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Characterisation of chocolate eating behaviour

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ABSTRACT

Knowledge concerning variation in chocolate eating behaviour amongst consumers, and the impact that differences in the physical properties of chocolate could have on such behaviour is limited. The eating behaviour of individuals, consuming two chocolate samples (A and B), of comparable melt viscosity but with different textural attributes, was investigated. Surface electromyography (sEMG) was used to evaluate masticator muscle activity and electroglottography (EGG) was used to record swallowing events. Results showed that observed differences in mouthcoating affected the in-mouth residence time: chocolate A, perceived as more mouthcoating, showed an increased total chewing time and time of last swallow. Key differences across subjects were: time and number of chews, time of last swallow and total number of swallows. Subjects were grouped into three clusters of eating behaviour characterised as, "fast chewers", "thorough chewers" and "suckers". The main differences between clusters were the time chocolate was kept in mouth, chew rate and muscle work.

1. Introduction

The dynamic sensory experience that occurs when consuming chocolate is very important to the consumer [1]. However, to date very little has been published in the literature concerning how individuals eat chocolate and what variation in eating patterns may occur. Characterisation of chocolate eating behaviour is important as it will help understand its influence on consumer perception of its texture and flavour [2]. Brown and Braxton, for example, demonstrated that consumer preferences for biscuits may be related to the way a sample breaks downs in mouth whilst chewing [3]. Previous work in systems such as chewy confectionery products has also indicated that different chewing and swallowing patterns may influence sensory perception [4]. Different eating patterns may therefore influence the sensory experiences associated with chocolate consumption and warrant further investigation.

From a wider perspective, it has been shown that variation in bite size and oral processing time impacts on food intake [5,6]. 'Slow' eating has also been shown to decrease food intake and result in increased satiety [7,8]. If variation in chocolate eating behaviour exists then this could also impact on chocolate intake levels which in turn may have health implications.

Eating behaviour is complex. According to Brown [9], chewing behaviour is the result of various physiological, anatomical and psychological factors, such as coordination of jaw movement, size and strength of masticatory muscles and the learned and habitual patterns of chewing. Changes to the physical properties of a food will also alter chewing behaviour, processing of food in the mouth, and the occurrence of swallowing events [10]. However, although studies on the instrumental analysis of food's physical properties are widespread, literature investigating eating behaviour in response to these properties is limited.

Techniques to measure physiological parameters during eating are available, but have not yet been applied to chocolate. Surface electromyography (sEMG) can be used to evaluate the activity of the masticatory muscles while chewing. It is nonintrusive and does not interfere with the eating process [2]. Electric currents from an active muscle are recorded and an electromyogram is produced. Different EMG traces are produced when foods of different textural properties are chewed (Pierson and LeMagnen, 1970 in Jack et al. [11]) enabling chewing patterns to be monitored and differences between foods or individuals to be identified [12]. Electroglottography (EGG) is a non-invasive, innocuous, simple and inexpensive technique that provides information about the vocal folds behaviour [13]. It is usually used in speech therapy but has recently been used to identify swallowing events [14]. EGG identifies the pharyngeal stage of swallowing [15] involving the closure and re-opening of the vocal folds [13].

The objective of this study was to employ EMG and EEG to investigate variation in the individual eating behaviour of chocolate and to determine if changes in eating behaviour relate to observed textural differences between two chocolate samples.

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2. Materials and methods

Two milk chocolate samples were manufactured to give differences in textural attributes but with the same composition and comparable melt viscosity (A and B) (Fig. 1). For confidentiality reasons no further detail concerning sample composition can be provided. After production, the samples were stored at room temperature until 4 weeks old and then transferred to a freezer (−24.3 °C). Samples were removed from the freezer the night before analysis and kept at room temperature (around 18 °C). This guaranteed that all test were performed with samples of the same age.

The two chocolates were evaluated by 40 chocolate consumers from the University of Nottingham (age 20–60 year, 15 males) in terms of preference, and for five textural attributes: hardness, speed of melting, smoothness, thickness and mouthcoating. Subjects did not have any masticatory dysfunction, pain during eating, dental prostheses or allergies to chocolate. The objective of these tests was to identify whether differences between the chocolates were perceived by a panel and subsequently relate this to the results obtained by the physiological tests (surface EMG and EGG).

In order to evaluate which chocolate was preferred, a paired preference test [16] was performed by each subject. They were asked to taste each sample and record which the most preferred. After a 10 min break a series of paired comparison tests [16] were performed for five textural attributes: hardness at first bite (force to bite into chocolate with front teeth), speed of melting (measure of time taken to become molten chocolate), smoothness (of bolus, as opposed to gritty/grainy), thickness (perceived viscosity of molten chocolate) and mouthcoating (extent to which residue coats the mouth after swallowing). Subjects were asked to taste each sample in the order presented and determine which was the most intense for the attribute in question. The meaning of the attributes and the required eating protocol were fully explained and discussed prior to testing to ensure all participants understood the assessments.

For all tests the two chocolate samples were presented in identical pots labelled with random 3 digit codes. Samples had similar shape and weight (2 squares of each type of chocolate weighing approximately 3.5 g each) and were presented in a random balanced order across the panel. Crackers and mineral water were provided for palate cleansing before and between the samples. All testing was performed at room temperature in individual booths, with appropriate ventilation and lighting [17]. Data was collected using FIZZ network software (v 2.31B, Biosystemes, France).

To monitor the chewing activity of the subjects, two bipolar disposable electrodes (Medicotest Ltd, UK) were placed at each side of the face, at either end of the masseter muscle [14]. A fifth electrode, acting as earth, was placed at the shoulder blade. The skin under the electrodes was carefully cleaned with facial wipes so that, for example, any residue of lotion/shaving cream was removed, guaranteeing that the electrodes were secured to the skin. Four replicates of each type of chocolate were presented, in random order, to the participants. They were asked to sit still, eat the samples as they would usually eat chocolate and not talk during the experiment. Subjects were asked to indicate with a hand gesture when they had finished eating each so that the recording of data could be stopped. Water and lime juice were available between samples so that the subjects could rinse their mouth of any leftovers from the previous sample.

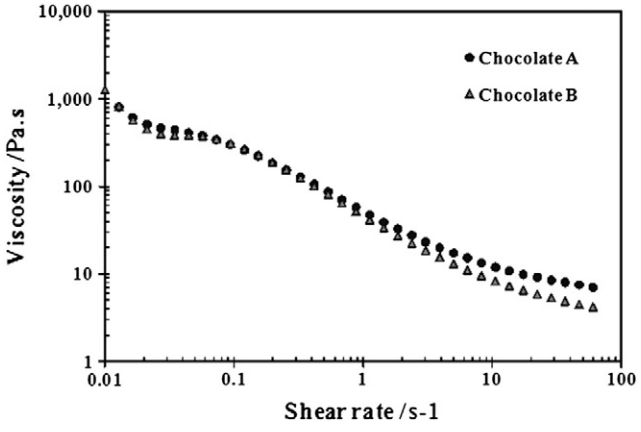

Fig. 1. Flow curve for molten chocolates A and B at 40 °C. Pre-shear: 20 s at 10 s-1.

Electrodes were connected to an analogue to digital converter (ADC) interface, 1401 MK II (Cambridge Electronic Design, Cambridge, UK). The signal collected was subjected to a low frequency high pass filter to remove any high frequency noise, therefore bringing the signal nearer to zero before amplifying it to a 5 kHz digital signal (1902 MKIII, Cambridge Electronic Design, Cambridge, UK). Then it was collected with the Spike 2 computer software package (v 5.9, Cambridge Electronic Design, Cambridge, UK). The rectification, smoothing of data and partial data analysis were performed with Sigview software (custom edition version, Goran Obradovic and SignalLab, England). The calculation of peak areas and identification of peaks start and finishing times was done through MatLab software (v 7.6.0.324, The Mathworks, U.S.A.) with a programme specifically designed to analyse this type of data. Nine chewing parameters were extracted from the data: total number of chews, number of side switches, time of last chew, total chewing time, total chew rate, proportion work right & left sides, normalised total muscle work and normalised total work rate [10]. The various parameters considered include time related and voltage related variables. All time related variables can be compared directly between subjects without any other measurements. The voltage related variables however need to be normalised before comparison. These variables depend not only on the electrical activity of the muscle but also on the size and composition of these, separation and orientation of electrodes, thickness of subcutaneous layer and electrical conductivity of the skin [10]. To normalise these variables, subjects were asked to consume chewing gum at the end of the session. Once the chewing gum was soft and the chewing activity steady, 1 min of EMG was recorded. The work rate for this minute was calculated and all voltage related variables were normalised by the division of this value [2].

To assess swallowing behaviour, a laryngograph (Laryngograph Ltd, London, UK) was used during the eating process. Two copper electrodes (3 cm in diameter) attached to an adjustable band were secured around the throat at the level of the thyroid cartilage and positioned approximately 3 cm apart. The electrodes detected the current passing through the throat with a frequency usually between 300 kHz and 5 MHz. While swallowing, the vocal folds close and the current passing through the throat increases since tissue impedance is lower than air impedance. Therefore, the frequency of the signal varies depending on the activity of vocal folds, and a positive signal is registered for swallowing action [14]. The signal was collected using Spike 2 software after direct input into 1401 MK II (ADC) where it was converted to an 800 Hz digital signal. The parameters extracted from the EGG are: the total number of swallowing events, the time of first swallow, the time of last swallow, the swallow rate and the time between last swallow and end.

Figs. 2 and 3 show examples of traces obtained from EMG regarding the activity of the left masseter muscle, and the activity of both right and left masseter muscles, respectively, while a subject was eating chocolate A. Each peak represents one chew, and the area under a peak corresponds to the muscle work as shown in Fig. 2. Fig. 3 shows the work of both right and left masseter muscles alternating. It is possible to identify which side is being used to chew at each period of time through the voltage intensity (peak height). Fig. 4 shows an example of an EGG trace recorded whilst a subject was eating chocolate A. Swallowing events can be identified from the EGG trace.