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REVIEW ARTICLE

Electromyography: An emerging technique for food texture evaluation

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ABSTRACT

Texture is the sensory and functional attribute of the food which depends on its surface, structural and mechanical properties. It is one of the important steps in designing new food products. Now an emerging technique "Electromyography" based on generation of myoelectrical activity during activation of masseter muscles is used to describe various texture related mechanical attributes of wide range of food products. EMG technique is influenced by various non-instrumental and instrumental variables: non-instrumental like number of sessions, number of food samples in a session, replicates of a sample, number of human subjects, facial anatomy, gender, age, time, personality, psychology, side of mastication, denture, swallowing problem and effect of training; and instrumental like frequency, amplification, data acquisition, voltage and time parameters. These variables bring about changes in the subject's chewing behaviour. EMG plays a significant role in texture evaluation of food and shows good correlation with sensory and textural analysis for various food products.

Keywords: Chewing, EMG, Sensory, Texture.

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INTRODUCTION

Electromyography (EMG) is a non-invasive technique [5] which can be used for the texture evaluation of foods on the basis of measurement of the bioelectrical activity of masseter muscles [5, 21, 18]. During activation of muscles there is an exchange of ions along membrane of cells which generate the electrical activity. EMG technique is a graphical representation of the myoelectrical activity which can be measured with the help of instrumentation which includes the following: 1) placement of surface electrode on the skin over the masseter muscles to detect the signals, 2) Amplifiers to increase the strength of the signals, 3) Filters to remove the noise signals, 4) Analog to Digital converter, and 5) PC for analysis (with software). Masticatory jaw movement is one of the reliable methods to investigate food texture. Various mastication parameters were used for differentiating foods for which human subjects show significant variation [44]. During chewing EMG activity is affected by texture of food, i.e. different food brings about different values for various EMG parameters [18].

In vivo oral methods can be used in the field of food technology to evaluate natural conditions in mouth during mastication. This understanding is helpful in explanation of food dynamic changes which occur during mastication [41]. Food texture depends on its processing during chewing. The video fluorographic showed different results for food with different consistency [15]. However, each individual showed variation among each other. The usage of acoustic-EMG based system for the analysis of food mastication measure the oral tactile perception in terms of electromyogram of both masticatory muscles and auditory

signals [17] which are generated during mastication and are used to differentiate texture of different foods. There is need for standardization to gather information on food texture based on EMG as there is no general procedure or guidelines on the important parameters to be considered during design of an experiment.

VARIABLES INFLUENCING CHEWING BEHAVIOUR DURING ELECTROMYOGRAPHY (EMG)

a. Non-instrumental

Number of session: It can vary from one [4] to three [1, 5]. Differences were obtained during analysis of signals generated in different sessions of experiment [33]. Therefore it is always advisable to use more than two sessions.

Number of foods in a session: Generally, duplicate or triplicate samples of the same food product are investigated in a single session [6]. The different food samples investigated per single session varies from two to eight [34] but typically two to four different food samples are most commonly used. This brings about reduction in the amount of tiredness during the experimental session.

Size and shape of food sample: During mastication variations were found in muscle activity due to changes in the height of food bolus in response to different sizes of food products served [40]. Physiological parameters of chewing were used to differentiate foods of different shape and textural properties [38]. Serving the cut samples of same weight eliminates the change in the mastication pattern with respect to mouthful size. However, the process of chewing becomes easier by decreasing the weight of cut sample with same volume [28].

Nature of food: Chewing behaviour of hard foods is different from that of soft foods in terms of shorter duration of chewing strokes, increased rate of chewing, higher frequency and amplitude of spikes in each stroke [52].

Time: The time of day is an important parameter which shows effect in terms of physiological need to eat food [19]. The subject's biological rhythm and level of tiredness also affects the rate of chewing of food. So it would be advisable to undertake the sessions at the similar timings of the day so as to have the similar physiological conditions. However, more research needs to be carried out to conclusively understand the effect of this parameter.

Number of subjects: Due to the advancement and automation in the EMG systems, data can be acquired from multiple subjects in a single session. The data can also be acquired simultaneously from both the masseter muscles. As a result more participants can be included in the same session and a number of sessions can be conducted per day [45, 47].

Face anatomy: There is little influence of face anatomy on the bite force during EMG session. Whereas, the differences were observed due to the occlusal contact of the teeth and their direction as compared to the face. There is an interrelation among the direction of teeth and the maximum bite force used [12].

Side of mastication: Less muscle activity is required during bolus formation when food is chewed in free style manner as compared to side imposed manner [37]. Natural chewing is more effective when chewing is done with both sides [29].

Secretion of saliva: The amount of saliva secreted during chewing influences the chewing process. Subject with efficient chewing needs less time to chew a product while when the chewing pattern is slow. For the slow chewers, the food sample mixes more with saliva which bring changes in the textural characteristics of food [7].

Gender: The effect of gender on EMG study is ironical. Some authors have observed no differences while others have observed significant differences, which may be attributed to the differences in food samples, personality characteristics and educative-cultural aspects. Women exert less force during chewing of food and leave longer gaps between chews as compare to men due to which they need a longer chew time [43]. Therefore, more research needs to be done to study the influence of gender on chewing activity.

Age: The effect of age on chewing behaviour resulted in decrease in parameters related to time and voltage with increase in the age of the subjects. Subjects with weak muscle contractions had more length of chewing cycle [25]. Muscle activity per chew was found to be lower in elderly people. Thus few single chews were less effective for food reduction in elderly people than in young ones. Whereas muscle activity required before swallowing of food is similar in both elderly and young people [26]. Aging induce some variations in the neuro-mascular activity which bring about changes in the chewing behaviour such as long chewing cycles [35]. Amplitude of the EMG activity during decreases during mastication process for young people whereas no such changes were found in elderly people [20]. It can be concluded that it is difficult for the elderly people to adjust chewing force according to change in food texture during mastication.

Psychological effect: The psychological effect of human subject on food texture is explained on the basis of food choices. The psychological factors like emotions and mood also influence the selection of food to be eaten [10]. It can be concluded that the EMG texture evaluation may be affected by the individual's psychological factors in addition to liking or disliking of a particular food due to cultural, ethical or other reasons. Psychological parameters which bring about changes in muscular activity during mastication need to be considered while evaluating food texture.

Personality characteristics: The personality characteristics of the human subject affect the rate of chewing and other EMG parameters during food texture evaluation. The effect of personality difference was more pronounced during long chewing assignments as compared to short ones. Individuals with more degree of competitiveness have the tendency to take larger bites [46]. Further research, analysis and further work need to be conducted to find the effect of individual chewing behaviours, as a result of personality differences, on the EMG texture evaluation of different foods.

Effect of training: The effect of training on the conduct of EMG sessions brings differences in the mastication behaviour of trained subjects with respect to untrained subjects. For a given different textured food samples more variation is found in trained subjects in comparison to untrained subjects for mastication parameters like chewing time, chewing work and chewing rate. For a given parameter in between two consecutive sessions untrained subjects show great variation as compare to trained subjects [14]. While for muscle work parameter trained members showed more variation for different textured foods, which is helpful in food texture evaluation through EMG [36]. Also, the effect of paying attention on chewing process, results in lengthening of the chewing time [5].

Effect of denture: The response of human subjects with denture for various foods using EMG showed that adaptation to denture increases the chewing efficiency in patients [54]. Thus time and training for adaptation to new condition of stability is provided to the subjects with complete denture.

Swallowing problem: Various texture modified foods and thickened fluids can be used as substitution foods for individuals suffering from dysphagia i.e. swallowing problem [2, 23]. Amplitude of electromyography response decreases during swallowing in elderly patients suffering from swallowing problem and patients with fixed implant prosthesis [11].

b. Instrumental Variables

Frequency, amplification and data acquisition: The signals generated during chewing of food required filtration for removing noise signals and must be amplified for obtaining usable values. For obtaining signals various frequency ranges were used which varies from 0–10kHz, 10Hz–40kHz, 20Hz–10kHz, etc. The obtained signals are amplified (200X, 500X, 1000X, 2000X and 3860X) and used for further analysis of muscle activities. The data acquisition occurs at different values of frequency range like 50Hz, 250Hz or 1000Hz [55]. The EMG signals are then transferred to computer for further analysis. The parameters which are used in EMG for texture evaluation of food products are classified into two groups i.e. voltage and time parameters.

Voltage parameters: Voltage groups consist of average voltage (mean of peaks amplitude), maximum voltage (largest peak), slope of pre-maximum gradient (ascending part of slope of EMG burst) and post-maximum gradient (descending part of slope of EMG burst) [36].

Time parameters: Time groups consist of parameters such as chewing time (total time for chewing), number of chews, average duration of chews (total time divided by no. of chews) and inter-chew time (time between two chews) [48, 50].

EMG AND FOOD TEXTURE

Integrated area of EMG is related with chewing work done during mastication [4]. The variation among primates in term of their muscle activity estimated through EMG arises due to change in food structure during chewing, bite location and the way in which muscles generate bite forces (56]. This study plays an important role in evolution studies as masticatory jaw movement is one of the reliable methods to investigate food texture [44]. Human subjects show significant variations in the different mastication parameters used for differentiating foods based on texture. Various changes which occurred during mastication of food were studied using EMG [8]. Subjects with varying chewing efficiency have different concept for texture perception of food. The difference was observed in chewing energy which can be attributed to the type of muscles used to fracture the food by various individuals [49].

Mastication process is classified in to two parts rhythmic and irregular movement of the first molar during chewing of foods having different textures. The rhythmic chewing is longer for tough foods and bigger sample sizes while irregular movement are longer for foods which adhere to the teeth when chewing [53]. The breakdown of food in mastication is dependent on toughness and modulus of elasticity

and these parameters show strong relationship between bioelectrical activity and mechanical properties of food [1].
The harder the food, the more is the chewing rate, muscle activity and relative contraction period while shorter is the chewing cycle duration [19]. The texture of various foods which were treated by macerating enzymes for the softness of food products showed different values for EMG especially in the later stages of mastication [42].
Increase in hardness of two model foods viz. elastic and plastic were analysed with EMG. The results showed that chewing is well explained with plastic model food as they are chewed at lower frequency [13]. Natural mastication behaviour was analysed using EMG with two different types of gels with different mouthful quantities and mechanical properties but with same fracture load. These were found to have same number of chew, total muscle activity and complete mastication time but the gel with more fracture strain required higher muscle activity then the other [21, 29]. Texture perception using EMG with biscuits showed a dynamic structural change in them during eating. EMG pattern of human subjects for biscuits showed strong inverse relationship between hardness and crumbliness.
EMG of apples studied under the influence of cooking, cutting and peeling showed that different kind of preparation is required for human subjects with different mastication abilities [27].
Mastication parameters (number of chew, masticatory time and muscle activity per chew) for the cooked rice with different water to rice ratio showed higher value for cooked rice having least water to rice ratio [32]. Softer rice contains more water which minimizes the total mastication effort. Mastication parameters for rice with different level of milling and water to rice ratio showed differences in EMG parameters. The rice having lower degree of milling and cooked with lower water to rice ratio showed more number of chews, muscle activity per chew and mastication time [30]. Texture of cooked rice with different amylose analysed by EMG showed differences in mastication parameters. The cooked rice cultivars having higher amylose content showed higher values for number of chews, sum of muscle activities, mastication time, burst duration and muscle activity per chew while lower inter burst durations [31].
The eating behaviour for buckwheat noodles using electromyography was studied and it was concluded that noodles kept for some time become soft and reduces the rate of mastication effort [22].
The effect of chewing and swallowing behaviour on volatile release from confectionary based food products was studied. It was concluded that during breakdown of food in in vivo conditions there is modification in food texture which may influence the release of volatile components and thus affects their flavour perception [3]. Flavour released modelling from food has been based on time intensity assessment of perceived sensation combined with EMG to monitor mastication [51].

EMG AND ITS RELATIONSHIP WITH TEXTURE AND SENSORY ANALYSIS

Different studies have shown a good correlation between various EMG parameter and instrumental/sensory textural parameters measured for different food products. Hardness is the chewing forcewhich can be calculated with the help of EMG. The tenderness is based on two EMG parameters viz. time and chewing works [49]. Adhesiveness has been related with the post maximum gradient. Crunchiness was related to EMG response during the first five chews with molars. Mastication parameters were correlated better with adhesiveness and stickiness than hardness. Significant correlations were found between EMG and instrumental parameters (cohesiveness and fibrous residues) [42].
EMG variables at different stages of mastication (early, middle and late) were compared to instrumental texture data. EMG parameters and two bite instrumental tests showed high degree of correlation for cooked rice having different amylose content [31].
EMG analysis of kelp snack was performed to study the process of mastication. EMG mastication parameters correlated significantly with tensile test and sensory assessment [24].
Beef texture was evaluated by sensory profile, chewing patterns and mechanical properties. The variations were observed at different rate of deformation, shear and dynamic tests due to different muscle composition, myofibrils status and cooking temperature. The research also concluded that upto 70% compression all the instrumental texture parameters correlated well with sensory and EMG studies. Juiciness was related to low strain mechanical parameter during initial stages of mastication while tenderness was related to high strain mechanical parameter during middle and later stages of mastication [34]. The relation between EMG, textural profile analysis and sensory time intensity for measuring tenderness of beef was studied. It was concluded that textural parameter changes during different stages of mastication [9].
EMG activity of muscles during chewing of gels showed high degree of correlation with mechanical compression load (at large strain) and with sensory hardness parameters [16].

The relation between sensory analysis, physiological studies and physicochemical properties of foods have been studied and found significant in explaining texture perception of food by human subjects [57]. Relationship between physiological parameters (chewing cycle, chewing time, amplitude and cycle duration) and textural characteristics (hardness, fracturability and adhesiveness) of food products were also found to be significant [39]. EMG technique is emerging as an upcoming reliable method for comprehensive texture evaluation of different foods.

CONCLUSION

EMG method is emerging as one of the best methods for determining the texture of different food products on the basis of their chewing and swallowing behaviours. This technique can be used to overcome the disadvantages of the texture analysis by sensory and instrumental methods. It is a reliable method if standardized experimental protocols are developed and followed.

COMPETING INTERESTS

The authors have declared that no competing interest exists.

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