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Adaptation of mastication mechanics and eating behaviour to small differences in food texture

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HIGHLIGHTS

- Seven cereals foods have been tested for masticatory behaviour
- Coupled EMG and Jaw kinematics were analyzed in a time resolved manner
- Fracture force is not a good predictor of oral processing of cereal foods
- Results suggests that food oral processing can guide texture development

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ABSTRACT

Eating behaviour is significantly modified with the consumption of soft or hard textures. However, it is of interest to describe how adaptive is mastication to a narrow range of texture. ElectroMyoGraphy (EMG) and Kinematics of Jaw Movements (KJM) techniques were used simultaneously to follow mastication muscle activity and jaw motion during mastication of seven cereal products. We show that parameters such as the time of chewing activity, the number of chewing cycles, the chewing muscle EMG activity and the volume occupied for each chewing cycle are amongst others significantly different depending on products tested, even though the textural product space investigated is quite narrow (cereal finger foods).

In addition, through a time/chewing cycle dependent analysis of the chewing patterns, we demonstrate that different foods follow different breakdown pathways during oral processing, depending on their initial structural properties, as dictated by their formulation and manufacturing process. In particular, we show that mastication behaviour of cereal foods can be partly classified based on the process that is used to generate product internal structure (e.g. baking vs extrusion). To the best of our knowledge, such time dependent analyses have not yet been reported.

Those results suggest that it is possible to influence the chewing behaviour by modifying food textures within the same "food family". This opens new possibilities to design foods for specific populations that cannot accomplish specific oral processing tasks.

1. Introduction

In recent years, health benefits related to the increase of the residence time of the food in mouth have been studied, and have been linked with for example food intake control [1–3]. In addition to those benefits in adults, several benefits of texture appropriateness during the development of chewing in children have been identified, from texture acceptance in adulthood [4] to potentially dentition [5]. In order to define food properties tuned to a certain oral processing time it is necessary to understand how foods are broken down in mouth and this topic has attracted interest from the food science community in the last two to three decades [6–8]. At the heart of this interdisciplinary science lies the anatomy and physiology of eating [9], and the food physical properties (e.g. brittleness and fracture strength) [6,10]. This understanding requires in vivo methods as ElectroMyoGraphy (EMG) or Kinematics Jaw Movements (KJM). EMG techniques have been used since late 80′s mainly to link mastication mechanics to sensory properties and in-vitro characterization [11–13] on all kinds of products going from jelly to chocolate, cheese, meat, vegetables and biscuits. Since 2000, the interest to investigate the process of food breakdown in the mouth has raised and the dynamic dimension was introduced [14]. Since mastication is not a static process and that there is continuous feedback between the central nervous system and the mouth to control mastication up to the point of swallowing [7], describing the dynamics of mastication mechanics appears of relevance. Several research groups

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Table 1
Weight and number of pieces given to study participants to maintain a constant volume of 4.2 cm^3 across samples.

	Weight	Number of pieces
E1	0.68	5
E2	0.94	10
E3	0.73	1
C1	3.6	1
B1	2.45	1
B2	3.14	1
B3	2.66	1

have successfully combined both techniques to improve understanding in this area [15,16]. Both techniques [16–19], which we argue are very complementary.

Although several papers have been published in recent years on the development of mastication in early childhood [20] using EMG [21–23] and KJM [24–26], the community lacks the understanding of the mature mastication behaviour of adult subjects., especially when considering commercial cereal based foods, ranging from breakfast cereals to granola bars. Such data would constitute the limit towards which one would expect data to tend to after development of such skills, and also to give an idea of the ability of the scientific protocols to differentiate between food textures when investigating mature mastication behaviour. In addition most of the data presented in children mastication development studies are collected with the aim to compare foods that are widely different in texture [25] (e.g. banana, gelatin, breakfast cereals). Although those differences are relevant in the context of mastication development from an academic perspective, they do not constitute a reference frame for specific food product development. One recent study, carried out by Hedjazi et al. [17], showed differences between different types of cereal foods, but this study only reports data from a single adult subject, which prevents any meaningful statistical treatment of the data, and thus scientific interpretation beyond the understanding of this single subject. In this study we aimed to fill both gaps identified in the literature; (i) define using both KJM and EMG adult mastication on a restricted range of texture (controlled, commercially available cereal food product typically used by children) and (ii) use KJM and EMG to probe mastication mechanics of such foods in a time resolved manner.

2. Material and methods

In this work we used simultaneously the EMG and KJM techniques to follow mastication muscle activity and the jaw motion during mastication of seven cereal based food products.

2.1. Study setup and product description

10 healthy volunteers (5 men, 5 women, aged 26–50, not consulting for dental treatment at the time of the study) were recruited and informed about the objectives of the study. In compliance with the World Medical Association Declaration of Helsinki (2008), written voluntary informed consent was obtained from participants prior to participation and data were anonymized.

Each subject tested each of the seven food products 4 times monadically and sequentially, in randomized order, across two sessions. The first repetition of the four carried out was discarded in order to prevent any transient effect coming from the sensory discovery of the product.

The seven food products were commercial cereal based products that were either extruded, such as breakfast cereals (E1, E2, E3), baked biscuits (B1, B2, B3), or a chewy/granola type cereal bar (C1). A piece of the C1 cereal bar was taken as a reference volume (4.2 cm^3). From this volume, weight and number of pieces was determined for all the products using the matrix density (see Table 1). The objective was to obtain sample sizes yielding the same bolus volume by the end of the chewing process.

2.2. Data acquisition

Data was acquired simultaneously by both techniques. All subjects involved in this study were equipped with the reflective markers (KJM) and surface electrodes (EMG) as shown in Fig. 1.

2.2.1. EMG

Data was collected at 1000 Hz using a Noraxon Myosystem 1400 fitted with Noraxon bipolar electrodes (Noraxon, Cologne, Germany) which were placed on top of the four different closing masticatory muscles (Right Temporalis (RT), Left Temporalis (LT), Right Masseter (RM), Left Masseter (LM)) and the group of opening muscles (Anterior Belly of the Digastric (ABD)) relevant to characterizing chewing behaviour (see Fig. 1). In Fig. 2, one can see a typical EMG recording (amplitude (μV) as function of time (s)) of all the muscles monitored during the chewing process.

The signal of the ABD is very weak compared to the other signals. It was found difficult to accurately position markers to segment the data in this channel. Thus it was decided to remove this channel from our analyses and to focus on the jaw closing muscles (RT, LT, RM, LM).

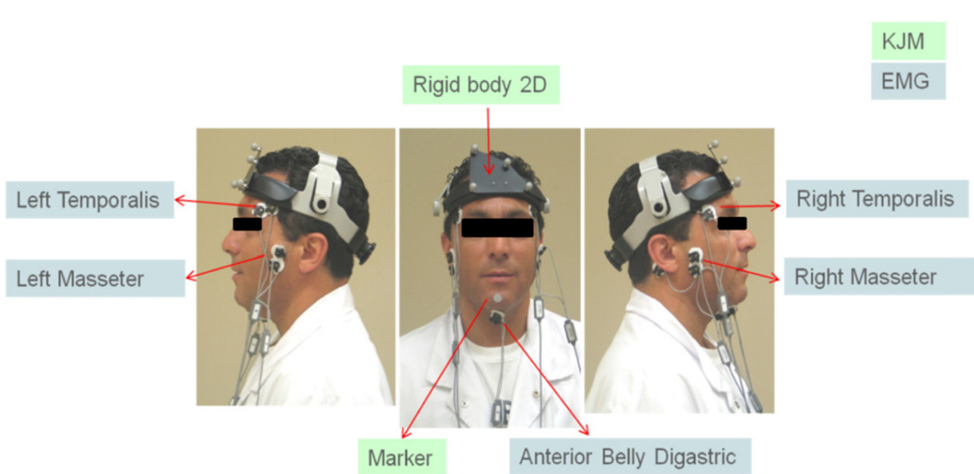

Fig. 1. Recording setup.