Application of electromyography (EMG) in food texture evaluation of different Indian sweets

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ABSTRACT

The present study was undertaken to correlate surface electromyography variables acquired during chewing of different Indian sweets with the instrumental texture parameters and their sensory attributes. Firstly, a comparison of acquired absolute EMG variables with the relative EMG variables was conducted. The results revealed that the relative EMG mastication parameters can effectively distinguish different textured food products by eliminating the subject variance. Then, the two different recordings of masticatory parameters in an EMG session for human subjects were correlated to investigate the reproducibility of chewing patterns. The correlation coefficients were found to be statistically significant (p<0.05) indicating highly reproducible chewing behaviour within a session for human subjects. Finally, acquired surface EMG variables were clustered into six representative variables using dendrograms. The principal component analysis conducted for these representative variables could explain 76% of cumulative proportion of variance. The scores of first principal component correlated significantly with instrumental and sensory hardness and sensory stickiness, while scores of second component correlated with sensory stickiness.

Key words: Electromyography, Instrumental texture, Mastication, Sensory evaluation.

INTRODUCTION

Texture, an important aspect of food quality, is a sensory property which is derived from the structure of the food and detected by several senses. It needs to be understood from both physical and psychological aspects (Gonzalez et al., 2004). Instruments used for testing of texture can only detect and quantify certain physical parameters, but human beings can perceive and interpret them in terms of sensory perception during chewing of the food. Texture profile analysis (TPA) is a standard method for texture characterization developed by Szczesniak (1963). It is used for classification of textural terms for both solid and semi-solid foods and can be related to mechanical measurements (Bourne, 1978; Szczesniak et al., 1963) and sensory attributes of texture (Brandt et al., 1963). The instrumental method of texture profiling quantifies the mechanical parameters from the force-deformation curve by compressing the test substance at least twice (Szczesniak, 2002).

Chewing is the most important function of the stomatognathic system (Nascimento et al., 2012). It is a physiological act required to break the food, with the application of various forces (compressive, tensile and shear) (Szczesniak, 2002), into smaller particles so that they are prepared for next functions of swallowing and digestion. An integrated complex of muscles, ligaments, bone and teeth structures are responsible for the function of chewing and are under control of central nervous system (Coelho-Ferraz et al., 2009). Due to the changes in physical properties of foods such as size, texture and moisture content during the chewing process in the mouth, the texture perception varies continuously (Guinard and Mazzucchelli, 1996). These changes in structural (molecular, microscopic or macroscopic), mechanical (hardness, cohesiveness, viscosity, elasticity and adhesiveness) and surface characteristics (moisture content, oiliness) can be detected by humans through their senses of vision, hearing, touch, pressure and kinesthetics (Szczesniak, 2002).

Sensory feedback provided during mastication is helpful in developing perception of texture with regard to satisfaction during eating as the oral phase of ingestion (Griep et al., 1996). Sensory evaluation depends upon both the physiology of the senses and the psychology of the perception of the food texture (Brown, 1994). Hedonic judgments are formed on the basis of progressive breakdown of food during mastication (Brown et al., 1998). Sensory parameters such as hardness or softness can be related directly to the resistance offered by food to the applied compressive forces. Parameters such as creaminess and juiciness are related to the thickness and smoothness of the food surface which further depends on the physical viscosity and frictional forces in the food (Guinard and Mazzucchelli, 1996).

Surface electromyography (sEMG) is a non-invasive technique in which electrodes are placed on the...
skin overlying the masticatory muscles to capture the electrical activity of the activated muscle fiber (Nascimento et al., 2012). There are two kinds of masticatory muscles. The first one is jaw closing muscle which elevates the mandible and the other is jaw opening muscle which withdraws the mandible (Shiowzawo, 2005). For rhythmic chewing, these muscles perform alternatively. During activation of muscles an electrical activity is generated due to the flow of ions across the cell membrane which is recorded and displayed for the analysis (Konrad, 2005). Upon chewing a hard food, masseter muscles work more due to which its EMG amplitude becomes greater (Gonzalez et al., 2001). Higher masticatory muscle activity is also shown when larger particles are being chewed (Slagter et al., 1993; Otenhoff et al., 1993; Diaz-Tay et al., 1991). Thus EMG variables provide a direct measurement of masseter muscle activity during chewing of food which can be related to instrumental food texture parameters and food texture perceptions through sensory evaluation.

The present study was conducted with the objective to record chewing patterns of human subjects for different Indian sweets with the help of surface Electromyography (sEMG) to investigate their relationship with sensory and textural parameters.

**MATERIALS AND METHODS**

**Subjects:** The conduct of present study was approved by the Ethical Committee of Guru Nanak Dev University, Amritsar. In this investigation, EMG studies were conducted on ten volunteer subjects (females, aged 18 – 26 years) who were free from any functional mastication problems, and required no dental treatments (Fig 1). Informed consent was given by all the subjects prior to the EMG sessions. Subjects were asked to masticate and swallow samples in a habitual way to avoid imposed eating (Kohyama et al., 2016). The recording sessions lasted for about half an hour.

**EMG:** EMG activities of both sides of masseter muscles, the jaw-closing muscles, were measured using EMG (Kohyama et al., 2014; 2016, Sodhi et al., 2010), while the subjects ate one mouthful (6 g) of seven different Indian sweets (cham cham, milk cake, petha, gulab jamun, chana margi, rasgulla and chocolate burfi). The signals were obtained from EMG using bipolar surface electrodes (Fig 2), filtered (10 – 500 Hz) then amplified 2,000 times and saved on a PC using MP-150 system (Acknowledge ver. 4.4.2, Biopac Systems Inc.) at 1,000 Hz.

**Texture analysis:** A modified two bite test on each food sample was conducted using texture analyzer (Shimadzu, Model EZ-SX) at room temperature. Sample was placed on plate of the instrument. The method of clearance was used to conduct the test. Keeping the sample height of 10 mm, the moving jig compressed the sample leaving clearance of 4 mm behind on both the compressions which measured the physical properties of the whole sample. The plunger rate was set to 1 mm/s throughout. Each sample was tested five times to average the results.

**Sensory evaluation:** Sensory evaluation was carried out for 7 samples by 10 subjects using hedonic scale. They were asked to evaluate the samples on the basis of sensory parameters (hardness, cohesiveness, fracturability, chewiness, gumminess and adhesiveness) and give marks accordingly on the sensory score card on the basis of 9 points where 9 represents highest perceived sensation and 1 represents least perceived sensation.

**Data analysis:** Two-way analysis of variance, cluster analysis and principal component analysis of acquired EMG variables were performed with Minitab Statistical Software (Minitab Inc., USA).

**RESULTS AND DISCUSSION**

Comparison of absolute versus relative EMG variables: EMG variables (chew number, mastication time, inter-burst duration, burst duration, total muscle activity, inter-burst duration per chew, amplitude per chew, early burst duration, early inter-burst duration, early amplitude, middle burst duration, middle inter-burst duration, middle cycle time, late...
muscle activity, late amplitude) were acquired during chewing of different Indian sweets by human subjects. The absolute EMG variables were subjected to statistical analysis. The two way analysis of variance indicated more variance in subjects as compared to the food samples (Table 1). Kohyama et al. (2008), Brown et al. (1994) and Kohyama et al. (1998) found identical results earlier. Accordingly, rather than using absolute values, the relative mastication parameters (ratio of mean value of 7 foods × duplicates) within each subject were used for statistical analysis. Kohyama et al. (2008) reported the use of relative values of EMG variables in kinesiology. A significant difference among different food samples was observed upon application of analysis of variance on relative mastication parameters (Table 2). The results showed that the relative EMG variables need to be evaluated to successfully distinguish texture of different Indian sweets.

Table 1: Subject factor versus food factor variations for absolute values of EMG variables.

| Food samples/Parameters | Rasgulla | Gulab jamun | Cham cake | Petha | Chana murgi | Chocolate barfi | F value subjects | F value foods |
|-------------------------|----------|-------------|-----------|-------|-------------|----------------|-----------------|--------------|
| No. of chews            | 15.25    | 18.10       | 19.60     | 23.60 | 21.3        | 15.20          | 20.75           | 9.25         | 8.14         |
| Mastication time (s)    | 13.09    | 15.72       | 15.67     | 19.12 | 17.28       | 12.44          | 16.91           | 23.29        | 8.31         |
| Inter-burst duration (s)| 8.41     | 10.62       | 10.22     | 12.17 | 10.55       | 7.89           | 10.31           | 34.59        | 6.69         |
| Burst duration (s)      | 4.06     | 3.85        | 4.38      | 5.86  | 5.60        | 3.77           | 5.23            | 7.62         | 9.35         |
| Total muscle activity (mV·s) | 0.71  | 0.38        | 0.52      | 0.85  | 0.55        | 0.45           | 0.66            | 23.11        | 11.40        |
| Per chew mastication parameters |
| Inter-burst duration (s) | 0.54    | 0.59        | 0.54      | 0.53  | 0.48        | 0.53           | 0.50            | 69.75        | 4.47         |
| Amplitude (mV)          | 1.73     | 1.22        | 1.49      | 1.64  | 1.29        | 1.39           | 1.48            | 26.15        | 2.83         |
| Early stage mastication parameters |
| Burst duration (s)      | 0.87     | 0.72        | 0.82      | 0.92  | 1.03        | 0.97           | 0.88            | 1.71         | 2.02         |
| Inter-burst duration (s) | 1.41    | 1.76        | 1.39      | 1.43  | 1.38        | 1.39           | 1.33            | 26.10        | 3.02         |
| Amplitude (mV)          | 4.28     | 3.50        | 4.19      | 4.77  | 3.32        | 3.92           | 4.67            | 75.60        | 9.74         |
| Middle stage mastication parameters |
| Burst duration (s)      | 0.78     | 0.67        | 0.73      | 0.84  | 0.77        | 0.74           | 0.77            | 2.29         | 1.47         |
| Inter-burst duration (s) | 1.85    | 1.87        | 1.54      | 1.67  | 1.68        | 1.52           | 1.40            | 10.23        | 1.85         |
| Cycle time (s)          | 2.43     | 2.51        | 2.27      | 2.36  | 2.00        | 2.17           | 2.14            | 9.55         | 1.18         |
| Late stage mastication parameters |
| Muscle activity (mV·s)  | 0.09     | 0.09        | 0.09      | 0.11  | 0.08        | 0.10           | 0.09            | 10.29        | 0.95         |
| Amplitude (mV)          | 2.18     | 3.26        | 4.58      | 5.03  | 4.17        | 4.57           | 4.35            | 64.61        | 10.36        |

Table 2: Food factor variations for relative values of EMG variables.

| Food samples/Parameters | Rasgulla | Gulab jamun | Cham cake | Petha | Chana murgi | Chocolate barfi | F value | p value |
|-------------------------|----------|-------------|-----------|-------|-------------|----------------|---------|--------|
| No. of chews            | 1.26     | 1.09        | 0.99      | 0.83  | 0.89        | 1.29           | 0.92    | 1.78   | 0.12   |
| Mastication time (s)    | 1.23     | 1.06        | 1.04      | 0.84  | 0.91        | 1.29           | 0.93    | 7.66   | 0.00   |
| Inter-burst Duration (s)| 1.22     | 0.99        | 1.06      | 0.84  | 0.94        | 1.32           | 0.97    | 6.009  | 0.00   |
| Total Burst Duration (s)| 1.16     | 1.28        | 1.08      | 0.81  | 0.83        | 1.27           | 0.91    | 8.99   | 0.00   |
| Total Muscle Activity (mV·s) | 1.03  | 1.75        | 1.10      | 0.71  | 1.04        | 1.39           | 0.92    | 12.45  | 0.00   |
| Per chew mastication parameters |
| Inter-burst duration (s) | 0.99    | 0.92        | 1.03      | 1.01  | 1.13        | 0.99           | 1.06    | 2.68   | 0.03   |
| Amplitude (mV)          | 0.89     | 1.37        | 0.90      | 0.89  | 1.15        | 1.08           | 1.02    | 4.93   | 0.00   |
| Early stage mastication parameters |
| Burst duration (s)      | 1.03     | 1.26        | 1.10      | 0.98  | 0.86        | 1.01           | 1.03    | 4.76   | 0.00   |
| Inter-burst duration (s) | 1.04    | 0.86        | 1.09      | 1.01  | 1.02        | 1.05           | 1.08    | 2.37   | 0.04   |
| Amplitude (mV)          | 0.95     | 1.33        | 0.91      | 0.88  | 1.27        | 1.05           | 0.89    | 6.70   | 0.00   |
| Middle stage mastication parameters |
| Burst duration (s)      | 0.98     | 1.17        | 1.09      | 0.93  | 0.96        | 1.05           | 0.99    | 2.25   | 0.05   |
| Inter-burst duration (s) | 0.92    | 0.89        | 1.15      | 0.99  | 1.27        | 1.08           | 1.15    | 3.35   | 0.01   |
| Cycle time (s)          | 0.96     | 0.94        | 1.08      | 0.99  | 1.14        | 1.05           | 1.06    | 1.82   | 0.11   |
| Late stage mastication parameters |
| Muscle activity (mV·s)  | 0.99     | 1.39        | 1.02      | 0.88  | 1.18        | 1.06           | 1.09    | 2.40   | 0.04   |
| Amplitude (mV)          | 0.88     | 1.49        | 0.88      | 0.89  | 1.11        | 1.04           | 1.05    | 9.61   | 0.00   |
Reproducibility of masseter muscle activities: The reproducibility of masseter muscle activity by studying variables (chew number, mastication time, inter-burst duration, burst duration, total muscle activity, inter-burst duration per chew, amplitude per chew, early burst duration, early inter-burst duration, early amplitude, middle burst duration, middle inter-burst duration, middle cycle time, late muscle activity, late amplitude) as observed during chewing of seven different textured foods using electromyography (EMG) of human subjects for two different recordings in a session was investigated. A statistically significant (p<0.05) correlation coefficients were indicated by two different recordings of various foods (Tables 3-7). Cluster analysis for various food samples generated dendrograms, which depicted the subject’s chewing behaviour during two recordings in an EMG session. Same subject’s recordings were observed to be more closely clustered with each other rather than those of other subjects. A representative dendrogram generated by cluster analysis for milk cake is shown in Fig 3. Thus it is concluded that chewing behaviour is reproducible within session for human subjects and can be used for investigating textural differences among different Indian sweets. High reproducibility for EMG variables within a session was reported earlier by Karkazis and Kossioni (1997), Pratiksha et al. (2018) and Rustagi et al. (2018). Lassauzay et al. (2000) while studying variability of the masticatory process during chewing of elastic model foods.

Table 3: Correlation coefficients of two different recordings in an EMG session for entire mastication parameters.

| Food         | Parameters     | r   |
|--------------|----------------|-----|
| **Rasgulla** | Chew no.        | 0.60|
|              | Mastication time (s) | 0.78*|
|              | Inter-burst duration (s) | 0.76**|
|              | Total burst duration (s) | 0.62|
|              | Total muscle activity (mV-s) | 0.16|
|              | Total muscle activity (mV-s) | 0.86**|
| **Gulab jamun** | Chew no.        | 0.56|
|              | Mastication time (s) | 0.63*|
|              | Inter-burst duration (s) | 0.76**|
|              | Total burst duration (s) | 0.34|
|              | Total muscle activity (mV-s) | 0.80**|
| **Cham cham** | Chew no.        | 0.86**|
|              | Mastication time (s) | 0.96**|
|              | Inter-burst duration (s) | 0.97**|
|              | Total burst duration (s) | 0.79**|
|              | Total muscle activity (mV-s) | 0.80**|
| **Milk cake** | Chew no.        | 0.91**|
|              | Mastication time (s) | 0.90**|
|              | Inter-burst duration (s) | 0.88**|
|              | Total burst duration (s) | 0.89**|
|              | Total muscle activity (mV-s) | 0.80**|
| **Petha**    | Chew no.        | -0.08|
|              | Mastication time (s) | 0.54|
|              | Inter-burst duration (s) | 0.73*|
|              | Total burst duration (s) | 0.47|
|              | Total muscle activity (mV-s) | 0.70|
| **Chana murgi** | Chew no.        | 0.44|
|              | Mastication time (s) | 0.72*|
|              | Inter-burst duration (s) | 0.68*|
|              | Total burst duration (s) | 0.25|
|              | Total muscle activity (mV-s) | 0.83**|
| **Chocolate barfi** | Chew no.        | 0.45|
|              | Mastication time (s) | 0.49|

* p ≤ 0.05; ** p ≤ 0.01

Table 4: Correlation coefficients of two different recordings in an EMG session for per mastication parameters.

| Food         | Parameters     | r   |
|--------------|----------------|-----|
| **Rasgulla** | Inter-burst duration (s) | 0.84**|
|              | Amplitude (mV)    | 0.92**|
| **Gulab jamun** | Inter-burst duration (s) | 0.83**|
|              | Amplitude (mV)    | 0.76**|
| **Cham cham** | Inter-burst duration (s) | 0.83**|
|              | Amplitude (mV)    | 0.86**|
| **Milk cake** | Inter-burst duration (s) | 0.91**|
|              | Amplitude (mV)    | 0.91**|
| **Petha**    | Inter-burst duration (s) | 0.71*|
|              | Amplitude (mV)    | 0.95**|
| **Chana murgi** | Inter-burst duration (s) | 0.81*|
|              | Amplitude (mV)    | 0.65*|
| **Chocolate barfi** | Inter-burst duration (s) | 0.91**|
|              | Amplitude (mV)    | 0.92**|

* p ≤ 0.05; ** p ≤ 0.01

Table 5: Correlation coefficients of two different recordings in an EMG session for early stage mastication parameters.

| Food         | Parameters     | r   |
|--------------|----------------|-----|
| **Rasgulla** | Burst duration (s) | 0.81**|
|              | Inter-burst duration (s) | 0.94**|
|              | Amplitude (mV)    | 0.77**|
| **Gulab jamun** | Burst duration (s) | 0.78**|
|              | Inter-burst duration (s) | 0.68*|
|              | Amplitude (mV)    | 0.83**|
| **Cham cham** | Burst duration (s) | 0.80**|
|              | Inter-burst duration (s) | 0.85**|
|              | Amplitude (mV)    | 0.66*|
| **Milk cake** | Burst duration (s) | 0.44|
|              | Inter-burst duration (s) | 0.95**|
|              | Amplitude (mV)    | 0.85**|
| **Petha**    | Burst duration (s) | 0.67*|
|              | Inter-burst duration (s) | 0.72*|
|              | Amplitude (mV)    | 0.64*|
| **Chana murgi** | Burst duration (s) | -0.04|
|              | Inter-burst duration (s) | 0.91**|
|              | Amplitude (mV)    | 0.92**|
| **Chocolate barfi** | Burst duration (s) | 0.39|
|              | Inter-burst duration (s) | -0.03|
|              | Amplitude (mV)    | 0.77**|

* p ≤ 0.05; ** p ≤ 0.01
Table 6: Correlation coefficients of two different recordings in an EMG session for middle stage mastication parameters.

| Food       | Parameters       | r     |
|------------|------------------|-------|
| Rasgulla   | Burst duration (s) | 0.53  |
|            | Inter-burst duration (s) | 0.19  |
|            | Amplitude (mV)    | 0.11  |
| Gulab jamun| Burst duration (s) | 0.37  |
|            | Inter-burst duration (s) | 0.24  |
|            | Amplitude (mV)    | 0.31  |
| Cham cham  | Burst duration (s) | 0.84**|
|            | Inter-burst duration (s) | 0.75**|
|            | Amplitude (mV)    | 0.72**|
| Milk cake  | Burst duration (s) | 0.75**|
|            | Inter-burst duration (s) | 0.72**|
|            | Amplitude (mV)    | 0.84**|
| Petha      | Burst duration (s) | 0.20  |
|            | Inter-burst duration (s) | 0.87**|
|            | Amplitude (mV)    | 0.47  |
| Chana murgi| Burst duration (s) | 0.58  |
|            | Inter-burst duration (s) | 0.44  |
|            | Amplitude (mV)    | 0.88**|
| Chocolate barfi | Burst duration (s) | 0.96**|
|            | Inter-burst duration (s) | 0.61  |
|            | Amplitude (mV)    | 0.17  |

*p≤0.05; **p≤0.01

Table 7: Correlation coefficients of two different recordings in an EMG session for late stage mastication parameters.

| Food       | Parameters       | r     |
|------------|------------------|-------|
| Rasgulla   | Muscle activity (mV·s) | 0.83**|
|            | Amplitude (mV)    | 0.91**|
| Gulab jamun| Muscle activity (mV·s) | 0.95**|
|            | Amplitude (mV)    | 0.93**|
| Cham cham  | Muscle activity (mV·s) | 0.85**|
|            | Amplitude (mV)    | 0.84**|
| Milk cake  | Muscle activity (mV·s) | 0.57  |
|            | Amplitude (mV)    | 0.82**|
| Petha      | Muscle activity (mV·s) | 0.84**|
|            | Amplitude (mV)    | 0.85**|
| Chana murgi| Muscle activity (mV·s) | 0.93**|
|            | Amplitude (mV)    | 0.80**|
| Chocolate barfi | Muscle activity (mV·s) | 0.46  |
|            | Amplitude (mV)    | 0.83**|

*p≤0.05; **p≤0.01

also concluded that for food sample replicates there is no difference between mastication variables within a session.

Cluster analysis: A smaller number of variables were picked up from total EMG variables (chew number, mastication time, inter-burst duration, burst duration, total muscle activity, inter-burst duration per chew, amplitude per chew, early burst duration, early inter-burst duration, early amplitude, middle burst duration, middle inter-burst duration, middle cycle time, late muscle activity, late amplitude) by the use of cluster analysis. Cluster analysis grouped the total EMG variables into clusters with the help of dendrogram (Fig 3). From each cluster, one variable was selected which represented that particular cluster. In our case six variables i.e. mastication time, total muscle activity, early amplitude, middle cycle time, early burst duration and early inter-burst duration were selected. From these variables, principal component analysis further selected a fewer independent variables which explained the variability in mastication behaviour of different human subjects. The cluster analysis on EMG parameters while
chewing foods has been reported earlier by Kohyama et al. (2008) and Pratiksha et al. (2018).

**Principal component analysis:** To explain the variability in mastication behaviour of different human subjects, a smaller number of independent variables were picked up by the technique of principal component analysis (Kohyama et al., 2008; Pratiksha et al., 2018). The principal component analysis of these six representative variables (mastication time, total muscle activity, early amplitude, middle cycle time, early burst duration and early inter-burst duration) resulted in two meaningful component (Table 8). A cumulative proportion of variance of up to 76% can be explained by these principal components. Pratiksha et al. (2018) in their study on different snacks also deduced two meaningful components, which could explain variability in mastication behaviour up to 88.7%. The first principal component showed comparatively higher values for total muscle activity, early burst duration and early inter-burst duration, whereas higher values were obtained for mastication time, early amplitude and middle cycle time for second principal component (Fig 5).

The principal component scores for each food are shown in Table 9. Due to difference in scores of all the food samples, it can be concluded that there are differences in textural attributes of foods while being chewed by human subjects (Fig 6). The scores of first principal component correlated significantly with instrumental hardness and energy A1 (energy under first compression) (Table 10). It also correlated with sensory hardness and stickiness (Table 11). However scores of second principal component did not correlate with any of the instrumental and sensory parameters. The results from the present study indicate that

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**Table 8:** Factor loading of the masticatory parameters for each principal components.

| Parameter                      | PC1   | PC2   |
|-------------------------------|-------|-------|
| Mastication time              | -0.20 | -0.56 |
| Total muscle activity         | -0.50 | 0.03  |
| Early amplitude               | -0.37 | 0.57  |
| Middle cycle time             | 0.37  | 0.39  |
| Early burst duration          | -0.45 | -0.28 |
| Early inter-burst duration    | 0.47  | -0.34 |
| Cumulative proportion (%)     | 54    | 76    |

**Table 9:** Principal component scores for the food samples.

| Food       | PC1 Score | PC2 Score |
|------------|-----------|-----------|
| Rasgulla   | -0.17     | -1.39     |
| Petha      | -3.81     | 0.57      |
| Milk cake  | 0.75      | -0.56     |
| Gulab jamun| 1.20      | 0.17      |
| Cham cham  | 1.02      | 2.15      |
| Chana margi| -0.32     | -0.74     |
| Chocolate barfi | 1.33 | -0.20 |

**Table 10:** Correlation coefficients between the principal component scores and texture instrumental parameters.

| Parameter     | PC1  | PC2  |
|---------------|------|------|
| Hardness      | -0.92*| 0.33 |
| Cohesiveness  | 0.27 | 0.07 |
| Gumminess     | 0.05 | 0.13 |
| Adhesiveness  | -0.28 | -0.86*|
| Stickiness    | -0.29 | -0.78*|
| Energy A1     | -0.92 | 0.22 |
| Energy A2     | 0.00  | 0.60  |

*p<0.05
out of all the EMG variables studied, early amplitude, total muscle activity, mastication time, middle cycle time, early burst duration and early inter-burst duration can be used to explain the textural behaviour of different Indian sweets investigated.

**CONCLUSION**

In this study surface electromyography, a non-invasive technique, was investigated for its application in distinguishing the texture of different Indian sweets. Investigation was conducted using ten human subjects who were served seven different textured Indian sweets. Due to high inter-subject variance for the acquired absolute values, the relative values were used for further analysis. It was also found that the two different EMG recordings within a session of human subjects were highly reproducible. The results indicated that out of all the EMG variables studied, total muscle activity, early burst duration, early inter-burst duration, mastication time, early amplitude and middle cycle time can be used to explain the textural behaviour of food samples investigated in the present study. The study found that EMG variables, which provide real-time information about whole chewing process, can significantly distinguish different textured Indian sweets and may emerge as a promising technique for their texture evaluation.

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**Table 11: Correlation coefficients between the principal component scores and sensory parameters.**

| Parameter   | PC1    | PC2    |
|-------------|--------|--------|
| Hardness    | -0.68* | -0.17  |
| Cohesiveness| -0.55  | -0.17  |
| Gumminess   | -0.42  | 0.29   |
| Adhesiveness| -0.04  | 0.28   |
| Stickiness  | -0.64**| 0.04   |

*p<0.1; **p<0.2
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