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Chewing Pattern Analysis and Panel Selection for Sensory Evaluation using Electronic Sensing System(ESS)

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Electronic Sensing System(ESS)을 이용한 저작 패턴의 분석과 관능검사 패널 선발에 관한 연구

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ABSTRACT

안면 특정 근육의 움직임으로부터 기록되는 Electronic Sensing System(ESS) 신호는 인간의 관능검사에 사용할 수 있다. 본 연구는 ESS를 이용하여 저작패턴에 따라 나타나는 결과들을 분석, 분류하고 각 그룹별로 같은 식품에 대한 관능 감지도의 차이를 검사하기 위하여 각 그룹별 씹는 특성을 파악하여 이에 따라 패널요원들을 선발하였다. 패널들을 젊은 남·여 및 노년 남·여 총 4그룹으로 구분하여 껌 및 당근의 저작과정에 대한 패턴 즉 속도, 시간 및 총 에너지를 비교한 결과, 젊은 남·여 그룹(n=47, 18~42세, 남성 27명, 여성 20명) 및 노년 남·여 그룹((n=44, 65세 이상, 남성 33명, 여성 11명)은 저작 특성들이 서로 달라 같은 식품에 대하여 서로 관능감지도가 달라질 수 있음을 나타내었다. 또한 ESS에 의한 각 패널들의 검사치를 분석한 결과 껌을 씹을 때의 에너지에 대한 표준편차는 2.0 이하(n=71) 그리고 씹는 속도의 경우는 0.1 이하로 반복실험의 재현성이 있었다. 91명의 패널들을 저작 에너지 및 씹는 속도에 따라 4 그룹(낮은 에너지를 사용하며 천천히 씹는 그룹, 낮은 에너지를 사용하면서 빨리 씹는 그룹, 높은 에너지를 사용하며 천천히 씹는 그룹, 그리고 높은 에너지를 사용하며 빨리 씹는 그룹)으로 분류하고 각 그룹별 평균값에 가장 비슷한 양상을 나타내는 6명씩 총 24명의 관능검사 요원들을 선발하였다.

Key words : Electronic Sensing System(ESS), 관능검사, 저작패턴, 재현성, 저작에너지, 저작속도, 패널선발.

Ⅰ. INTRODUCTION

Food texture has long been recognized as an important sensory attribute of food which often determines quality and acceptability, and has the greatest effect to consumer's food selection and preferences. In food industry, it is becoming more important to maintain quality and predict consumer acceptance, and in developing a new product or optimizing processing variables.

Both instrumental measurements and sensory evaluation techniques are used in food texture research to assess texture parameters. Many instrumental methods have been used to evaluate the textural characteristics of food.[1~4)] Instrumental measurements of the mechanical properties of food often correlate poorly with sensory evaluation, because of heterogeneity of foods, textual changes during chewing and implicated mastication movement in humans. Additionally, there were many factors of biological and psychological influences in the mouse.[5~8)]

Sensory and instrumental tests have been often carried out in order to obtain correlations between two methods.[9)] The evaluation of the relationship between sensory attributes and instrumental parameter often assumes a linear relationship between a single sensory attribute and a single instrumental parameters. However, the failure to examine the possibility of a nonlinear relationship often result poor statistical correlations.[9)] Furthermore, the use of several instrumental parameters for the prediction models has been suggested by Meullenet.[4)]

Electromyography(EMG) has been used to investigate food attribute during the masticating of food.[10~15)] Boyar et al.[5)] reported that the available techniques for examining mastication process provide knowledge about food texture, and the potential using EMG curve gives a direct measure of muscle activity required for chewing foods. EMG has been also used to characterize food texture, and several studies have been addressed the relationship EMG characteristics and food texture parameters.[1,8,14,15)] It can be conventionally used to obtain a series of parameters describing the muscle work including the timing of chew sequence, the number of chews, the chew rate and the chewing pattern etc. These parameters were used collectively to determine subjects' chewing behaviors and chewing style.[16,17)] Brown et al.[11,12)] showed that the temporal aspects of the chew cycle were producible between EMG record and developed method, which describes chewing behavior based on data obtained from EMG record. This method gives information on mastication movement and force, as well as differences among subjects, and therefore may give closer results to subjectively perceived texture than other instrumental measurement.

Clearly it is most important to understand how consumers chew food and how individuals differ in their chewing patterns. Kilcast and Lewis[18)] used integrated peak height of EMG to measure the mastication activity of individuals' chewing of fruit pastilles. Sakamoto et al.[15)] used EMG data to determine mastication patterns for 43 food products. They concluded that chewing behavior was a function of EMG parameters and EMG was a potential tool for observing sensory characteristics during chewing. Brown et al.,[1] examined that differences in subjects' break down pattern in mouth may account for the abilities of subjects to distinguish samples in term of texture and flavor.

Individual variation in chewing patterns may have an influence on their sensory perceptions. In order to explore the relationship between sensory evaluation and chewing pattern, EMG measurements have been substituted sensory methods in tenderness determination of beef which is cooked at temperature range of 45~80℃.[19] Different patterns of chewing behavior may lead to significantly different sensory ratings and also lead the consumers to draw different perceptual conclusions about the texture of food.[1,13] It is possible that average sensory scores from sensory panels may be distorted according to the representation of chewing behavior within the panel.

Therefore it is very important in food industry to evaluate the chewing pattern from the chewing behavior of panels and to select the panels according to their chewing pattern. Many commonly measured parameters of the mastication process are also significantly affected by factors which were age and gender of the subjects but these factors were not related to the texture of food products.[20~22]

In this study, we have attempted to characterize chewing pattern by chewing behavior of individuals and classify the chewing pattern by chewing parameters using electrical sensing system(ESS) which was developed in our laboratory with user-friendly data acquisition and analysis software to investigate the relationship between the features extracted from the ESS signal and food attributes.[23] We also examined the reproducibility of the chewing pattern by ESS and whether the chewing pattern by ESS was affected by age or gender of individuals.

Ⅱ. MATERIALS AND METHODS

1. Food Samples

Fresh raw carrot and chewing gum (Plentpak, Wrigley Jr. Company, Chicago, IL) were purchased from a local supermarket(Dillon's, a subsidiary of Krogers, Manhattan, KS). Carrots were cut into 1 cm cross sections, placed in a zipper sealed plastic bag (Ziploc®), and then stored at 4℃ for 24±2hr. The carrot samples were allowed to equilibrate at 21±1℃ for 60 min. before testing. Chewing gums were stored at ambient temperature, unwrapped and folded into thirds for ESS testing. Carrots were used for the chewing pattern classification as described by Brown et al.,[11,12] and were considered as foods that progressively changed in texture during chewing. Chewing gum, on the other hand, has little change in size and consistency during chewing and the effects of the rhythmical chewing pattern are relatively small.[22]

2. Recruitment of Panelist Selection

91 panelists were recruited from the Manhattan, KS community. 47 were in the age range from 18 to 42 years, and 44 were 65 years or older. These panelists were selected on the basis of no missing teeth, however dentures and crowns were allowed. There were 27 females and 20 males in the young group, and 33 females and 11 males in the older group. Of the 91 panelists, 69 were North American, 11 were Asian, and 11 were European. All panelists were paid for participation.

3. ESS Data Acquisition

The ESS system consists of surface electrodes, an amplifier, data conditioning and data acquisition. Data analysis software was developed using Lab View package (National Instruments, Austin, TX).[23] Surface electrodes (E5G, Astro-Med, Inc, West Warwick, RI) were used to obtain the ESS signals from facial muscle motion. The electrode measured the muscle tension and frequency of movement (Nm/sec) and converted the signals into voltage units. The voltage was amplified by a high performance A.C. amplifier (P511, Astro-Med, Inc, West Warwick, RI) with 12 position built-in calibrators for simplifying the calibrations. This amplifier featured high gain (from 50 to 200,000), adjustable filters, low noise, and output that was easily interfaced with peripheral devices. A control box which designed in our lab served as an interface between the output of the amplifier and the data acquisition board. Panelists could control the data acquisition using buttons on the control box for starting or stopping. The ESS data were acquired by using a data acquisition(DAQ) board (AT-MIO-16E-10, National Instruments, Austin, TX) featuring 24-bit A/D conversion up to 100 KS per second scan rate.

In this research, masseter muscle motion behavior was recorded during chewing of either gum or carrot. Two channels with five electrodes were used. The masseter muscle was identified as the central point on the line drawn between the bottom ends of the nose and the ear. The panelist's facial skin was cleaned with alcohol (75% concentration) and conductive cream (EC2, Astro-Med, Inc, West Warwick, RI) was used to fix the electrodes on the face. Two electrodes were placed on the left masseter muscle (Channel 1): the first one was at the masseter muscle location and the other was about 2cm vertically below the first one. Another two electrodes were placed on the right masseter muscle following the same facial geometrical description as for the left side (Channel 2); one electrode was placed on the arm as an earth electrode for both Channel 1 and 2.

Carrot or gum were each evaluated by chewing naturally on both sides, using only the left side for chewing, and using only the right side for chewing. The panelist was encouraged to chew at his/her natural chewing pace. For natural chewing, the panelist was allowed to adjust the food inside the mouth and to chew on the left side or right side upon his/her preference.

4. The ESS Test for Chewing Pattern

Panelists were asked demographic information and the ESS test procedure was reviewed before testing. Panelists chewed the first gum for 60 seconds naturally and expectorated. The panelist was provided a second piece of gum which was chewed on the left side for 30 seconds. A third piece was chewed on the right side for 30 seconds before expectoration. The carrot was given next, and the panelist chewed it naturally first until ready for swallowing. A second carrot slice was provide for the left side chewing prior to swallowing and the third slice was chewed on the right side until completely masticated and swallowed. Panelists had a 5 minutes break between tests and distilled water was used for rinsing the mouth between tests.

Duplicate data were collected for chewing energy or the total energy distribution (voltage x second), e.g., the energy of the entire chewing curve from start to finish and chewing time. The extracted features from the acquired data have been described previously by Wang et al.[23] The acquired ESS is the electrical potential of the muscle motion (voltage) divided by the chewing time. The extracted ESS parameters include: 1) chewing activity, the amount of energy per 10 seconds, and 2) chewing speed, the number of chews divided by the chewing time (60 or 30 seconds),and chewing time, the swallowing time.

Ⅲ. RESULTS AND DISCUSSION

1. Reliability of ESS Measurements

The ESS measurements of the chewing patterns for 91 persons in this study were consistent and reproducible for most of the tested persons. Chewing activity ranged from 6.6 to 51.0 (voltage, V) for all subjects and chewing speed ranged form 0.7 to

<Table 1> **Consistency of ESS measurements for free style chewing with gum[a] and carrot[b]**

Chewing energy (voltage)		Chewing speed (number of chews / chewing time)	
Low	6.6~11.5	Slow	0.7~1.1
Low-Medium	11.5~14.6	Slow-Medium	1.1~1.2
Medium-High	14.7~20.6	Medium-Fast	1.3~1.4
High	20.7~51.0	Fast	1.4~1.8

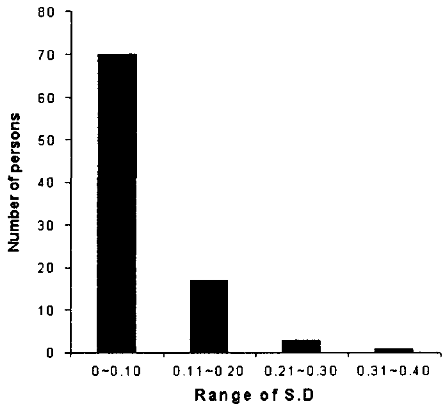
[a] chewing naturally for 60 seconds chewing energy and chewing speed.

[b] chewing time until swallowing a raw carrot.

1.8 chews/sec., which was devided to 4 groups by number of persons(n=22 or 23) <Table 1>. The standard deviations for each panelist for the largest majority(n = 71) was 2.0 or less <Fig. 1>, and only three persons had standard deviations of more than 6.0. The same pattern was noted for chewing speed <Fig. 2>. Values ranged from 0.7 to 1.8 chews/min for the free style chewing of gum and the standard deviations around the mean of the two measurements for 70 persons was less than 0.1 <Fig. 2>. Based on these data, reproducible values were obtained for chewing speed and chewing energy, and these two measurement were used for determination of the groups for further testing.

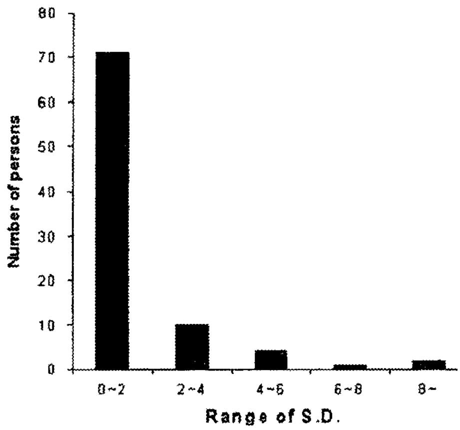
2. Gender and Age-specific Chewing Patterns Differences

The current study hypothesized that chewing patterns would differ based on gender



<Fig. 1> **Standard deviation(S.D.) distributions of subjects using ESS for chewing energy[a].**

[a] chewing naturally with gum for 60 seconds.

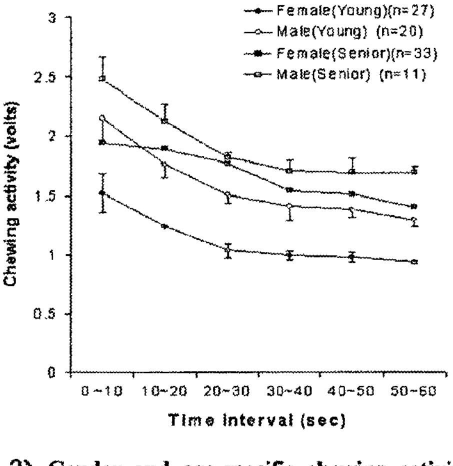


〈Fig. 2〉 **Standard deviation(S.D.) distributions of subjects using ESS for chewing speed[a].**

[a] number of chewing times with chewing number / chewing seconds.

and age. The younger groups ranged from 18 to 42 years, and senior groups were between 60 and 87 years old. The results for chewing activity using chewing gum based on gender and age are shown in 〈Fig. 3〉.

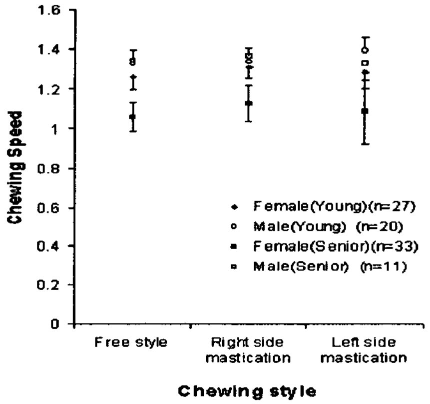
The significant differences in gender and age-specific related chewing pattern appeared on ESS data analysis using the chewing gum and eating a raw carrot. Chewing activity of senior group was significantly higher than that of younger within the gender groups, and females used less energy than males.



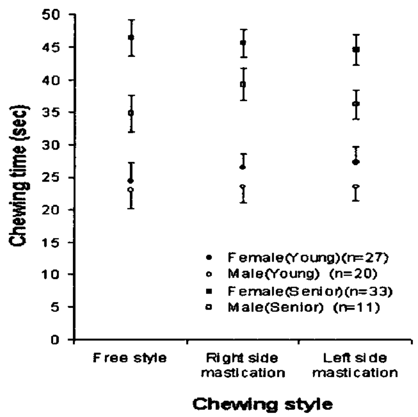
〈Fig. 3〉 **Gender and age-specific chewing activity differences at the free style gum chewing.**

The change of the chewing activity of massester and temporalis muscles during chewing sequence was shown in <Fig. 3>. The highest chewing activity level revealed on the first bite section(0~10 seconds) and fell down during chewing gum because of gum softening during chewing. The chewing speed of the senior-female group was significantly lower than the other groups and younger females were faster than senior females <Fig. 4>. The chewing time for carrots of younger persons was significantly less than that of senior groups <Fig. 5>.

An interest finding were not the coincidence in chewing speed and chewing time between the younger and senior-male group, the similarity of chewing speed of the younger and senior males for gum and the difference in chewing time for carrot



<Fig. 4> Gender and age-specific chewing speed differences at free style gum chewing.



<Fig. 5> Sex and age-specific chewing time differences at free style eating of raw carrot.

between the senior and younger group. It was true for natural chewing as far deliberate sided mastication <Fig. 4, 5>.

Same as our result, Karlsson et al.[21] found that aging was associated with a reduction of velocity when elderly individuals (mean age, 80 years; range 78~84) were compared to younger persons (mean age, 28 years; range 24~33). The apparent differences in chewing activity, chewing speed and chewing time in age are probably dependent on age-associated changes resulting in an impairment of both central and peripheral mechanisms. Age-related changes, such as a reduced cross-sectional area of masseter muscles and a decrease of velocity of nerve impulse as well as motor fibers might be one possible explanation of the reduced velocity.[25,26]

Previous investigations.[22,26] found that the significant differences in gender related chewing patterns appeared to be independent on jaw size differences and the dentoskeletal and muscular differences that exist between males and females. Jaw function and parafunction are associated with temporomandibular disorders(TMD) that affect up to 80% of western populations, and that TMD are more common in females.[22]

3. Classifications of Chewing Pattern

The 91 persons were divided into four groups based on chewing patterns involving total energy and chewing speed : The groups were Ⅰ) low energy and slow chewers, Ⅱ) low energy fast chewers, Ⅲ) high energy and slow chewers and Ⅳ) high energy with fast chewing. <12.8 V energy, mean = 10.1 V, and those characterized as high energy chewers used> 18.1 V energy, mean = 27.2 V). Slow chewers had chewing speed less than 1.2 chews/sec., mean = 1.0 chews/sec. and fast chewers had speed greater than 1.3 chew/sec., mean = 1.5 chews/sec.

We have classified 91 subjects into 4 groups based on their chewing patterns and selected 6 persons who had mean values for chewing parameters were selected from each group for the follow-up studies <Table 2>.

Group Ⅰ(mean age, 65.7) was dominated by senior, included Ⅰ young female, 4 old females and 1 old males and Group Ⅱ (mean age, 33.8) was largely younger but 1 old female was included in the low energy fast chewing group. Group Ⅲ(mean age, 54.7) was 2 young males and 4 old females in this group. Group Ⅳ(mean age, 50.3) was evenly divided into young and senior but included 1 female and 5 males. Sakamato et al.[15] categorized into six groups for food stuffs according to the

<Table 2> Selected panelist(n=24) based on chewing energy and chewing speed for additional testing

Panelist No.	Age	Sex	Chewing energy		Speed of chewing	
			Value	S.D.	Value	S.D.
Group I : Low energy and slow chewers						
P29	19	Female	11.5	0.6	1.1	0.1
P35	68	Female	10.9	0.3	0.9	0.0
P40	64	Male	10.6	0.6	1.2	0.0
P58	79	Female	10.5	0.1	0.9	0.2
P68	83	Female	6.6	0.5	0.9	0.1
P83	81	Female	7.9	0.2	0.9	0.1
Mean	65.7		9.66	0.37	0.96	0.07
Group II : Low energy and fast chewers						
P04	24	Female	9.9	1.6	1.3	0.1
P11	28	Female	11.0	0.4	1.4	0.0
P16	22	Female	8.6	0.1	1.4	0.1
P38	18	Female	8.9	0.3	1.4	0.1
P50	28	Female	12.5	0.2	1.8	0.0
P81	83	Female	12.8	0.1	1.4	0.0
Mean	33.8		10.61	0.44	1.44	0.04
Group III : High energy and slow chewers						
P06	20	Male	25.3	1.4	1.0	0.0
P44	34	Male	22.1	2.6	1.2	0.1
P59	61	Female	48.2	2.8	0.7	0.0
P62	80	Female	35.7	0.5	1.1	0.0
P70	63	Female	20.6	1.7	0.9	0.1
P78	70	Female	27.3	0.2	0.9	0.1
Mean	54.7		29.87	1.51	0.96	0.07
Group IV : High energy and fast chewers						
P02	27	Male	18.5	2.5	1.5	0.1
P09	27	Male	42.0	0.4	1.8	0.0
P31	24	Male	20.7	0.3	1.5	0.1
P39	69	Male	27.4	0.7	1.8	0.0
P49	78	Male	20.5	1.4	1.5	0.1
P63	77	Female	18.1	0.8	1.3	0.0
Mean	50.3		24.54	1.01	1.59	0.06

changing patterns of chewing energy. Brown et al.[1,13] showed the different sensory results for firmness and rubberiness of model food between 5 groups according to chewing time and chewing work rate, the differences of sensory results for the stickiness and flavor of cooked pasta between 4 groups according to chewing efficiency.

Ⅳ. CONCLUSION

The mastication process provides knowledge about food texture, and the potential of using Electrical Sensing System(ESS) curve gives a direct measure of muscle activity required for chewing foods, and different patterns of chewing behavior may lead to significantly different sensory ratings and also lead the consumers to draw different perceptual conclusions about the texture of food.

In this study, we have attempted to analysis characterize chewing pattern by chewing behavior of individuals and classify the chewing pattern by chewing parameters using ESS. We also examined the reproducibility of the chewing pattern by ESS and whether the chewing pattern was affected by age or gender of individuals.

The ESS measurements of the chewing patterns for 91 persons were consistent and reproducible for the most of the tested persons. The standard deviations for each panelist for the largest majority(n=71) was 2.0 or less in chewing activity and the same pattern was noted for chewing speed.

The significant differences in gender and age-specific related chewing pattern appeared on ESS data analysis using the chewing gum and eating a raw carrot. Chewing activity of senior groups was significantly higher than that of younger within the gender group, and females used less energy than males. An interest finding were not the coincidence in chewing speed and chewing time between the younger and senior-male group, the similarity of chewing speed of the younger and senior males for gum and the difference in chewing time for carrot between the younger and senior adults.

We have classified 91 subjects based on their chewing patterns and selected 24 panelists from 4 groups to investigate the effect of various chewing parameters to the sensory evaluation for further testing, and this study will provide a method of selection of panelists, which is able to have same chewing patterns and to express closer sensory results with data analysis of food products. This method will also offer a numerical way to describe chewing behavior which highlights individual differences.

REFERENCES

1. Brown WE, Dauchel C and Wakeling (1996) : Influence of chewing efficiency on texture and flavour perceptions of food. *J Texture Studies* 27, pp.433-450.
2. Cardello AV and Segars RA (1989) : Effects of sample size and prior mastication on texture judgments. *J Sensory Studies 4*, pp.1-18.
3. Lee WE Ⅲ (1985) : Evaluation of time-intensity sensory responses using a personal computer. *J Food Sci* 50, pp.1750-1753.
4. Meullenet J (1998) : Relationship between sensory and instrumental texture profile attributes. *J Sensory Studies*. 13, pp.77-93.
5. Boyar MM and Kilcast D (1986) : Electromyography as a novel method for examining food texture. *J Food Sci* 51, pp.859-860.
6. Hutchings JB and Lillford PJ (1998) : The perception of food texture-The philosophy of the breakdown path. *J Texture Studies* 19, pp.103-115.
7. Kapsalis JG and Moskowitz (1978) : Views on relating instrumental tests to sensory assessment of food texture applications to product development and improvement. *J Texture Studies* 9, pp.371-393.
8. Tornberg E, Fjelkner-Modig S, Ruderus H, Glantz P, Randow K and Stafford D (1985) : Clinically recorded masticatory patterns as related to the sensory evaluation of meat and meat products. *J Food Sci* 50, pp.1059-1066.
9. Szczesniak AS(1990. 9) : Texture-Is it still on overlooked food attribute?, *Food Technol* pp.86-95.
10. Ahlgren J and Owall B : Muscular activity and chewing force (1970) : A polygraphic study of human mandibular movements. *Archs oral Biol* 15, pp.271-280.
11. Brown WE (1994) : Method to investigate differences in chewing behaviour in humans: 1 .Use of electromyography in measuring chewing. *J Texture Studies* 25, pp. 1-16.
12. Brown WE, Shearn M and Macfie HJH (1994) : Method to investigate differences in chewing behaviour in humans: 2. Use of electromyography during chewing to assess chewing behaviour. *J Texture Studies* 25, pp.17-31.
13. Brown WE, Langley KR, Martin A and Macfie HJH (1994) : Characterization of patterns of chewing behaviour in human subjects and their influence on texture perception. *J Texture Studies* 25, pp.455-468.
14. Brown WE, Eves D, Ellison M and Braxto D (1994) : Use of combined electro-

myography and kinesthesiology during mastication to chart the oral breakdown of foodstuffs: Relevance to measurement of food texture. *J Texture Studies* 25, pp.455-468.

15. Sakamoto H, Harada T, Matsukubo T, Takaesu Y and Tazaka M (1989) : Electromyographic measurement of textural changes of foodstuffs during chewing. *Agric Biol Chem* 53(9), pp.2421-2433.
16. van Eijden TMGJ (1990) : Jaw muscle activity in relation to the direction and point of application of bite force. *J Dent Res* p. 69(3), pp.901-905.
17. Gay T, Rendell J, Majoureau A and Maloney FT (1994) : Estimating human initial bite forces from the electromyography bite-force function. *Archs Oral Biol* 39(2), pp.111-115.
18. Kilcast and Lewis. (1990) : Structure and texture there importance in food quality. *BNF Nutrition Bulletin* 15(2), 103-113.
19. Mathevon E, Mioche L, Brown WE and Culioli J (1995) : Texture analysis of beef cooked at various temperatures by mechanical measurements, sensory assessments and electromyography. *J Texture Studies* 26, pp.175-192.
20. Karlsson S and Carlsson GE (1991) : Characteristics of mandibular masticatory movement in young and elderly denature subjects. *J Den Res* 69(2), pp.473-476.
21. Kiliaridis S, Karlsson S and Kjellberg H (1991) : Characteristics of masticatory mandibular movements and velocity in growing individuals and young adults. *J Den Res* 70(10), 1367-1370.
22. Gerstner GE and Parekh VV (1996) : Evidence of Sex-specific differences in masticatory jaw movement patterns. *J Den Res* 76(3), pp.796-806.
23. Plesh O, Bishop B and McCall W (1986) : Effect of gum hardness on chewing pattern. *Exp Nuro* 92, pp.502-512.
24. Wang F, Carson L, Sun S and Setser C (1999) : Electronic sensing system(ESS) for texture characterization of foods during chewing, *J Food Sci.*
25. Campbell MJ, McComas AJ and Petito F (1973) : Physiological changes in aging muscle. *J Neurol Neurosurg Psychiatr* 36, pp.174-182.
26. Newton JP, Abel RW, Robertson EM and Yemm R (1987) : Changes in human masseter and medical pterygoid muscles within age: A study by computed topography. *Gerodontics*. 3, 1987, pp. 151-154.

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