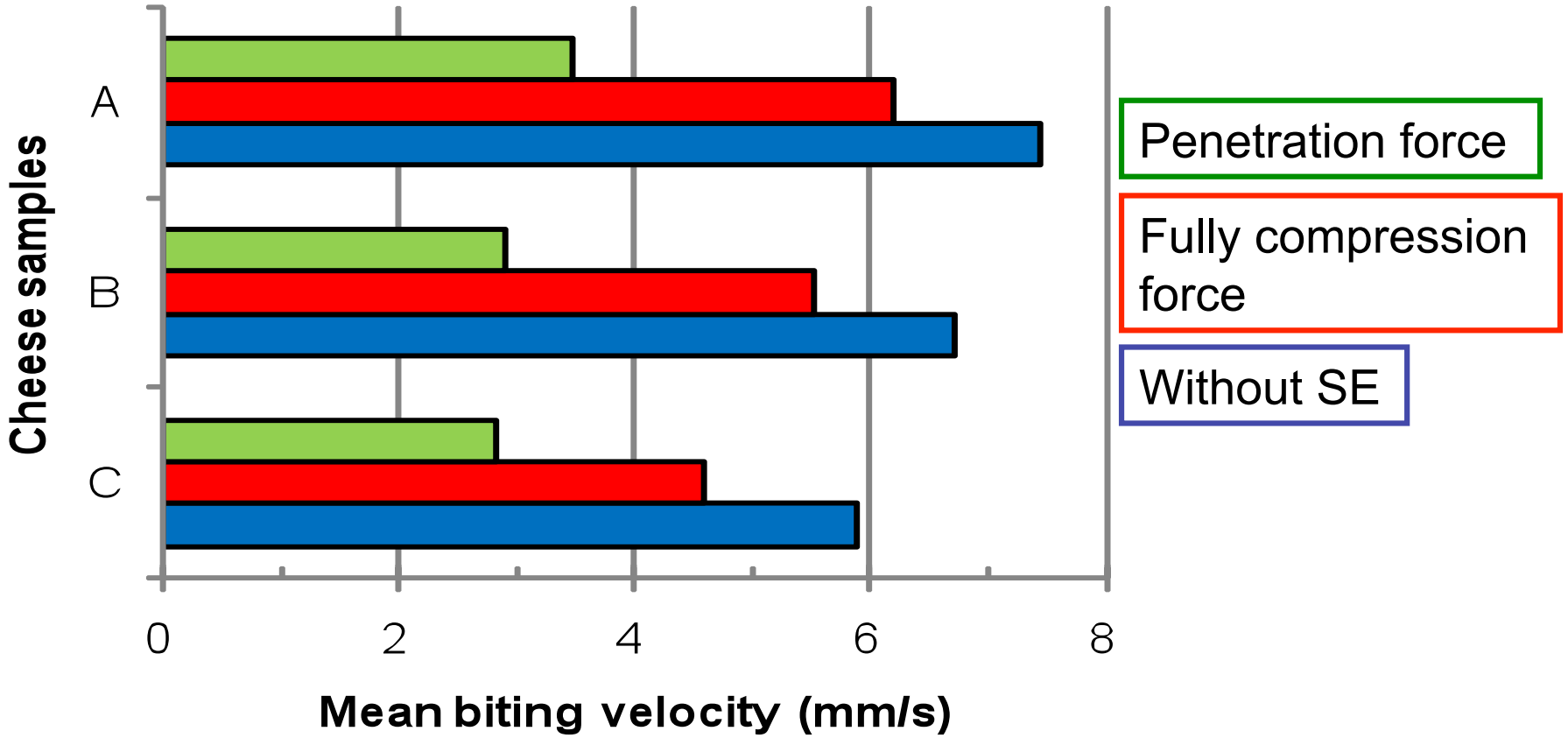


H. Dan, F. Hayakawa & K. Kohyama: Appetite, **50**, 158-166 (2008)



H. Dan & K. Kohyama: Archives of Oral Biology, **52**, 455-464 (2007)

Estimation of Bite Speed

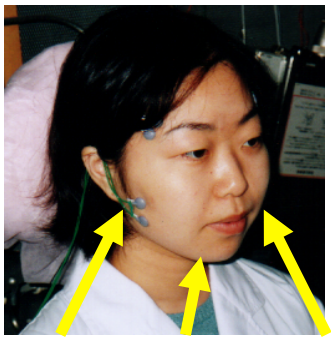


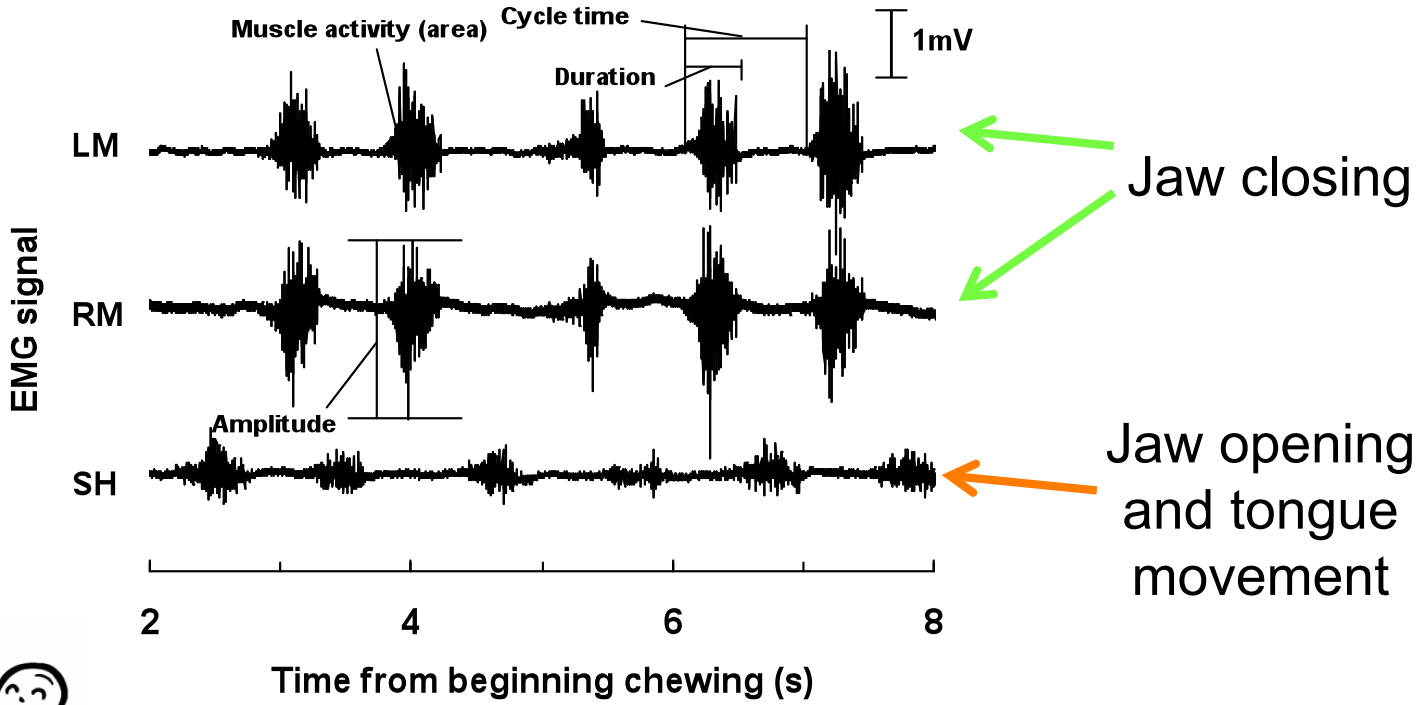
Fracture deformation / Peak time = Biting velocity

Biting velocity depended on biting way and sample

H. Dan & K. Kohyama: Archives of Oral Biology, **52**, 455-464 (2007)

Electromyography during mastication





Sample: 9g standard rice cake.

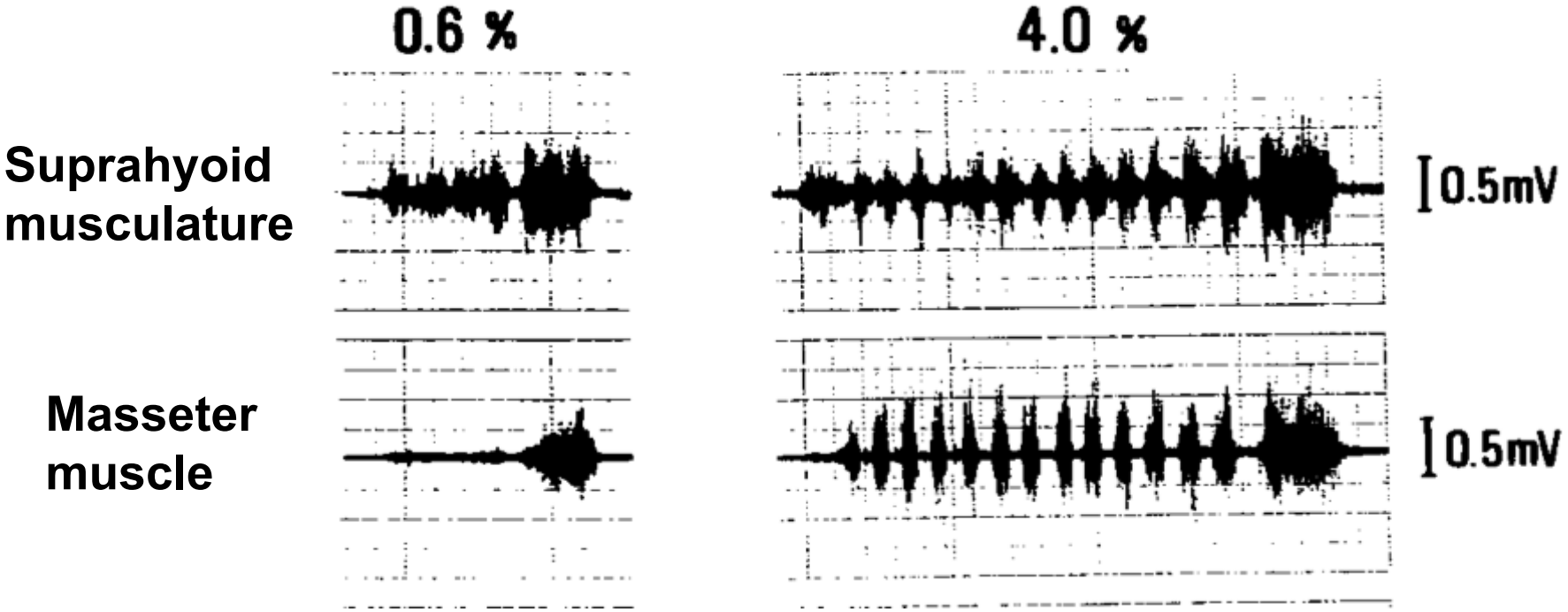
From Ms: No.chews, Mastication time, Cycle time
Both muscles: Amplitude, Duration, Muscle activity
SH/M: ratio of amplitude, ratio of muscle activity

Five chewing strokes in the early stage of mastication.

A subject took a piece of sample and kept it in the mouth. The subject then started chewing the sample at time zero.

K. Kohyama *et al.*: Biosci. Biotechnol. Biochem., **71**, 358-365 (2007)

EMG example in jelly eating

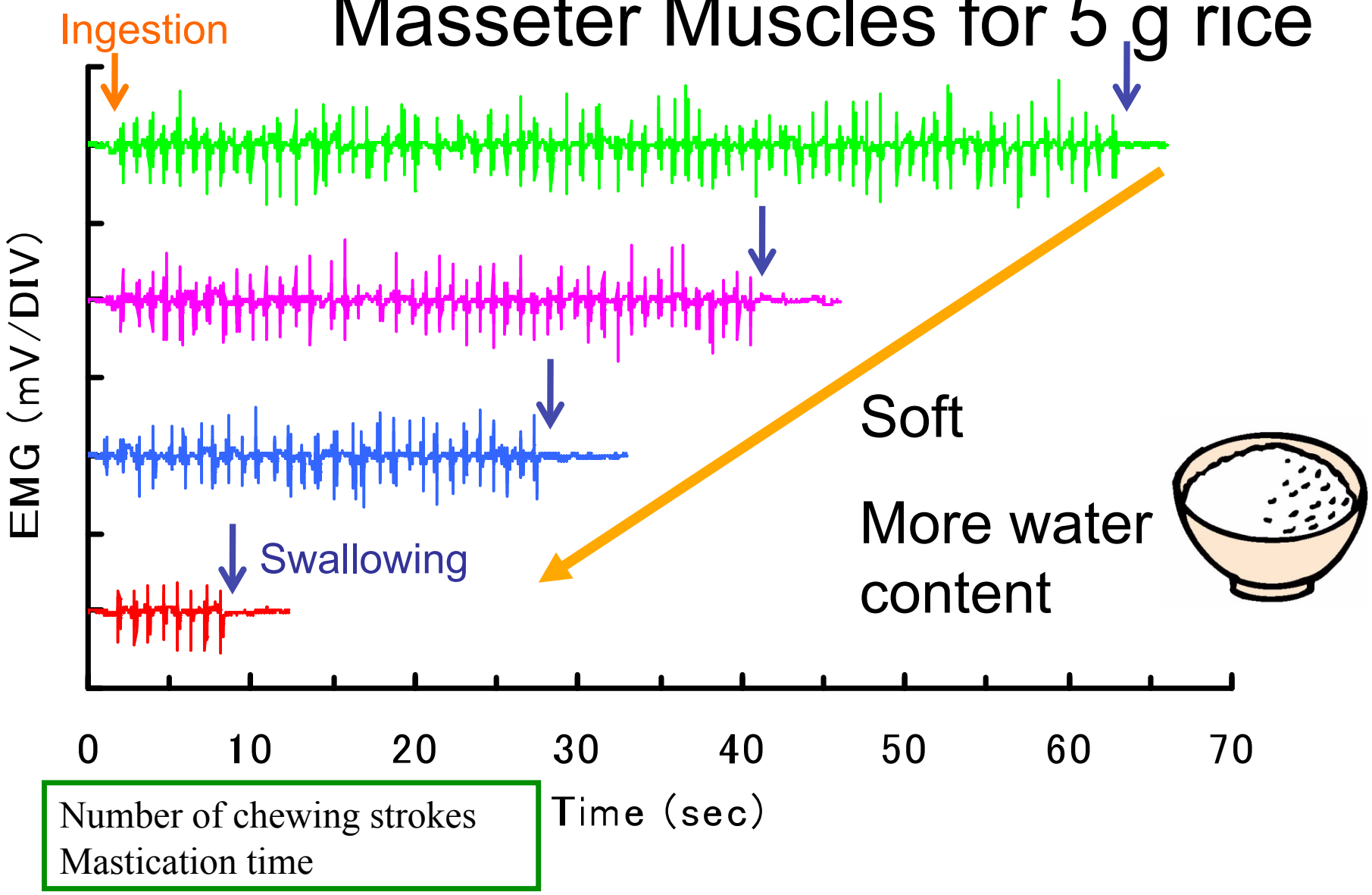


Soft gel (0.6% agar) was disintegrated by the tongue pressure against the hard palate while hard gel (4.0%) was chewed by the molar teeth.

Both the muscles acted at the swallowing.

K. Shiozawa, K. Kohyama, and K. Yanagisawa : J. Jpn. Soc. Masticat. Sci. Health Prom. (in Japanese), **3**, 51-56 (1993)

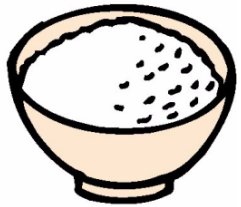
Example of Electromyograms from Masseter Muscles for 5 g rice



Number of chewing strokes
Mastication time

Y. Nakayama & K. Kohyama：J. Jpn. Soc. Masticat. Sci. Health Prom. (in Japanese), **14**, 43-49 (2004)

Water amount and Texture

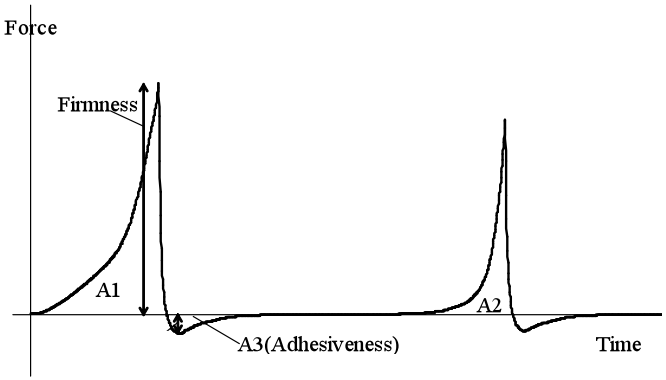


Water ratio (w/w)	Water (%)	Firmness (kPa)	Adhesiveness (A3, kJ/m^3)	Cohesiveness (A2/A1)
1.5	60.4a	51.2d	0.80a	0.296a
2.0	64.2b	43.9c	1.01ab	0.303a
3.0	72.9c	28.6b	1.29b	0.325a
4.0	79.2d	18.0a	1.81c	0.374b

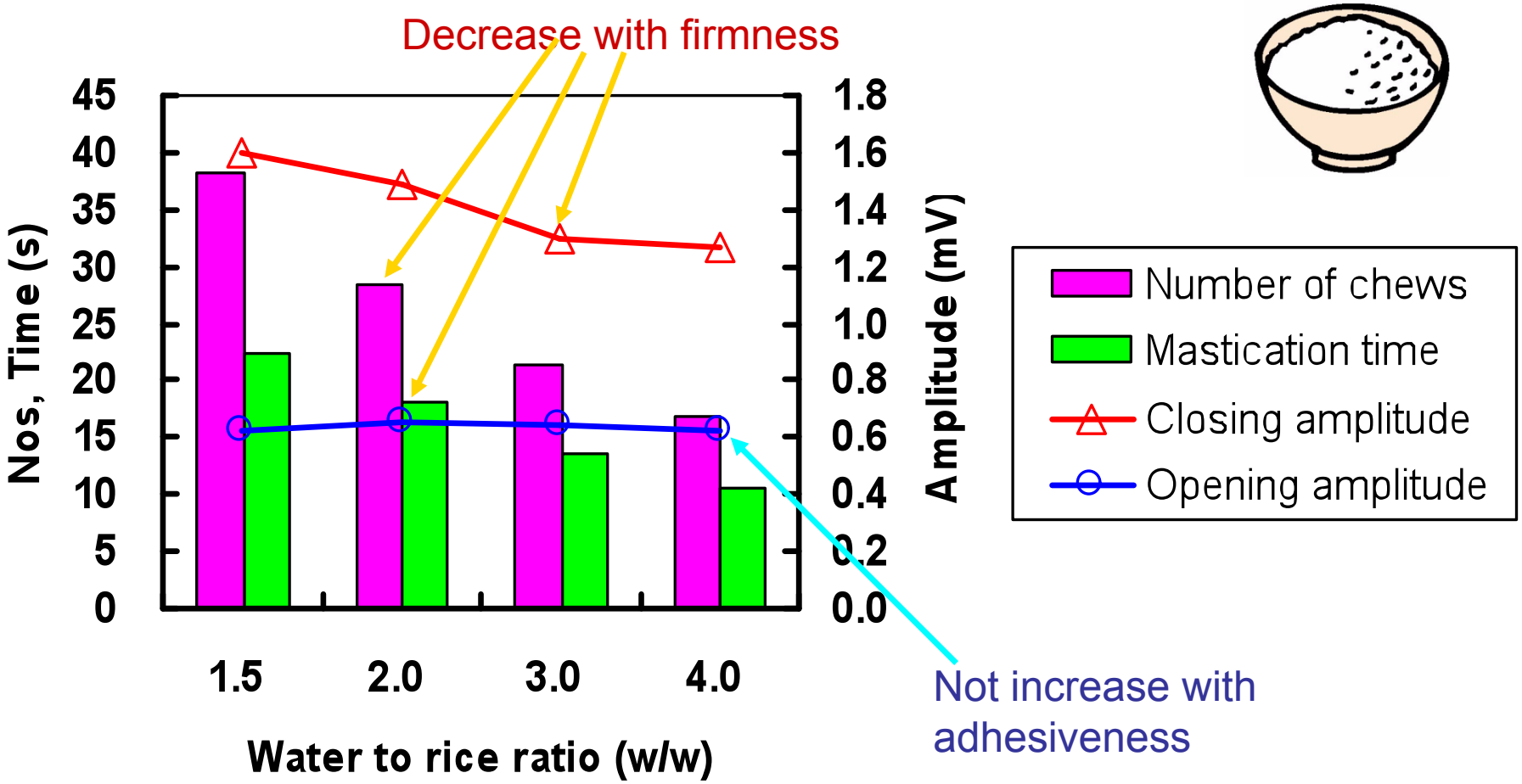
Values with different letters in a column differ significantly ($p<0.05$).

Wash-free type normal rice (*Koshihikari*) cooked with different water amounts.

K. Kohyama *et al.*: Biosci., Biotechnol., Biochem., **69**, 1669-1676 (2005)



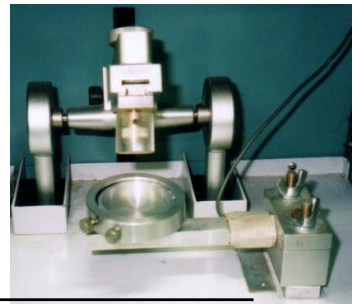
EMG results of rice cooked with various water



Soft rice cooked with more water (2-4 times to rice) is easy to consume.

K. Kohyama *et al.*: Biosci., Biotechnol., Biochem., **69**, 1669-1676 (2005)

Amylose Content and Texture of cooked rice

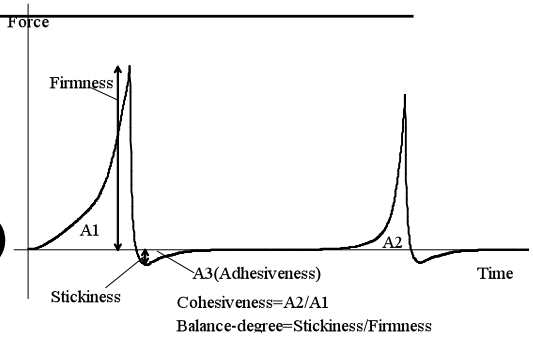


Variety	Amylose (%)	Firmness	Stickiness	Adhesiveness	Cohesiveness	Balance-degree
Mochiminori	1.80	1.88a	0.820b	0.217b	0.695c	0.436c
Milky Queen	9.26	2.24b	0.789b	0.173b	0.652a	0.352b
Koshihikari	16.27	2.49c	0.850b	0.208b	0.674b	0.341b
Hoshiyutaka	26.53	3.22d	0.065a	0.006a	0.679bc	0.020a
Yumetoiro	29.17	3.75e	0.000a	0.000a	0.695c	0.000a

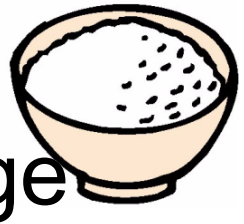
TPA values are in T.U.

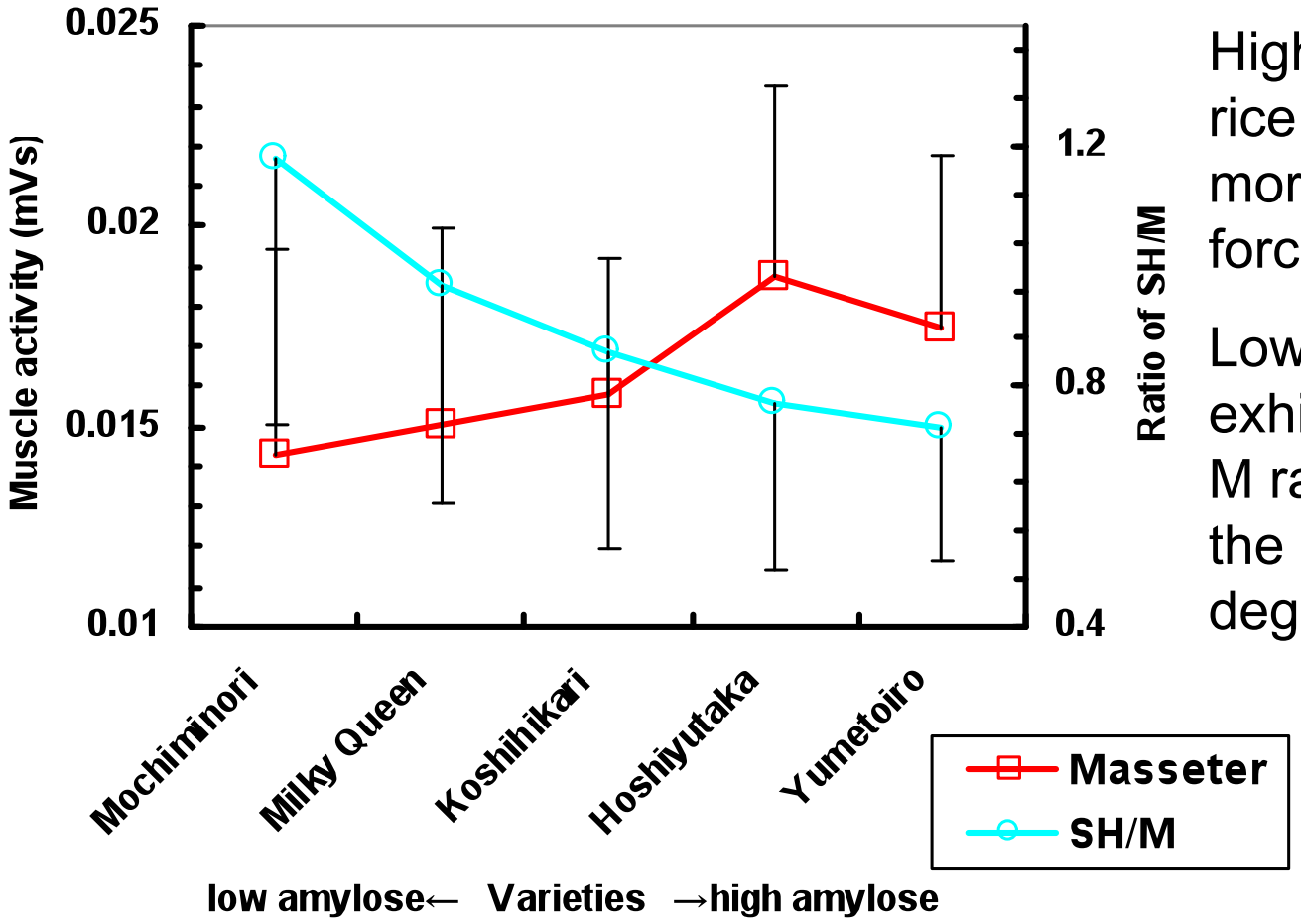
Values with different letters in a column differ significantly ($p<0.05$).

K. Kohyama *et al.* : J. Texture Studies, **29**, 101-113 (1998)



Amylose content changes the early stage



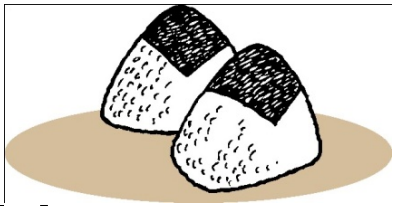


High amylose rice requires more chewing force as it is firm.

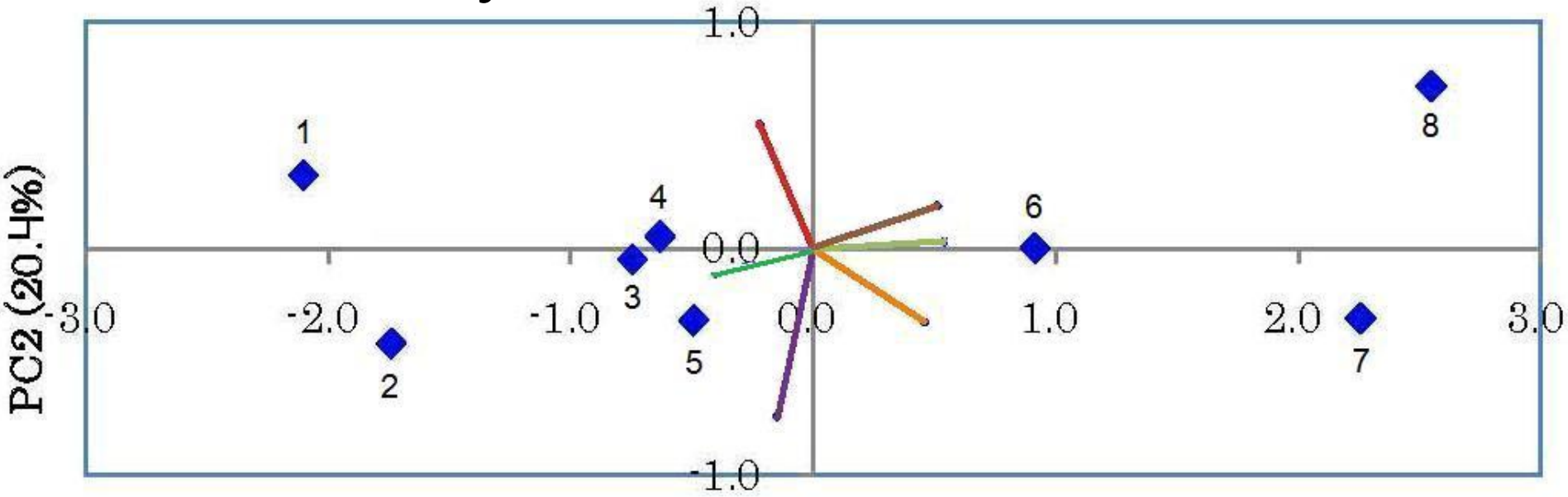
Low amylose rice exhibits high SH/M ratio same as the balance-degree.

The cultivar differences were significant in the early stage, but not significant in later stages of mastication.

K. Kohyama *et al.* : Journal of Texture Studies, **29**, 101-113 (1998)



PCA analysis with different rice cultivars



Selected EMG parameters from 19

- Mastication time
- Duration per chew
- Muscle activity per chew
- Early stage interburst
- Middle stage cycle
- Late stage amplitude

→ Amylose content

cultivar 1(0.4%) to 8(33.3%)

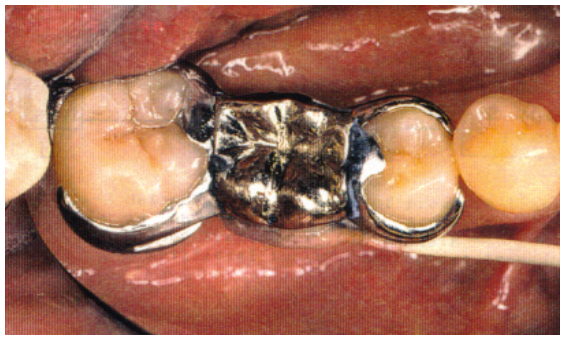
PC2 = changed during mastication, cannot be measured by instrumental tests

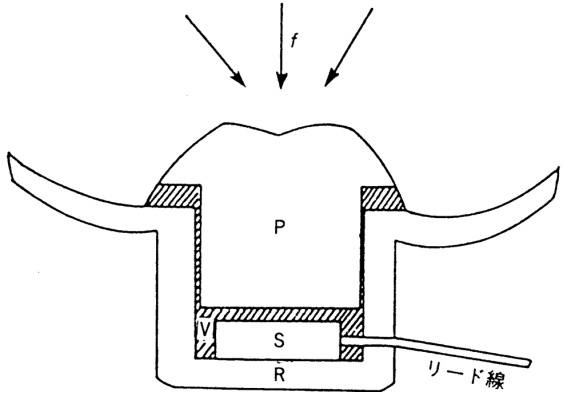
N. S. Sodhi, *et al.*: to be presented at Food Oral Processing Conference

Cooked Rice Cake (Mochi)

Highest mastication force: 18.5kgf.

J. Takahashi & F. Nakazawa: Jpn. J. Home Econ. (in Japanese), **38**, 107-113 (1987)





Artificial tooth pressure sensing device

About 50% of elderly people →

Mochi has been difficult to consume than before.

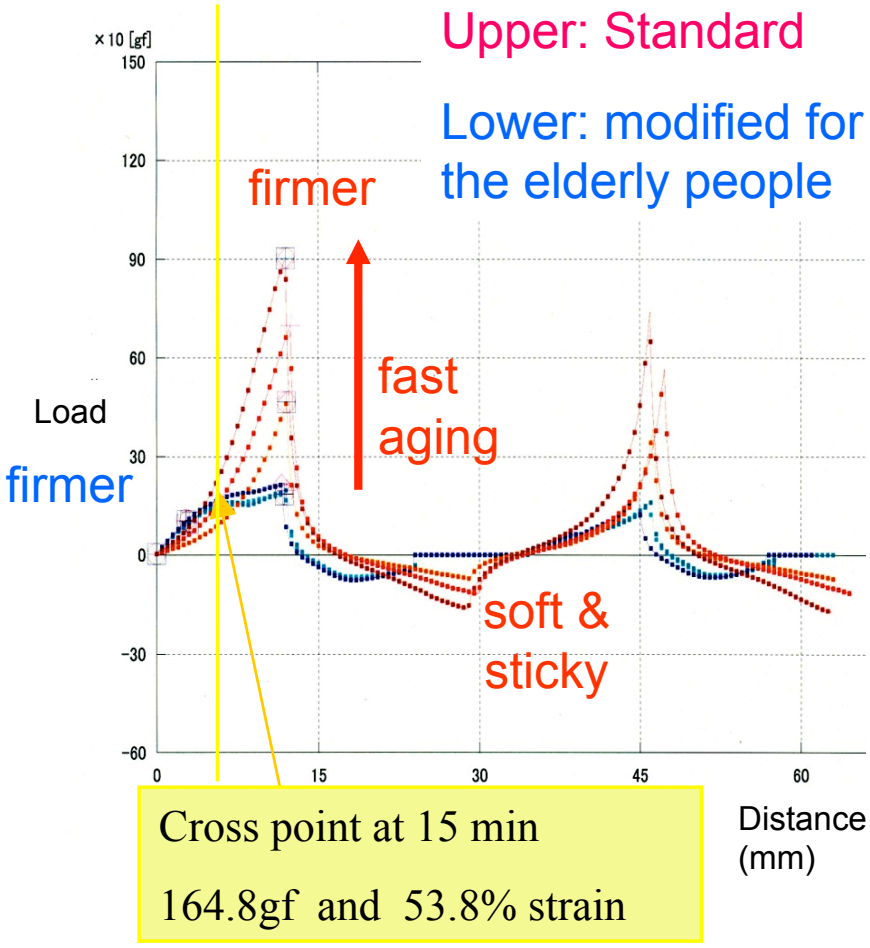
Meal survey for 556 elderly people in Kasama City, Ibaraki

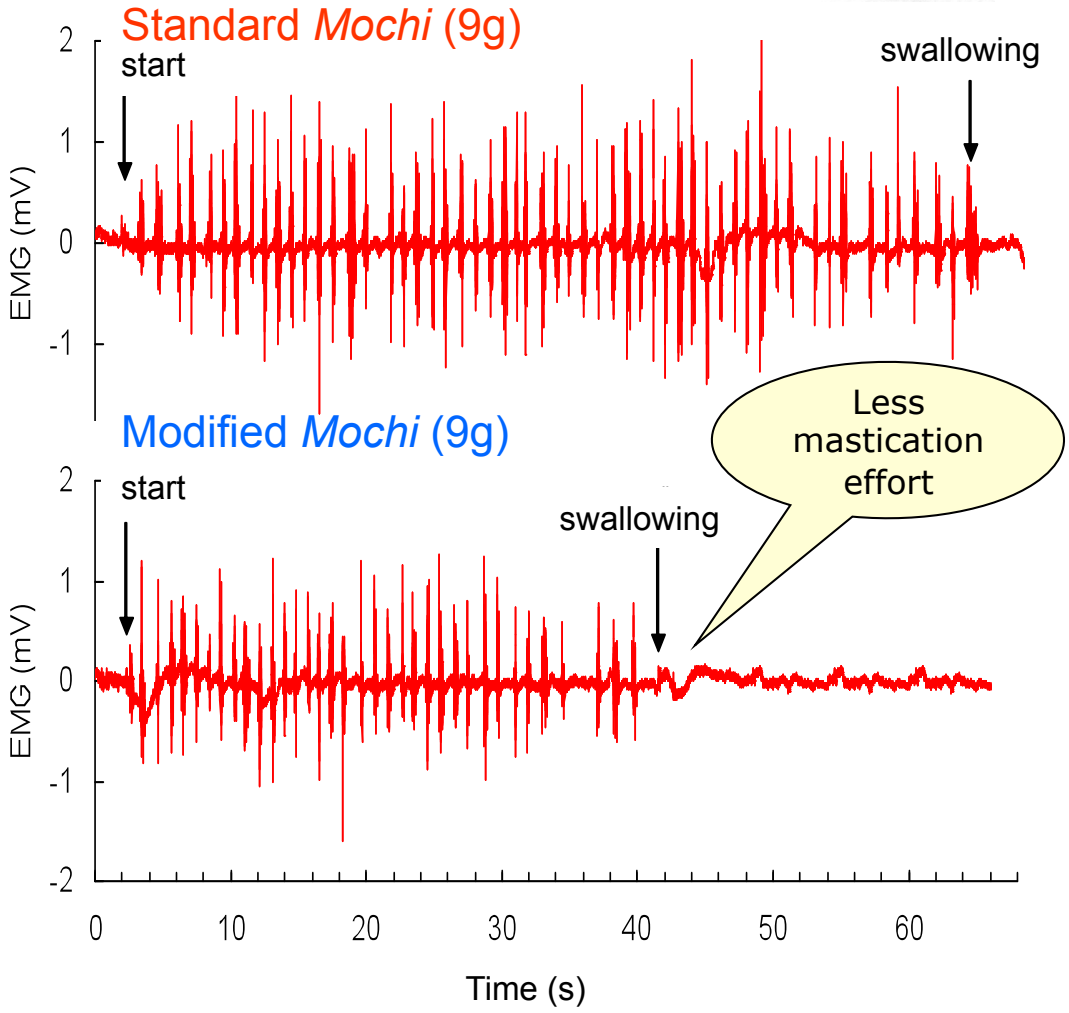
Numbers of elderly people are suffocated by Mochi.

To prevent suffocation

1) A small piece of rice cake
2) Texture modification of rice cake

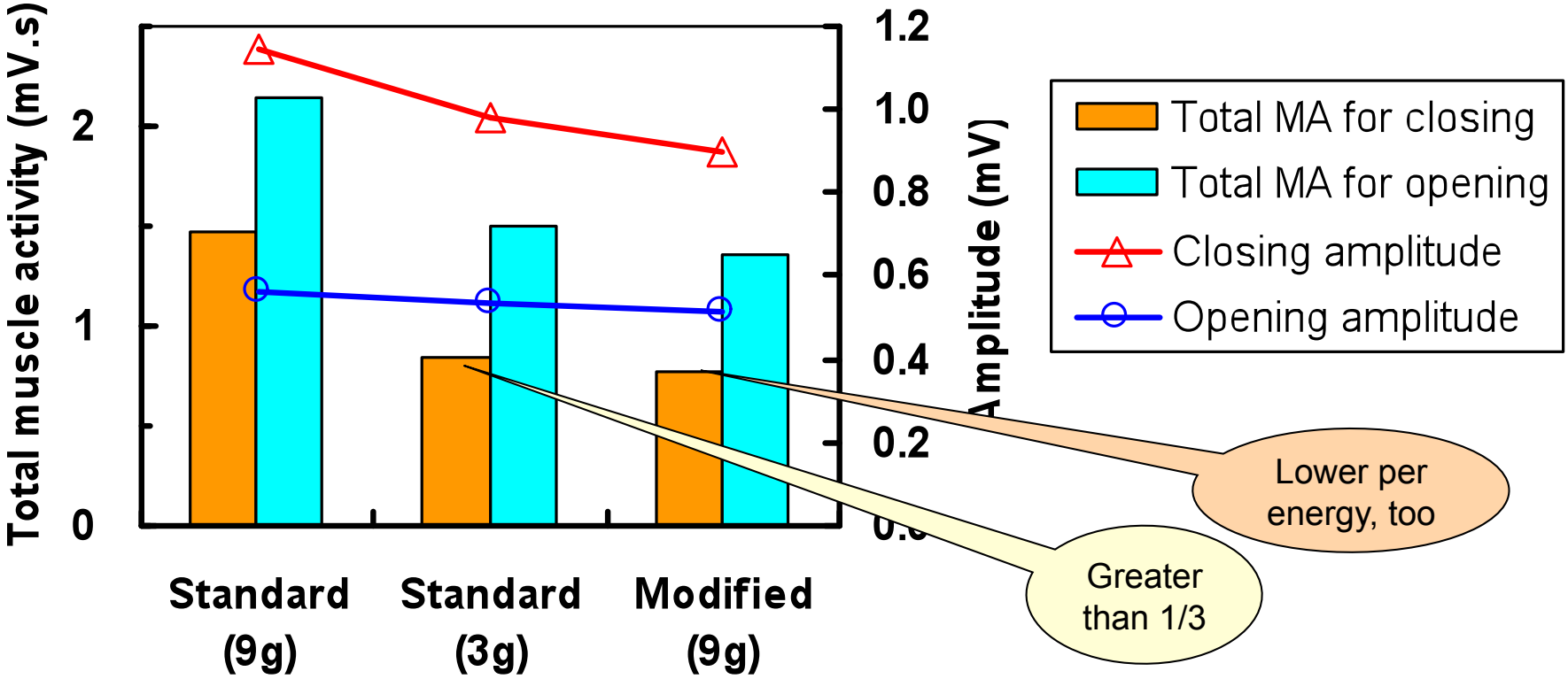
Texture of *Mochi* (rice cake)





K. Kohyama *et al.*: Biosci. Biotechnol. Biochem., **71**, 358-365 (2007)

Results of Mastication Recordings

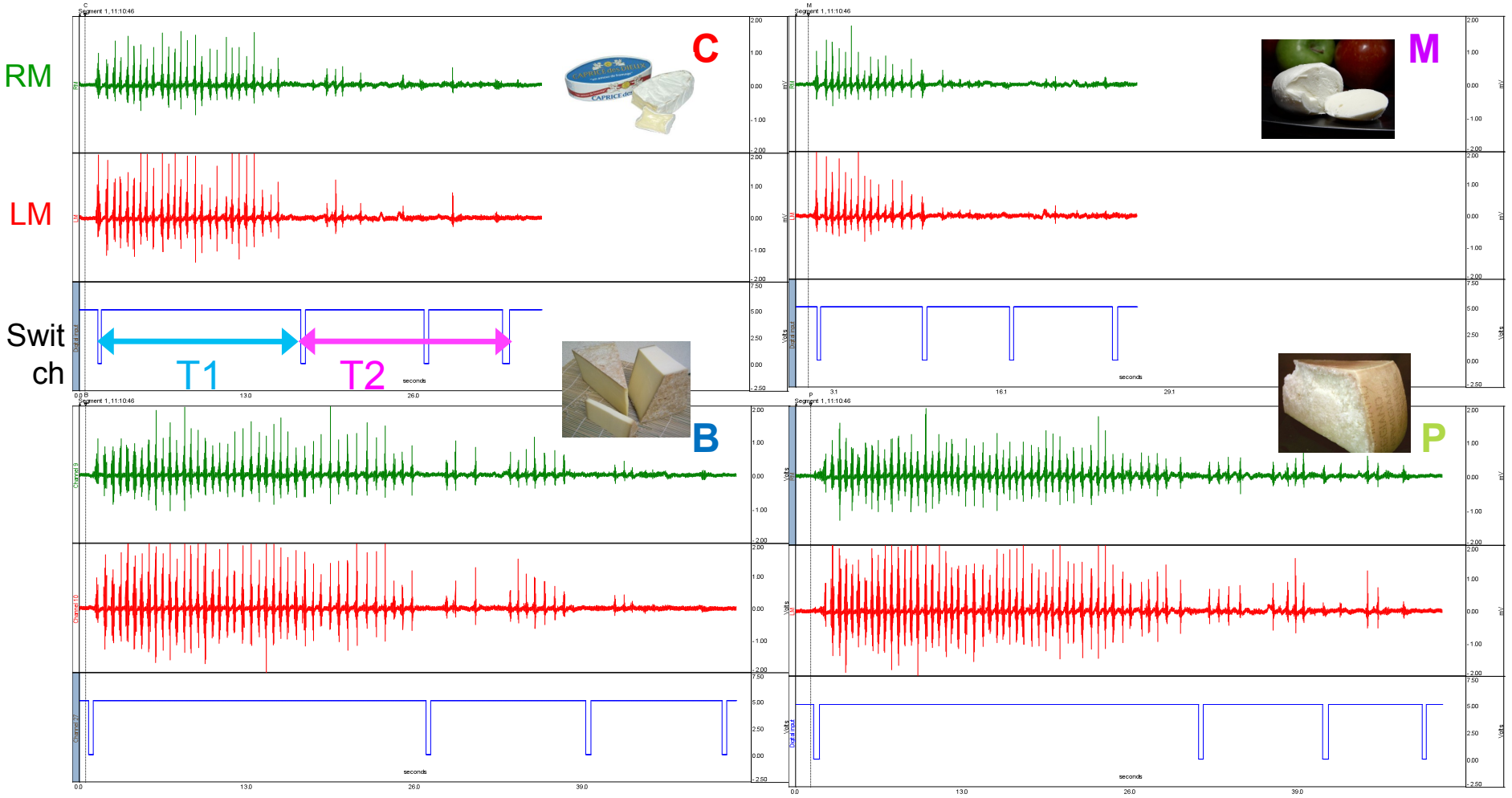


Small amount mouthful reduced mastication time, muscle activities of jaw closing muscles, but EMG duration and muscle activity of jaw opening muscles unchanged.

Yawaraka Fukumochi reduced mastication time, chewing cycle, EMG amplitude, duration, muscle activity for both muscles.

K. Kohyama *et al.*: Biosci. Biotechnol. Biochem., **71**, 358-365 (2007)

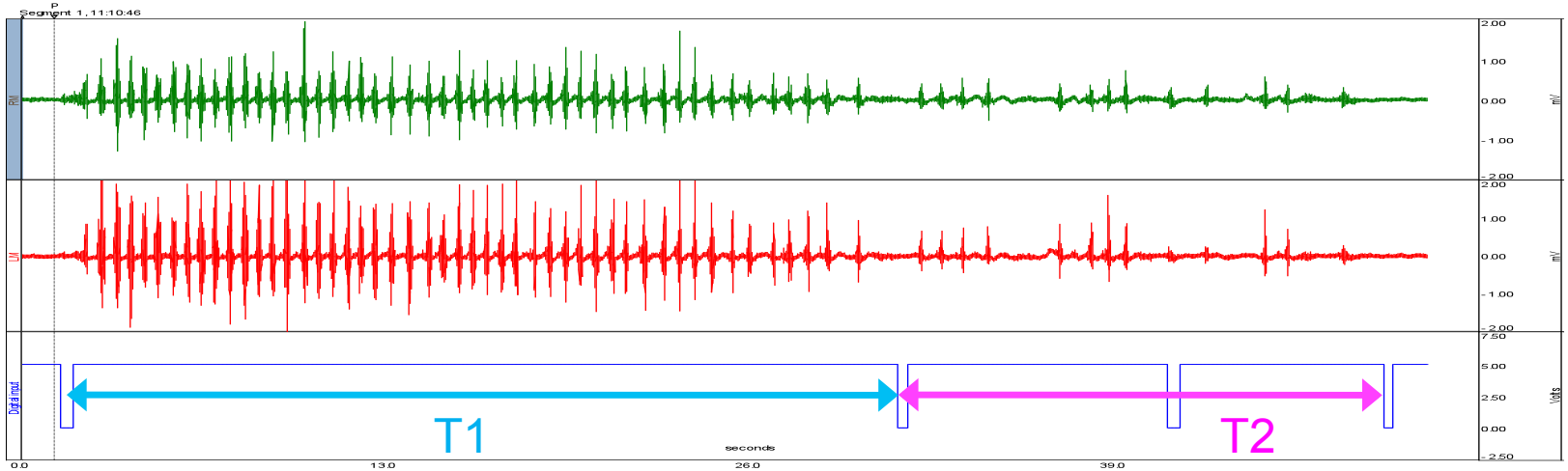
EMG results of natural cheeses



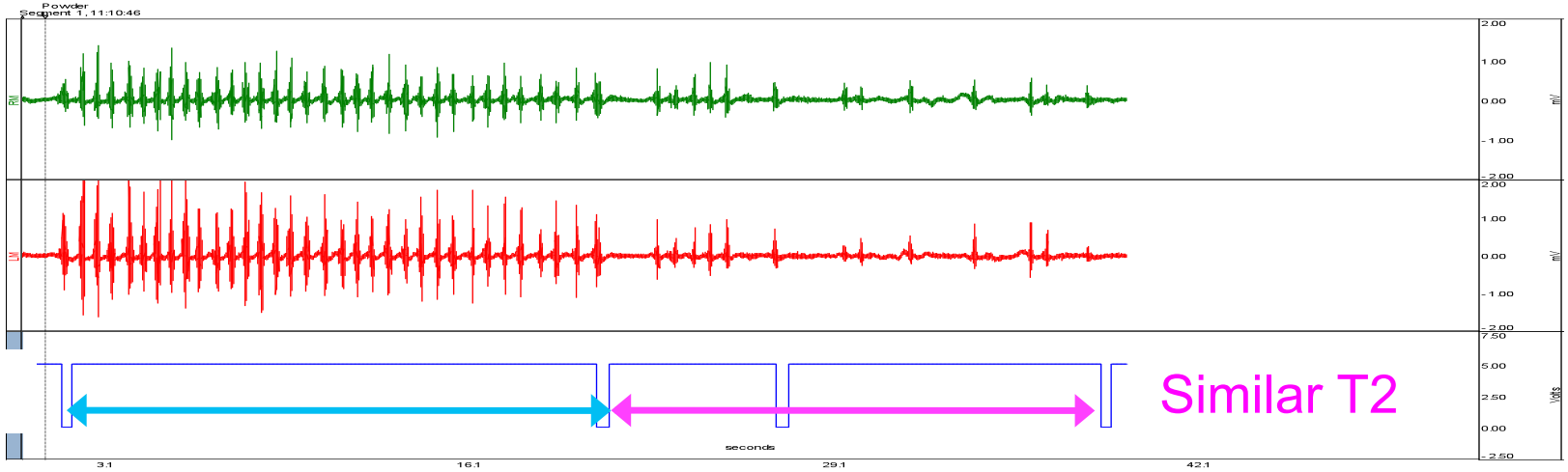
EMG examples of a subject during eating 5 g cheese samples.

Effects of shredding

A block



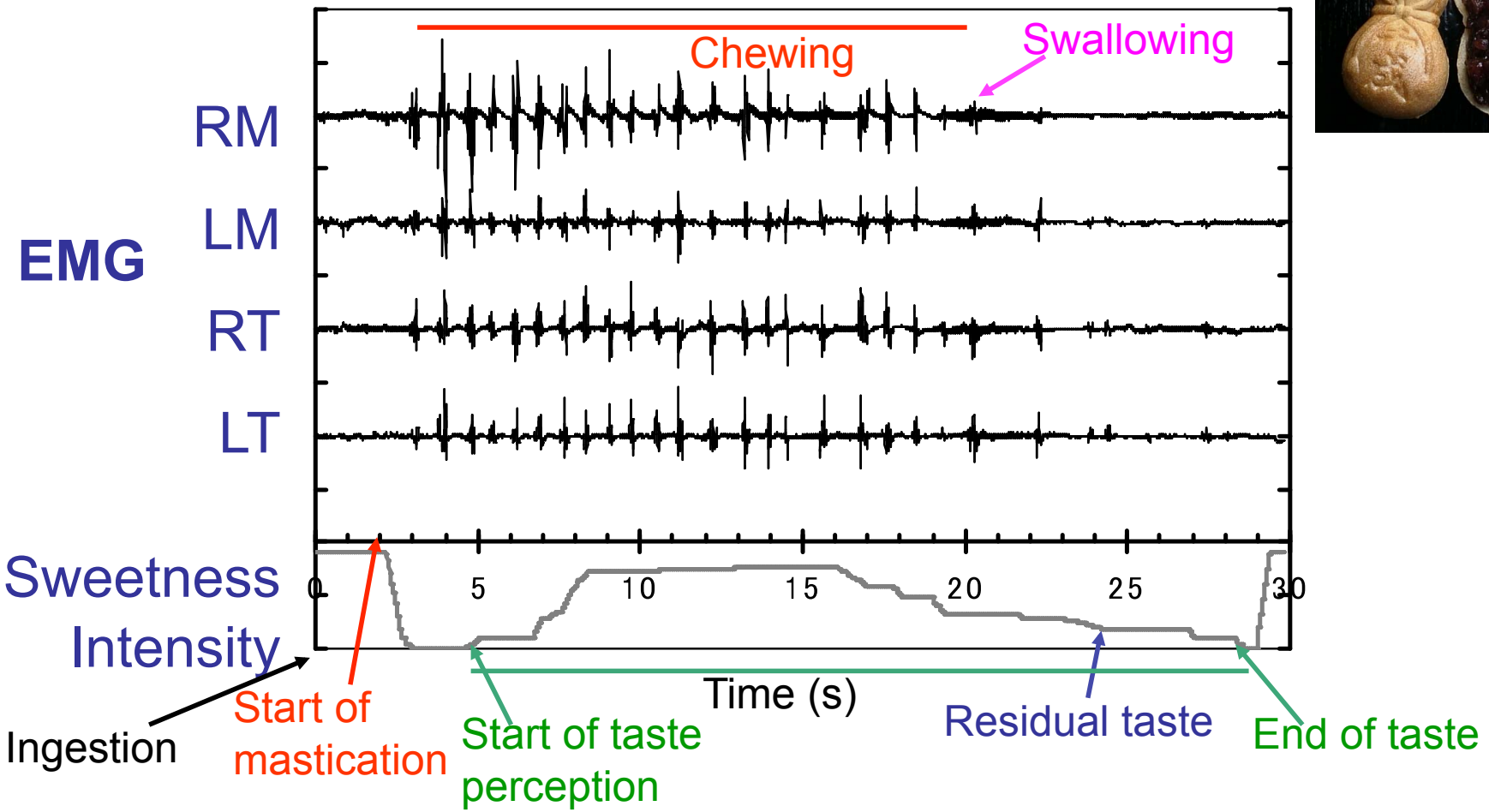
Shredded



EMG examples for 5g of Parmigiano-Reggiano.

EMG and Time-Intensity chart

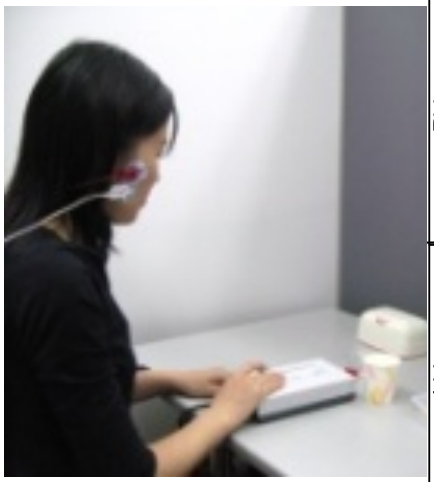
Sweetness release during mastication from a piece of *Monaka* (bean jam filled in a shell made of glutinous rice).

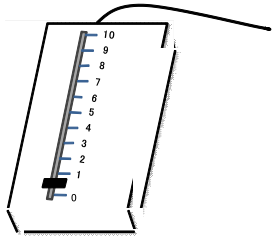


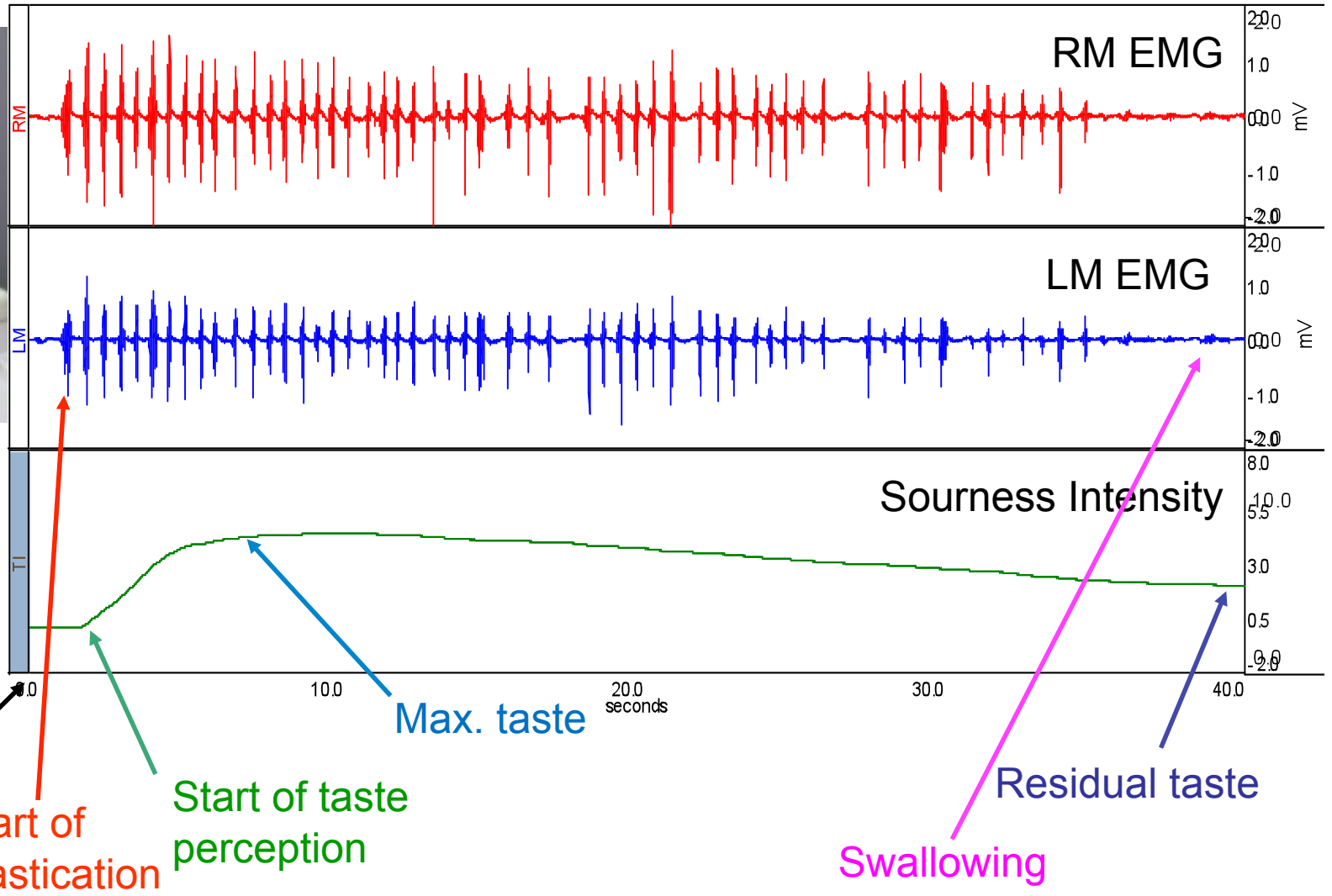
K. Kohyama *et al.*: Rep. Natl. Food Res. Inst. (in Japanese), **67,** 21-26 (2003)

Poster 008

EMG and Time-Intensity chart for gummy jelly



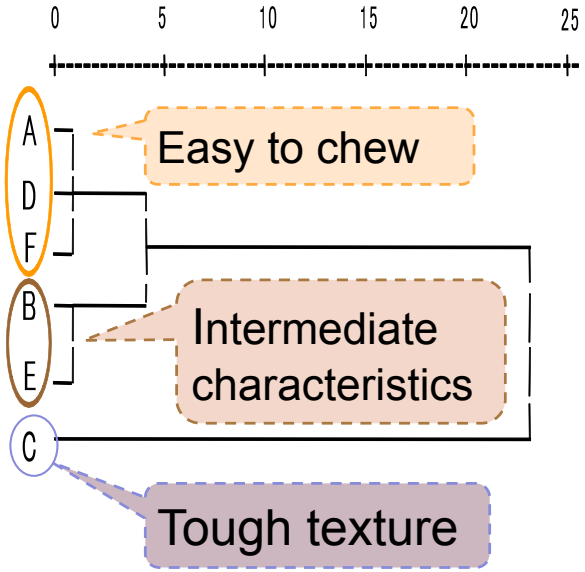




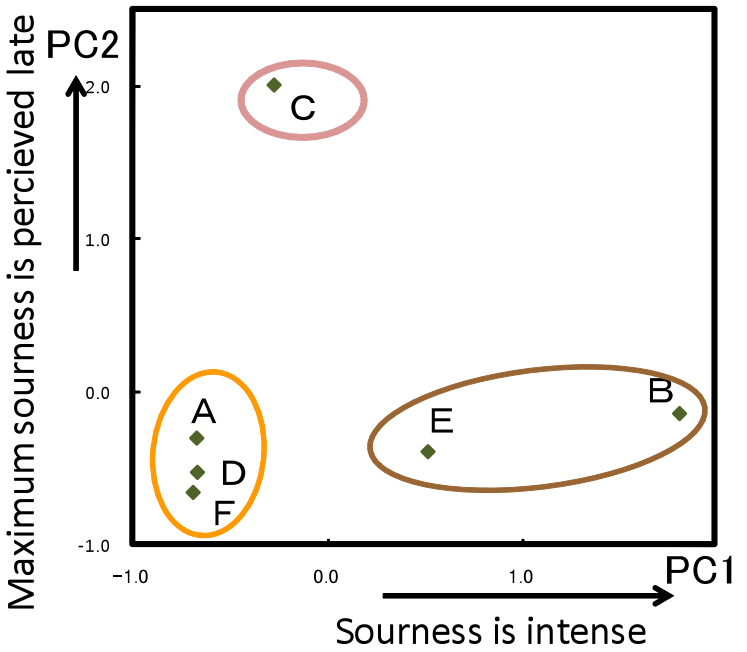
F. Hayakawa *et al.* : Food Sci. Technol. Res., **15**, 75-82 (2009)

Characteristics of gummy jellies

Cluster analysis on EMG parameters



Principal component analysis on sensory time-intensity parameters



EMG parameters were not significantly related to rupture stress and strain, and mechanical stress values at ≦60%.

Texture measured with EMG was related to mechanical stress under very large compressive strain (90%), and it related to flavor release measured by the T-I sensory evaluation.

Summary

Application of the Human Mastication Measurement on Food Texture Analysis

1) time course analysis of texture change in the mouth during mastication
2) combined with T-I analysis for interaction between texture and flavor release
3) relation with physical properties
4) novel, objective sensory evaluation methods without language
5) effects of serving / eating methods
6) individual differences between subjects

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Thank you for your attention!