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Research Note

Oral Processing of Crackers: Changes in the Secondary Textural Characteristics

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Abstract

To investigate the secondary textural properties associated with the later stages of oral processing, Melba toast and cream crackers were milled to minimize sensations associated with the first bite. Assessors used the Temporal Dominance of Sensations technique to document their experience of eating these biscuit crumbs. Two sensations, "sticks to palate" and "compacted on teeth", dominated the significant sensations during oral processing. Similarities between these biscuit crumbs and the behaviour of other low water, low fat foods during oral processing exists. This behaviour is inconsistent with the Hutchings and Lillford breakdown path, but shows similarities to what takes place in a domestic food processor when liquid is added to a dry powder to produce a dough. It is suggested that foods with varying levels of initial structure could embark on oral processing from different points in the breakdown path.

Practical Application

This paper helps us understand the breakdown path of dry, carbohydrate rich foods like crackers.

Keywords

Breakdown Path; Chewing; Low Water Food; Mastication; Models of Swallowing; Moisture Map; Oral Processing; Secondary Textural Characteristics

Introduction

Hutchings and Lillford (1988) proposed a model to explain the breakdown path of solid foods during oral processing [1]. The model identifies two thresholds, one for the degree of structure and the other for the degree of lubrication. It is only when both of these thresholds are met that the food is of a consistency suitable for swallowing. In naming the axes, the authors argued that moistness could result from both water and/or fat choosing the term "degree of lubrication" to capture the scale. This recognition prompted Chen and Rosenthal (2015) to plot the water content versus fat content for a wide variety of foods on a fat-free, dry-weight basis, thus creating their moisture map (Figure 1) [2]. This map appears to separate foods into groups with common structural and textural characteristics.

Hutchings and Lillford's breakdown path has become widely adopted to explain what occurs during oral processing of many solid foods. Clearly it fits well for most fresh foods whose structure needs breaking up and for

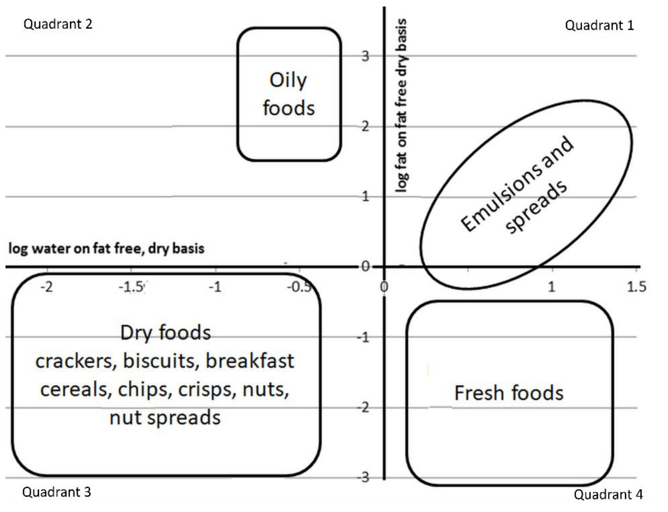

Figure 1: Chen and Rosenthal's Moisture Map.

which adequate lubrication is a readily available from saliva and the constituent components of the food (fourth quadrant of the moisture map). Furthermore emulsions, spreads, and many oil rich foods are well lubricated and rarely require much oral processing to enable them to be swallowed (first and second quadrants). However, many of the foods that lie in the third quadrant of the map do not seem to behave in a way consistent with the breakdown path model. This was first recognised by the anecdotal experience of eating peanut butter. On crushing roasted peanuts oil is liberated and the kernel ground to produce a small particle size distribution, the paste has relatively little structure and is highly lubricated by the oil naturally present [3]. When eaten it appears to thicken within the oral cavity suggesting that structure is actually forming. Rosenthal and Share (2014) used the Temporal Dominance of Sensations technique to follow the breakdown path of roasted peanuts, roasted peanut meal and roasted peanut paste [4]. They showed that while whole nuts and meal seemed to follow Hutchings and Lillford's breakdown path, the paste, with relatively little initial structure, seemed to thicken and stick to the palate during oral processing. Sesame paste (Tahini), like peanut butter is derived by grinding an oil rich seed and behaves in a similar way in the mouth. Rheological testing of sesame paste during hydration shows how the material thickens as the water activity increase, becoming a hard solid before starting to soften with elevated levels of hydration [5,6]. Presumably, when introduced to the mouth saliva becomes mixed with the oil forming a crude emulsion. The dry suspended particles start to adsorb water from the saliva and every wet surface onto which they contact, thus they stick to the roof of the mouth and the tongue producing a sticky, throat choking mass. Only with continued hydration does the stickiness reduce allowing a swallowable consistency.

In addition to nut butters, the third quadrant of the moisture map is where crackers, biscuits and extruded snacks lie. A number of other researchers have commented that when such foods are masticated, the final sensations tend toward sticky and cohesive mass. For example, when breakfast cereals are consumed without milk, the final sensations that predominate are sticky and cohesive textures [7].

In their seminal paper, the "Texture Profile Method", Brandt, Skinner and Coleman (1963) separated the first-bite characteristics like hardness and brittleness (in the case of solids) from a second masticatory phase which gives rise to sensory attributes like gumminess, cohesiveness, chewiness and adhesiveness [8]. During the first-bite, catastrophic structural breakdown occurs in solid foods, giving rise to a variety of mechanical textural (bite force, hard, sticky), geometric (splinters, crumbly) and auditory sensation (snapping, crunchy, sounds with varying intensity and pitch) [9]. During the masticatory phase (chewing), further mechanical and auditory sensations occur. Attributes such as hardness, springiness, drying sensation, disintegration, toughness, gooeyness, crunchy sounds, exist [9].

The purpose of this study was to eliminate the first-bite phase and to concentrate on the sensory attributes that arise during the masticatory phase. By milling food samples many of the sensations associated with the first-bite would be minimized and the assessors are able to focus on the masticatory phase. However, some sensory attributes, such as hardness are known to be common to both the first bite and the masticatory phase [9]. We hypothesise that Moisture Map quadrant 3 foods do not fit with Hutchings and Lillford's breakdown path and that while initial structure can be broken during the first bite, the subsequent crumbs thicken up into a sticky cohesive dough like mass which requires extended oral processing and added liquids before they can be swallowed.

Materials and Methods

Sample preparation

Melba toast (Sainsbury's, London, UK) and the cream crackers (Jacob's, Leicestershire, UK) were purchased from a local store.

Separately the materials were milled in a food processor, and the resulting meal passed through a 1 mm mesh. After sieving, samples were stored at room temperature (20°C) in airtight containers and used within 5 days of preparation.

Five-gram samples of milled product were weighed into a clean dry plastic cups prior to offering to assessors.

Participants and sensory testing

Twenty-one healthy, untrained, naïve participants were recruited from students at Coventry University (Coventry, UK). All of the participants were over 18 years old. Assessors were either native English speakers or had an International English Language Testing System score of over 6.0 and thus had a good grasp of the meaning of common words to describe food texture. None of the assessors any history of food allergies, eating disorders or swallowing difficulties.

Before the sensory test, the participants were provided with a background information sheet and offered an opportunity to ask questions regarding the nature of the study. When satisfied with the experimental protocol they were invited to give informed consent to participate.

The Temporal Dominance of Sensations technique was used to gather data on perception during oral processing of the samples [7]. Software written by Marco Morgenstern (New Zealand Institute for Plant & Food Research Ltd©), was used. For comparability, the same descriptive terms used by Rosenthal and Share (2014) were used, namely: 'Hard'; 'Soft'; 'Chewy'; 'Crunchy'; 'Compacted on teeth'; and, 'Sticks to palate' [4].

Attributes were defined as:

- 'Hard' is resistance to biting compression of the jaw.
- 'Soft' is a yielding sensation when the product is processed in the mouth, it results in the material appearing to deform and flow when chewed (even with gentle chews). It also manifests through contact and deformation by the tongue.
- 'Chewy' describes a material which exhibits cohesive and elastic characteristics. Such a material possesses solidity which yields under the stress of chewing, but which regains some of its former structure after each chew.
- 'Crunchy' is the friable characteristic of suddenly yielding when bitten, with the generation of sound.
- 'Compacted on teeth' is a sticky sensation where the product adheres to the teeth during and after chewing
- 'Sticks to palate' a sticky sensation where the product sticks to the roof of the mouth and the tongue during and after oral processing.

Participants were instructed to introduce the sample to the mouth and click on the "start" button on the computer screen using a computer mouse. Participants were trained by explaining, demonstrating and offering the opportunity to trial the software. They were provided with identical samples of the milled cream crackers and Melba toast as were used later in the study. This enabled the assessors to become familiar with the methodology and the samples. Assessors were instructed to eat normally and record the dominant sensation at any particular time using the computer mouse. Assessors were provided with water and told they could sip water at any time. Between samples assessors were instructed to rinse their mouth and drink at least one mouthful of water.

After training the assessors were given test samples for data collection undertaken. Fresh water was provided. As samples were distinctive, no attempt was made to randomize the serving order, instead the balanced block of: Melba toast, cream cracker, Melba toast, cream cracker was used throughout.

Results

Pineau and colleagues (2009) annotated the Temporal Dominance of Sensations graphs with a chance line based on the number of attributes, they also added a confidence line to reflect the 95% probability level [10]. Essentially it is only the values that exceed this confidence line that can be considered to be statistically meaningful ($p<0.05$). Figure 2 represents the Temporal Dominance of Sensations curves for both cream crackers and Melba toast. Rather than start at the origin, we have truncated the vertical axis at the 95% confidence level, thus ignoring all data for which we are statistically uncertain.

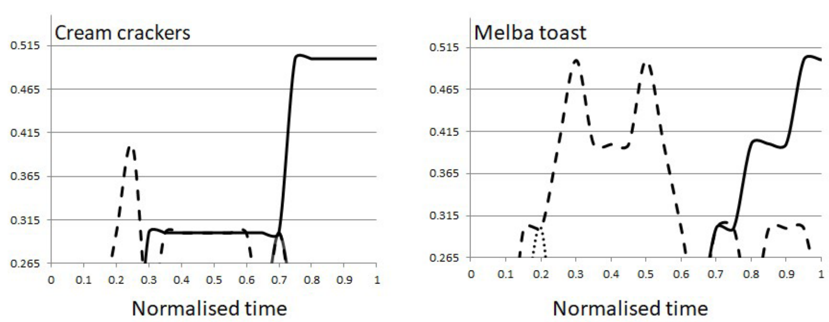

Figure 2: Temporal Dominance of Sensation for the two biscuit crumbs (— compacted on teeth; - - sticks to palate; ···· crunchy; —— chewy).

Figure 2 shows a clear lag to the first significant selection for both cream crackers (7.5 seconds) and Melba toast (6.2 seconds). This is not to say that assessors did not respond sooner, but that the variation in sensations between the panel was below the 95% confidence line. Also noteworthy are the peaks and troughs in the dominant sensation at any particular time. This is because other sensations are selected by a smaller number of assessors, and below the 95% confidence level.

Discussion

While assessors had a choice of six attributes to describe the oral sensations, figure 2 shows only four features above the 95% confidence level. Both graphs are dominated by the sensations "sticks to palate", leading to "compacted on teeth" for both Melba toast and cream cracker. The sensation "crunchy" does occur briefly, for the Melba toast (as equally dominant with "sticks to palate"). Similarly, "chewy" occurs for the cream crackers, but is overlaid by "sticks to palate" and in reality, both are less dominant than "compacted on the teeth" at that time.

The oral experience is similar to that obtained in other studies with third quadrant foods on the moisture map (Figure 1). Lenfant and co-workers (2009) studied dry breakfast cereals and showed a gradual change in the textural properties towards stickiness. Similarly cake and dry biscuits gave rise to "gooey" cohesive sensations prior to swallowing [9]. While the dominant sensations for biscuits changed from hard/crumbly to crunch/crispy to dry and finally to sticky and cohesive sensations [11,12].

Hutchings and Lillford's breakdown path was presented as a "discussion paper" and holds well for foods of quadrants 1, 2 and 4 of the moisture map (Figure 1). They speculate as to the break down path for dry sponge cake (which probably fits the third quadrant of the moisture map), and this speculation does not match the behaviour of other materials in this quadrant. While not explicit in their model, there is a suggestion that structure loss is an active process, requiring muscular work while increasing lubrication is passive and only requires time for the ongoing secretion of saliva. In the case of dry foods from the third quadrant, the physical work continues beyond the initial structural breakdown as the secretion of saliva leads to a cohesive mass [4,7,11,12]. As with these studies our data for cream cracker and Melba toast crumbs seems to suggest structure development as the material "sticks to the palate" and becomes "compacted on teeth". While TDS does not provide the intensity of the sensations it does identify what is dominant.

Figure 3 attempts to separate the different activities during oral processing. It considers the consistency of the contents of the mouth arising from foods being introduced in varying states or by prior oral processing. The two right hand columns show the oral processes of mastication and saliva secretion.

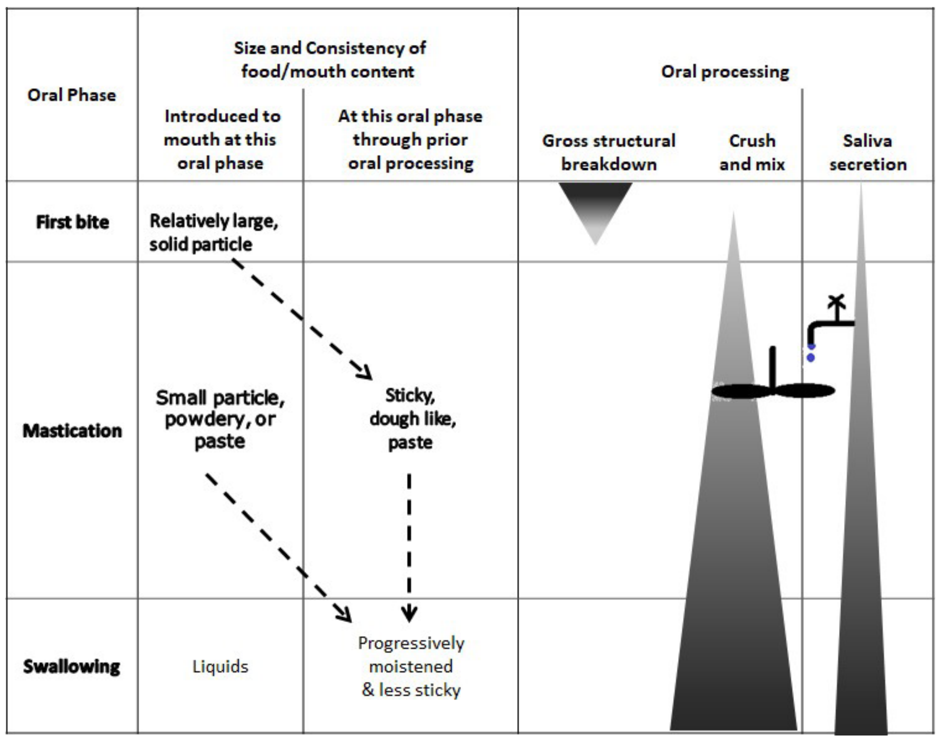

Figure 3: Schematic of stages during oral processing of low water foods.

The first bite, possibly only relevant to relatively large particles, results in gross structural breakdown. This is followed by crushing and mixing with the ongoing supply of saliva. The resultant dough becomes progressively moistened and less sticky, until it becomes a bolus that can be swallowed.

Smaller particles enter the mouth during the masticatory phase and like those which result from a first bite, they experience crushing and mixing with the ongoing secretion of saliva. The continuous secretion of saliva leads to gradual moistening of that dough, the small particle size resulting from mastication ensures an enhanced saliva uptake [13].

Swallowing has been divided into three phases (oral, pharyngeal and oesophageal) [14], during the oral phase of swallowing the material in the mouth is moulded into a bolus and forced to the back or the oral cavity. The material that enters this phase of oral processing is either the sticky, dough-like, paste resulting from the masticatory phase or a liquid introduced to the mouth at that time.

While not wishing to under play the role of lingual amylases, the crushing and mixing action together with the gradual addition of saliva, results in a paste. This paste gradually becomes less cohesive, less sticky and moister until suitable to swallow [7,9]. In many respects the masticatory phase is akin to gradually adding liquid to a dry powder in domestic food processor.

Perhaps a matter of semantics, but an important question is whether the cohesive mass which "sticks to the palate" and "compacts on the teeth" is actually a bolus? In his excellent review of oral food processing, Chen (2009) discusses the evolution of thought on what constitutes a bolus [14]. If a bolus were simply defined as a mixture of food particles with saliva, then this cohesive mass might be a bolus. But if the bolus is formed in the oropharynx [15], then the material we describe cannot be one. Compelling evidence against the paste being a bolus, is that it is "hard to swallow" [4]. We need to differentiate between bolus formation and the creation of a sticky paste resulting from oral processing of a dry powdery food, for something must happen to such a paste for it to become a bolus - namely further crushing and mixing with additional fluid.

Conclusion

The masticatory phase of oral processing for Melba toast and cream cracker crumbs behave like other low water, low fat foods inasmuch as they absorb saliva developing a dough like structured material. This behaviour is inconsistent with Hutchings and Lillford's break down path, but is more akin to a domestic food processor used to produce a dough through gradual additions of water (or saliva) or fat to a dry powder.

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