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Texture changes in bolus to the "point of swallow" - fracture toughness and back extrusion to test start and end points

Bryony James[a]*, Ashley Young[a], Bronwen Smith[a], Esther Kim[b], Arran Wilson[b], Marco P. Morgenstern[b]

[a]*Chemical and Materials Engineering, University of Auckland, Auckland, New Zealand*
[b]*The New Zealand Institute for Plant and Food Research, Lincoln, New Zealand*

Abstract

The change in texture of a food bolus during chewing, from first bite to swallow, is dramatic for solid foods and a variety of analytical techniques are required to quantify the texture at any given point in the chewing cycle. The objective of the work presented in this paper is to develop mechanical and rheological tests relevant to a model food, allowing the texture of the bolus to be quantified at first bite, and when masticated to the point of swallowing. This paper presents one aspect of the "Food Structure Platform" programme, a multi-disciplinary New Zealand programme investigating the influence of structure on the textural attributes of solid foods. The programme team is developing model foods and novel techniques to test their mechanical and rheological properties.
The first model food developed by the Food Structure Platform is a biscuit with a well defined range of hardness within one basic recipe. This was tested in 3-point bending to determine fracture stress and relate that to texture perceived on first bite. The biscuit samples were also masticated to the point immediately prior to where the subject would have normally swallowed then expectorated for rheological testing. Modified TPA and back extrusion, based on a cup and piston test piece, were used to test the rheological properties of the bolus from each of the biscuit models. Good correlations were found with fracture stress of the biscuit and sensory hardness for first bite. At the point of swallow the bolus had a consistent cohesiveness and saliva content irrespective of starting texture, whilst the hardness and adhesiveness was affected by starting texture/recipe.

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Keywords: bolus rheology; food texture; back extrusion; fracture stress; sensory hardness

1. Introduction

Food breakdown occurs during oral food processing, comminuting solid foods to a semi-solid bolus which combines solid particles and saliva [1,2]. Structural and mechanical features of a food dictate its

* Corresponding author. Tel.: +64-9-9237307; fax.: +64-9-3737463
E-mail address: b.james@auckland.ac.nz

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initial texture whereas the structural and rheological properties of the bolus dictate the texture immediately prior to swallowing [2,3,4]. The "Food Structure Platform" is a multi-disciplinary programme in New Zealand conducting fundamental research on the influence of structure on the textural attributes of solid foods and the change of texture during mastication. The programme team is developing model foods and novel techniques to test the mechanical and rheological properties of the food and the bolus.

As a solid food material is broken down during mastication its textural attributes alter dramatically [5,6,7,8]. At some point a decision is made that food is suitable and safe to swallow [9]. The rationale for this subconscious decision is still poorly understood despite the importance of texture to the enjoyment (and hence selection) of food [10]. Ultimately when the swallowing process is dysfunctional, as often happens in the elderly, it can lead to health issues such as dysphagia [11]. By developing analysis techniques capable of following a model food from initial bite to the point of swallowing this programme is contributing to a fundamental understanding of an essential process.

This paper presents one aspect of the programme, the development of a biscuit based model food and its examination using mechanical testing, for initial texture, and modified TPA and back extrusion tests to examine the rheological properties of the bolus at the point of swallow. The objective of the work presented in this paper is to develop mechanical and rheological tests relevant to a model food, allowing the texture of the bolus to be quantified at first bite, and when masticated to the point of swallowing.

An increasing body of work recognises the importance of relevant mechanical properties to the perceived textural attributes of solid foods. Measurements of fracture toughness and fracture stress and strain have been reported as suitable instrumental indicators of "crispness" for fruit and vegetables [12]. Instrumental measurements for hardness are often used as indicators for "crunchiness" [13] and Texture Profile Analysis (TPA) is a standard technique for numerous textural attributes [14,15,16]. Correlating instrumental measurements with sensory properties is not a trivial exercise, often complicated by a mismatch in vocabulary between sensory scientists and instrument operators. The Food Structure Platform addressed this issue early in the programme [17].

As a solid food is broken down during chewing (oral processing) it becomes a bolus comprising solid particles and saliva. Measuring the rheological properties of the bolus is challenging and the two main techniques being developed are measurements of "squeeze flow" [18,19,20] and "back extrusion" [21,22,23,24]. In the current study back extrusion has been used as the aim was to develop a rheological testing technique that can be applied to the bolus at numerous points during the chewing cycle, even when the particle size is still quite large (at the start of chewing). Back extrusion offers many advantages as it is a relatively simple testing geometry that can be applied to a wide range of both time independent and time dependent fluids [23].

The results presented in this paper concentrate on the rheological testing of the bolus at the point of swallowing. A fuller description of the mechanical properties of the model food biscuits is presented elsewhere [25].

2. Materials and Methods

Development of the first model food system in the Food Structure Platform is based on a biscuit structure. Biscuit recipes were developed varying the fat:sugar:starch ratio along an axis between biscuits with extremes of texture (shortbread and gingernut) [25]. Five biscuit types were produced with ratios as shown in Table 1.

Table 1. Biscuit based model foods

Biscuit	Sugar/fat ratio
SP1	0.71
SP2	1.10
SP3	1.47
SP4	1.87
SP5	2.24