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Analysis of Masseter muscle activities acquired by Surface Electromyography for different textured Indian food products

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ABSTRACT
The objective of this study was to check whether the masseter muscle activity parameters measured by surface EMG can be a meaningful method to distinguish food texture of different Indian food products. The variation of five foods and eight subjects for eighteen parameters of masseter muscles activity were examined. These parameters were studied for entire mastication period, per chew mastication and at three different stages of mastication i.e. early, middle and late stages of mastication. As subject factor variation was more than that of food factor for absolute masticatory parameters so relative mean values for masticatory parameters were used to eliminate human subject variation. Statistical analysis found significant ($p<0.05$) differences for various masticatory parameters of different foods investigated in the present study. It was concluded that surface EMG could be a reliable method for conducting food texture evaluation.
Key Words *- Masseter muscles, Electromyography, Food texture, Chewing.*

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INTRODUCTION

Texture being a single and simple word is a vital parameter of food quality. It explains the complex phenomenon of manifestation of structural (molecular, microscopic or macroscopic), mechanical (hardness, cohesiveness, viscosity, elasticity, adhesiveness) and surface characteristics (moisture content, oiliness) of foods which are detected by various senses [21]. Texture perception varies continuously with the physical characteristics (size, texture and moisture) of foods during their mastication in the mouth [7] because of breakdown of food by compressive, tensile and shearing forces [21]. Accordingly, the course of mastication forms the basis of texture evaluation [4].

Surface electromyography (sEMG) is a non invasive technique [4] which can be used for textural evaluation of foods on the basis of measurements of the bioelectrical activity of masseter muscles [4, 9, 10]. There are two kinds of masticatory muscles, jaw closing muscle and jaw opening muscle - the first one elevates while the other withdraws the mandible, which perform alternatively for rhythmic chewing [19].During activation of muscles there is generation of electrical activity because of ion flow across the cell membrane which are recorded and displayed for the analysis [15, 16, 17].

During oral processing there is a dynamic structural change in food [3, 18, 20]. Depending upon the rheology of a food, each individual will experience different chewing patterns [5].

Although, the individual EMG parameters for each individual are stable and reproducible but varies from subject to subject (Gonzalez *et al.,*2004). Muscle activity changes according to different shape of food, height of food bolus and textural properties of food during mastication [6]. Bilt *et al.*[1] and Chen [5] reported relationship between oral physiology and food characteristics during the process of mastication.
The main objective of this study was to record masseter muscle activities using surface electromyography for different Indian foods and to examine the effect of food texture on masticatory activity during chewing.

MATERIALS AND METHODS

Samples: Five different textured foods (jelly, cake, *dhokla, rasgulla, paneer*) were purchased from the local market of Amritsar. *Jelly* and *rasgulla* were served in their original shape while *cake, dhokla* and *paneer* were cut into pieces (10mmx10mmx10mm).All foods items were served fresh to the human subjects.
Subjects: EMG studies were conducted on eight healthy subjects,all female, aged 22 – 28 years with same body weight index to reduce inter subject variation due to gender, age, etc. [12]. All human subjects were free from any functional mastication problems and required no dental treatments [13]. All subjects gave their informed consent before starting of the experiment. The conduct of present study was approved by the Ethical Committee of Guru Nanak Dev University, Amritsar.
EMG measurements: Subject was seated comfortably with position of face in opposite direction to the screen of computer system on which EMG data is displayed. Prior to the experiments all human subjects were explained with the experimental set up of EMG, so that they feel familiar with the technique. All recordings were taken in silent room at same time of a day, so that experimental conditions remain the same. Before placement of the bipolar surface electrodes (EL 503, Biopac systems Inc., Goleta, CA) [14] on the masseter muscles on both sides of the face, skin resistance was reduced by scrubbing the area with 70% alcohol using tissue paper. The conductance of the test was also improved by use of pre gelled electrodes during the experiment. The masseter muscles were identified while the subject clenched the teeth and then electrodes were placed 2 cm apart over this area. Reference electrode was placed on the left wrist for ground as all human subjects were right handed (Fig. 1).
Five food products with two replicates were served to human subjects in random order along with control food (any one test food) used to check the correct position of the electrode and base line.The subject took food sample by themselves and masticates them in normal habitual manner of chewing because impose chewing result in error [10]. Human subjects were asked to raise their right hand whenever they finished with swallowing.To avoid muscle fatigue subjects were given time interval of 2-3 min. in between two recordings. Each complete EMG session lasted for about 30 min.
EMG signals were recorded from both left and right masseter muscles and filtered (10-500Hz) with removal of noise at 50Hz caused by the power supply and amplified 1000 times using EMG 100C amplifiers (Biopac System Inc.). EMG signals were saved on PC using MP-150 system (Biopac System Inc.) at 1000Hz frequency.
Data analysis: Surface EMG signals which were obtained as shown in Fig. 2. The signals were analyzed using AcqKnowledge software(ver. 4.4, Biopac Systems Inc). EMG variables obtained for entire mastication, per chew and at three different stages (early, middle and late) of mastication were examined. The variables were analyzed as follows:
(A) ***For entire mastication period***
(1) Chew number i.e. no. of bursts
(2) Mastication time i.e. total time for chewing
(3) Total burst duration i.e. sum of all burst durations
(4) Total muscle activity i.e. sum of all time integral of EMG voltages
(B) ***For per chew mastication***
(5) Burst duration i.e. time interval from the onset to the cessation of EMG activity
(6) Inter burst duration i.e. duration between two bursts
(7) Cycle time i.e. sum of burst and inter burst duration
(8) Muscle activity i.e. time integral of the EMG voltages
(9) Amplitude i.e. peak to peak voltage

(C) ***For early stage of mastication (first three chews)***
(10) Burst duration
(11) Muscle activity
(12) Amplitude
(D) ***For middle stage of mastication (middle three chews)***
(13) Burst duration
(14) Muscle activity
(15) Amplitude
(E) ***For late stage of mastication (late three chews)***
(16) Burst duration
(17) Muscle activity
(18) Amplitude
Variables at serial no. 3-18 were obtained from both the masseter muscles, so they were averaged and then averaged for a chewing cycles [10].
Statistics: Two-way analysis of variance of massseter muscle activities acquired using surface EMG was performed with Minitab Statistical Software (Minitab Inc., USA).As subject factor variation was more than that of food factor so the relative mastication parameters (ratio to mean value of 5 foods × duplicates) within each subject were served for statistical analysis.

RESULTS AND DISCUSSION

Subject factor variance:

Two way analysis of variance of the acquired absolute EMG variables was performed. All subjects showed significant variations among various mastication parameters i.e. each subject showed distinct values for different mastication parameters among five different textured food products. However, it was observed that F values for subject factor variation were much higher than food factor variation indicating more variation in subjects as compared to textural variations in the food samples (Table 1). Kohyama *et al.* [11] also reported similar results.

Food factor variance:

For entire mastication period

During entire mastication period, relative mean values for all EMG parameters varied for different foods [no. of chew (0.76-1.39), mastication time (0.79-1.30), total burst duration (0.76-1.35) and total muscle activity (0.63-1.26)] as shown in Table 2. All foods showed statistically significant($p<0.05$)results for all the mastication parameters. The relative mean values for all parameters had minimum value for jelly and highest value for *paneer.* This is due to semi solid nature of jelly and hardness of *paneer*. The harder the food, the more is the chewing rate, muscle activity and relative contraction period [9].

For per chew mastication

At per chew level of mastication, narrow range of relative mean values for EMG variables were found for various foods [burst duration (0.98-1.05), interburst duration (0.91-1.09), cycle time (0.94-1.05), muscle activity (0.87-1.29) and amplitude (0.89-1.23)] as listed in Table 3. All foods showed statistically significant ($p<0.05$)results for all the parameters except for burst duration and muscle activity. *Paneer* and jelly showed minimum and maximum values for burst duration, inter burst duration and cycle time, respectively, depicting an inverse relationship between per chew mastication parameters and entire mastication period parameters. This is attributed to the highest number of chews required to masticate *paneer* while least for jelly. *Dhokla* showed minimum values for muscle activity and amplitude. Steiner *et al.* [20] reported that soft foods require minimum muscle activity and amplitude for their breakdown.

For different stages of mastication

During different stages of mastication i.e. early, middle and late all the EMG parameters (burst duration, muscle activity and amplitude) showed statistically significant results($p<0.05$) except for burst duration at middle stage which became significant at higher p-value ($p<0.10$)(Table 4). At different stages of mastication *jelly* showed maximum value for burst duration because of its gummi nature.

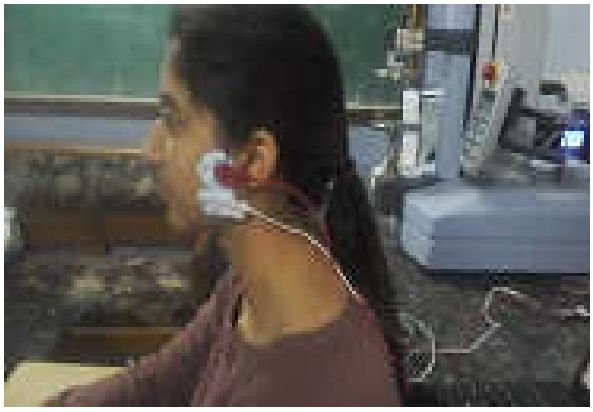

Fig1. Human subject with bipolar surface electrodes

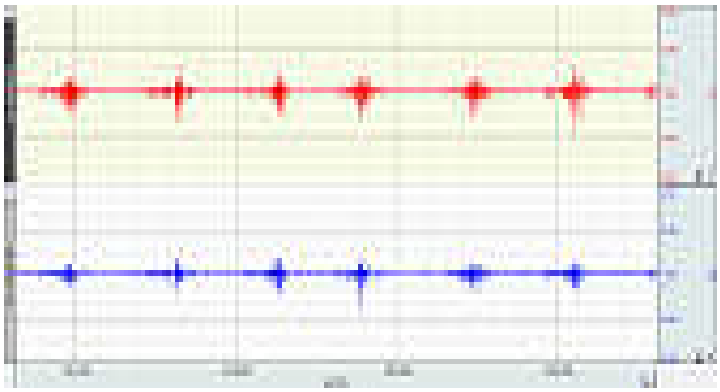

Fig 2. Typical EMG chart depicting acquired masseter muscle activities during mastication of a food sample

TABLE 1. EMG MASTICATORY PARAMETERS (ABSOLUTE VALUES) FOR VARIOUS FOOD SAMPLES SHOWING SUBJECT FACTOR VARIATION.

Food samples	Jelly		Cake		*Dhokla*		*Rasgulla*		*Paneer*		F value Subject	F value Food
	Mean	Sd	mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd		
Entire mastication period parameters												
Chew no.	16.81	7.48	23.19	9.01	19.13	8.17	20.88	6.93	30.25	11.34	16.75	11.54
Mastication time (s)	14.04	4.75	19.64	5.98	15.29	4.88	16.87	5.36	22.81	6.56	10.55	9.40
Total burst duration (s)	4.71	1.81	6.76	2.62	5.27	1.65	6.31	2.18	8.31	2.42	14.73	12.49
Total muscle activity(mV·s)	0.35	0.33	0.56	0.35	0.42	0.36	0.70	0.56	0.68	0.54	41.43	8.83
Per chew parameters												
Burst duration(s)	0.29	0.05	0.30	0.04	0.29	0.06	0.30	0.03	0.28	0.05	17.73	1.10
Inter burst duration(s)	0.59	0.13	0.58	0.10	0.55	0.11	0.52	0.12	0.50	0.12	20.61	4.19
Cycle time(s)	0.88	0.15	0.88	0.11	0.83	0.13	0.83	0.12	0.78	0.12	19.54	3.90
Muscle activity(mV·s)	0.24	0.44	0.19	0.24	0.17	0.22	0.30	0.45	0.17	0.21	3.09	0.32
Amplitude(mV)	1.03	0.76	1.12	0.60	0.98	0.68	1.29	0.67	1.02	0.61	170.72	9.60
Early stage parameters												
Burst duration(s)	0.22	0.12	0.19	0.16	0.14	0.14	0.16	0.12	0.15	0.15	21.48	2.39
Muscle activity(mV·s)	0.02	0.01	0.03	0.01	0.02	0.01	0.15	0.34	0.02	0.01	1.34	1.10
Amplitude(mV)	0.98	0.78	1.15	0.57	0.92	0.68	1.28	0.66	1.05	0.74	77.14	5.46
Middle stage parameters												
Burst	0.20	0.13	0.12	0.13	0.15	0.13	0.16	0.10	0.15	0.16	10.34	1.10

duration(s)												
Muscle activity(mV·s)	0.02	0.01	0.02	0.01	0.02	0.02	0.23	0.43	0.02	0.02	1.32	1.88
Amplitude(mV)	1.01	0.83	1.15	0.70	1.00	0.74	1.36	0.70	1.02	0.64	86.98	6.34
Late stage parameters												
Burst duration(s)	0.20	0.11	0.12	0.12	0.13	0.13	0.14	0.11	0.13	0.14	12.89	1.59
Muscle activity(mV·s)	0.02	0.02	0.02	0.01	0.02	0.01	0.15	0.35	0.02	0.01	1.36	1.13
Amplitude(mV)	1.08	0.78	1.07	0.57	1.01	0.59	1.29	0.62	0.96	0.51	74.35	5.25

TABLE 2. EMG MASTICATORY PARAMETERS (RELATIVE MEAN VALUES) OF ENTIRE MASTICATION PERIOD FOR DIFFERENT FOODS

Food samples	**Jelly**		**Cake**		***Dhokla***		***Rasgulla***		***Paneer***		**F value**
Entire mastication parameters	Mean	Sd	Mean	sd	mean	sd	mean	sd	mean	Sd	
Chew no.	0.76	0.08	1.04	0.20	0.88	0.14	0.97	0.21	1.39	0.13	13.97
Mastication time (s)	0.79	0.11	1.11	0.22	0.87	0.15	0.96	0.20	1.30	0.14	8.90
Total burst duration (s)	0.76	0.09	1.07	0.20	0.86	0.15	1.01	0.17	1.35	0.11	14.94
Total muscle activity(mV·s)	0.63	0.11	1.12	0.29	0.76	0.12	1.26	0.27	1.26	0.16	13.24

TABLE3. EMG MASTICATORY PARAMETERS (RELATIVE MEAN VALUES) OF PER CHEW MASTICATION FOR DIFFERENT FOODS

Food samples	**Jelly**		**Cake**		***Dhokla***		***Rasgulla***		***Paneer***		
Per chew parameters	mean	sd	mean	sd	mean	Sd	mean	Sd	mean	Sd	**F value**
Burst duration(s)	1.00	0.06	1.02	0.06	0.99	0.13	1.05	0.07	0.98	0.07	1.45*
Inter burst duration(s)	1.09	0.15	1.07	0.10	1.01	0.08	0.95	0.07	0.91	0.08	4.45
Cycle time(s)	1.05	0.09	1.05	0.06	1.01	0.10	0.98	0.05	0.94	0.05	4.15
Muscle activity(mV·s)	0.92	0.66	1.03	0.46	0.87	0.41	1.29	0.61	0.93	0.39	0.75*
Amplitude(mV)	0.90	0.17	1.07	0.10	0.89	0.09	1.23	0.13	0.96	0.09	11.27

*indicates non significant values ($p<0.05$)

TABLE4. EMG MASTICATORY PARAMETERS (RELATIVE MEAN VALUES) OF DIFFERENT STAGES OF MASTICATION FOR DIFFERENT FOODS

Food samples	**Jelly**		**Cake**		***Dhokla***		***Rasgulla***		***Paneer***		**F value**
Early stage parameters	mean	Sd	Mean	Sd	mean	Sd	mean	Sd	mean	Sd	
Burst duration(s)	1.80	1.27	0.92	0.37	0.67	0.37	1.00	0.42	0.90	0.40	0.71
Muscle activity(mV·s)	0.65	0.21	1.09	0.39	0.71	0.22	1.71	1.01	0.84	0.29	4.36
Amplitude(mV)	0.82	0.21	1.13	0.14	0.83	0.11	1.24	0.16	0.98	0.16	8.85
Middle stage parameters	mean	Sd	Mean	Sd	mean	Sd	mean	Sd	mean	Sd	**F value**
Burst duration(s)	1.63	1.14	0.66	0.43	0.84	0.37	1.11	0.54	0.76	0.50	2.26*
Muscle activity(mV·s)	0.58	0.32	0.85	0.44	0.70	0.32	2.16	1.33	0.71	0.34	6.42
Amplitude(mV)	0.84	0.25	1.06	0.13	0.86	0.10	1.31	0.26	0.93	0.13	5.97
Late stage parameters	mean	Sd	Mean	Sd	mean	Sd	mean	Sd	mean	Sd	**F value**
Burst duration(s)	1.78	1.12	0.79	0.46	0.75	0.41	0.93	0.25	0.75	0.45	3.30
Muscle activity(mV·s)	0.76	0.27	0.93	0.30	0.78	0.27	1.70	1.02	0.83	0.30	3.67
Amplitude(mV)	0.93	0.19	1.00	0.05	0.93	0.11	1.25	0.15	0.90	0.08	7.96

*indicates non significant values ($p<0.05$)

CONCLUSION

Masticatory parameters acquired by surface EMG of human subjects while chewing different textured food products showed significant differences indicating that surface EMG could effectively distinguish between these varied textured food products. Measurement of bioelectrical activity of masseter muscles by EMG, a technique for evaluating physiological process of chewing, could be a new method for texture assessment of foods. It will be useful in understanding the concept of food texture perception in real time situation. Moreover, it can also be combined with other techniques like texture profile analysis and sensory analysis for explaining the concept of texture evaluation.

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