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Tongue pressure measurement in food science

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Recently published two articles relating to tongue pressure measurement during food oral processing and its usefulness for food texture study are highlighted. Tongue pressure measurement must be a new approach for texture design of food products particularly for specified consumer group with reduced capability of eating. In this article, a novel sensor for the measurement is introduced with emphasizing its advantages which enable natural and habitual eating behavior. Potential usage of the measurement to know the dynamics of food oral processing and to visualize the interaction between a food and the tongue are also indicated. Tongue pressure measurement can contribute to the progress of food texture study on both academic and industrial sides.

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Introduction

Food texture analysis on human *in vivo* measurements is now popular in the food science field. Electromyography [1–4], biting force measurement [5–9], palatal pressure measurement [10•,11•,12•], ultrasonic or ultrasound method [13,14], and videofluorography [15–17] are representative and provide us with a lot of insights into food oral management in human. The topic dealt in this article is tongue pressure measurement, and two related articles reported recently by the research team of Osaka University and Niigata University [18••,19••] are focused. They have been successful in mapping tongue pressure during oral processing using a novel device developed by the research team [20•] mainly for clinical purpose. On the basis of the success, they have been trying to visualize the interaction between a food and the tongue during oral processing in human. Since the tongue plays a crucial role throughout food oral processing, which initiates from cognition, followed by size reduction (mastication or squeezing), bolus formation, bolus transportation, and swallowing [21], it is reasonable from physiological point of view to link tongue movement with food texture. As a series of their trials, in these two articles, effects of food texture on tongue movement were investigated, and consistency [18••] and rheological nature (i.e. elastic or plastic) [19••] were selected as a dominating attribute of food texture. The idea of the research team to apply the device to food science is breakthrough.

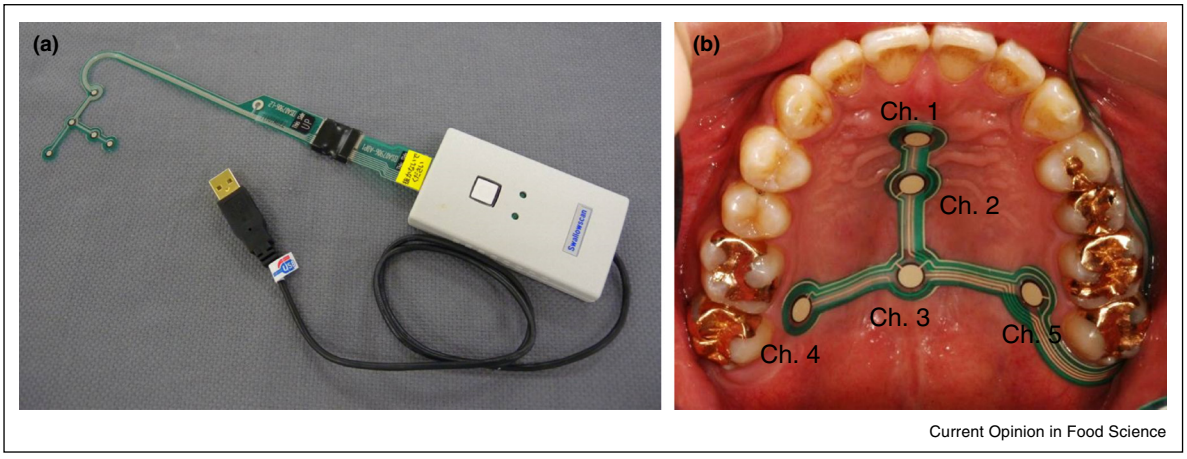
Apparatus for tongue pressure measurement and its advantages

The devise is a T-shaped sensor sheet with five measuring channels (presented as Ch. 1-5) attached to Swallow Scan system (Figure 1), enabling real-time monitoring of tongue pressure based on an electrical transducer mechanism (resistance to electrical current). The devise was originally established to architect the design of palatal plate particularly for tongue cancer patients. Measurement of the contact pressure between the tongue and the hard palate is necessary for customizing of palatal plate because the intensity and the pattern of the contact can change by the shape of the tongue after surgery. There are many technical advantages in the devise which support the idea of the research team. It is only 0.1 mm in thickness with different sizes and mechanical flexibility for easy adaptation to oral shape and does not change the oral physiology nor interfere with the occlusion. Also, the sensor sheet does not cover the overall area of the hard palate and thus does not interfere the perception of taste, aroma, or texture. It does not prevent natural and habitual eating behavior in human, and this must be no doubt the greatest benefit for food texture study. Manometer, in which a small balloon type probe is normally inserted into the oral cavity [22], may not cause too much discomfort to subjects but does not necessarily ensure natural eating. In addition, the devise is wearable and portable, and experiments can be carried out even on chair-side or bed-side. So far, over 20 articles have been published on this system, covering a wide range of research field from clinical, including diagnostic, treatment, and rehabilitation for the elderlies [23], tongue cancer patients, and stroke patients [24], to food texture study and providing the system with scientific validation.

Link of tongue pressure measurement to food texture

Most reports on tongue pressure measurement deal with only swallowing but not so frequently with a whole series of food oral processing. Using this system, temporal and spatial distribution pattern of tongue pressure during oral processing is elucidated, and thus human eating behavior

Figure 1



Swallow scan system **(a)** and location of measuring channels **(b)**.

(or food eaten behavior) can be visualized using tongue movement as a benchmark. Rheological nature of food samples does not basically cause difference in temporal pattern of tongue pressure during squeezing, presenting first onset at the mid-median part (Ch. 2), followed by the anterior-median (Ch. 1) and the posterior-median (Ch. 3) parts and then by the circumferential parts (Chs. 4 and 5) regardless of rheological nature (Figure 2). However, some differences are found between elastic and plastic (i.e. deformable) food samples in offset, and as a result, duration of squeezing for plastic food sample tends to become shorter than that for elastic food sample when consistency is low, whereas vice versa when consistency is high. Also, spatial distribution pattern of tongue pressure during squeezing is different between elastic and plastic food samples; the maximum amplitude at the anterior-median and mid-median parts are larger than that at the circumferential parts for elastic food sample, whereas no significant difference between channels for plastic food sample (Figure 3). These findings present difference in tongue movement during size reduction caused by food texture and also give us a hint on suitable food texture to specified consumer group with tongue-related digestion disorder.

For product development

There must be an intention of the research team to utilize this system for food product development for the elderlies. Usage of polysaccharide gels as a model food is an implication because gel is a dominant food matrix for clinical foods particularly for dysphagic patients as seen in pudding and jellies [25,26]. Decreased capability of generating tongue pressure has implication to eating and swallowing behaviors for the elderlies, and food texture design based on tongue pressure is valid in this regard. The author believes that concept of 'comfortable to the tongue' should lead to innovation of food product development for the elderlies. It is possible to synchronize tongue pressure measurement with other *in vivo* measurements, and when focusing on swallowing, usage of a bend sensor which monitors the laryngeal movement [27•] should be beneficial. Actually, in combination with bend sensor placed on the frontal neck (Figure 4), the coordination between laryngeal movement and hyoid motion during swallowing was elucidated, and the sequential order of tongue pressure and hyoid movement was displayed successfully [28]. In place of bend sensor, manometric catheter is applicable to see the oropharyngeal pressure flow dynamics during swallowing [29]. In addition, bodying sensation of beverages can be assessed by changes in both duration and the activity of the larynx required for one swallowing cycle using bend sensor [30•].

For future study

Discussion of tongue pressure measurement could be further expanded to cover some important aspects of food oral processing, such as dynamics of swallowing behavior, eating capability assessment, and artificial tongue etc. Tongue movement is basic to understanding the swallowing process, and tongue pressure measurement not only visualizes tongue movement but also clarifies different functions by tongue anatomy [31]. Tongue pressure relates to eating and swallowing capabilities of the elderlies [32,33], and its measurement can provide guidance of food choice for them. Usage of artificial tongue should be an idea for mechanical simulation of palatal reduction (i.e. size reduction by tongue-palate compression) [34,35], and tongue pressure measurement can help fabrication and selection of artificial tongue.