leatherhead food research

From first bite to swallow: the science of oral processing

Understanding how products deliver texture and mouthfeel during consumption

Dr Pretima Titoria

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Optimising textural, mouthfeel and flavour release profiles is a high priority for food and beverage product developers. Traditionally, this relies upon trial and error. But combining oral processing science with ingredient and processing knowledge provides a more focused approach. In this White Paper, Dr Pretima Titoria discusses the key principles, methodologies and benefits of oral processing.

Principles of oral processing can be exploited across a broad spectrum of food and beverage renovation and innovation. It can benefit challenging areas, such as development of healthier products with reduced sugar, salt and fat content. Healthy versions often deliver inferior textural and organoleptic qualities. To overcome this, we first need to find out why. What roles do fat globules, sweeteners and salt play in the texture and flavour release profiles? Understanding this provides a strong position from which to innovate and renovate products more strategically and quickly.

Oral processing is a relatively new area of science. It is gaining popularity and recognition because it allows us to manipulate ingredient functionality to create a microstructure that generates particular textural breakdown characteristics and mouthfeel.

Figure 1 demonstrates microstructural differences between standard cheese and reduced-fat cheese, and how these impact textural breakdown and flavour release profiles in-mouth. As shown in Figure 1a, the protein-continuous networks in the standard and reduced-fat cheese were similar, but the fat distribution different. The latter had many smaller droplets. Figure 1b shows how microstructures deformed during chewing. Fat droplets in the standard cheese emulsified into a mixture of large and small droplets, but “coalesced” into larger droplets in the low-fat cheese.

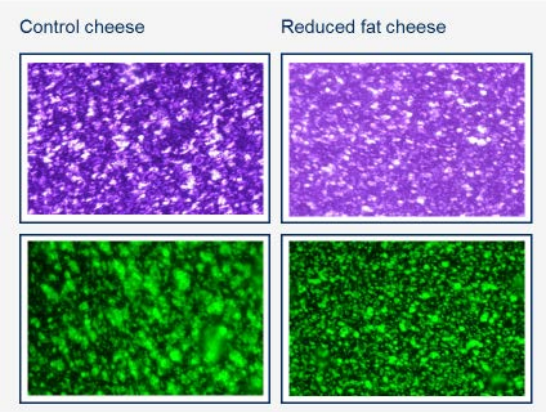


Figure 1a: Intact microstructure of standard and low-fat cheese (protein network stained purple, fat stained bright green)

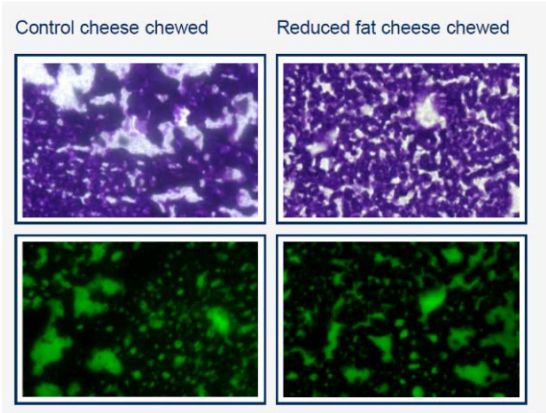


Figure 1b: Transitionary changes as function of chewing in standard and low-fat cheese

Maximising textural and flavour enjoyment requires an ability to map and understand behaviours of ingredients/components, microstructures and products from first bite to point of swallowing.

Oral processing – food deconstruction in the mouth

Oral processing is a dynamic process involving interrelated destructive steps:

1. First bite
2. Chewing & mastication
3. Transportation
4. Bolus formation
5. Swallowing

The mechanics of saliva production and bolus formation also play a role, with the former being more relevant to product design. Saliva[1] provides a lubrication effect which smooths food movement in the mouth, interacting with food components and leading to structure formation or breakdown. Furthermore, during this complex process, saliva impregnation of the food matrix influences release profiles of flavour compounds, affecting consumer perception[2].

Characterising from consumption to swallowing

Figure 2 shows the behaviour of a product as it transitions (or transports) from drink-in point (consumption) to swallowing. Upon consumption, bulk properties dominate mouthfeel, but just before swallowing, surface properties dominate. Bulk, transitionary and surface properties are defined by different attributes, depending on whether the product is liquid, semi-solid or solid. These attributes can be quantified by appropriate techniques, explored in the following sections.

Rheology, tribology, particle shape/size and microscopy: tools for characterisation

Texture and mouthfeel attributes are key influencers of consumer experience and acceptability. They are generally predicted based on knowledge of material properties in intact products, i.e. *prior* to consumption. However, this is restrictive.

Understanding how the product delivers textural and mouthfeel attributes *during* consumption can inform and enhance product development.

Ongoing studies focus on techniques to capture dynamic aspects of oral processing. The most popular and current approach involves a combination of rheology and tribology[3] (see definition below), with complementary microscopy

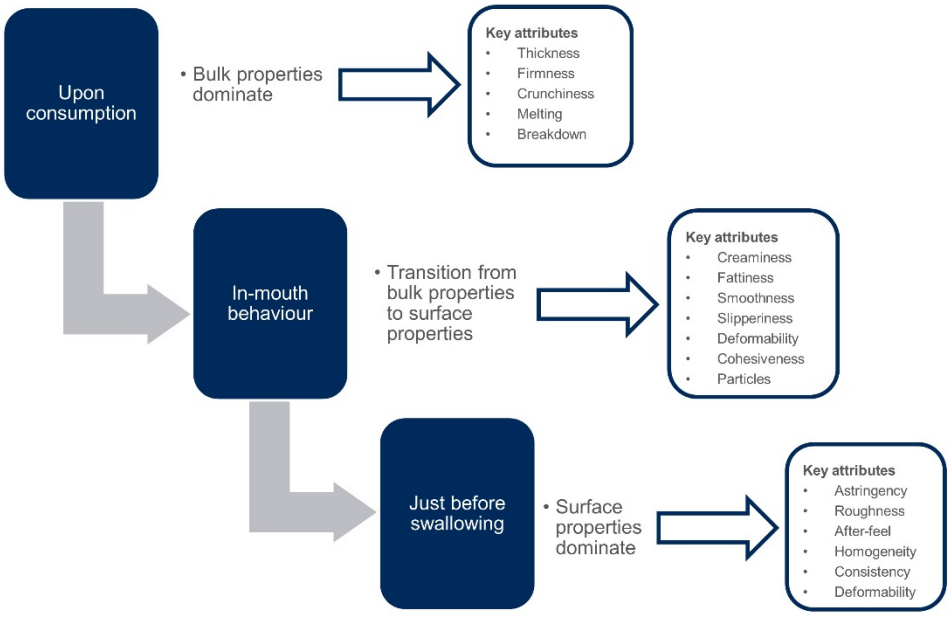


Figure 2: Structural changes from original product to point of swallowing (oral processing); adapted from Stokes *et al.*[Error! Bookmark not defined.]

as well as particle size and shape analysis. Characterisation of products' rheological properties has well-established methodologies, using a range of viscometers and rheometers. However, tribology measurement is still in its infancy. Several studies are underway to explore, evaluate and consolidate principles of tribology measurement within the food and beverage industry.

Figure 3 demonstrates how different stages of oral processing can be characterised in terms of properties and associated attributes. It uses rheology and tribology as the main techniques. However, the relationship between instrumental measurements and sensory assessment needs to be validated.

The relationship between rheology/tribology and sensory science

Relating sensory feedback to instrumental data (microstructural, particle size/shape and rheological/tribological) is an ongoing challenge. Traditional methods using trained panels and consumers are well-recognised and documented. However, Temporal Dominance Sensation (TDS) is gaining attention because of its closer correlation to rheological and tribological measurements.

It's claimed that TDS captures multidimensionality of the perceptual space over time. It involves assessment of the most intense (dominant) percept at any moment and scores the intensity. Figure 4 shows an example of TDS, demonstrating how sensory panellists perceived the standard and low-fat cheese samples. It indicates a strong prospect of potential correlation between sensory and instrumental analysis (Figure 3). This could underpin a powerful package of tools for targeted product development.

The rheology-sensory science relationship has been extensively studied. Now the tribology-sensory science relationship has sparked intense awareness and interest. For instance, Cargill[4] demonstrated the predictive power of tribology methods in a range of lemon-lime beverages, confirming that tribology results were consistent with sensory panel data. Use of tribology measurements could potentially accelerate product development cycles, reducing the need for costly trained sensory panels during the product development process.

- **Rheology** is the understanding of bulk deformation of products and the subsequent flow, when a certain amount of force is applied.
- **Tribology** is the study of friction and lubrication between interacting surfaces in relative motion.

- **Microscopy** is used to visualise microstructural changes of a product before and after mastication (chew and spit).
- **Particle size & shape** has a significant impact on mouthfeel characteristics from bulk properties (~>100 μm) to transitionary (~0.1 μm to ~100μm) to surface properties (~mm – ~nm)[5]. It can be measured using imaging technologies, laser diffraction or sieving.

Exploiting the science of oral processing for product development

Using these approaches in product innovation and renovation can deliver enormous benefits. It can accelerate development of products with desirable organoleptic properties. And it can underpin advances in specialised products for populations with chewing, swallowing or choking issues, such as the elderly and babies or young children.

Understanding how components within food and beverage products break down in the mouth to deliver textural, mouthfeel and flavour profiles provides valuable insights. It enables product developers to select the right types of ingredients or processing conditions for desirable microstructures and textures. It can also reduce the time and cost of product development cycles.

Once the approaches are fully verified, they will provide an objective framework for a new age of science-led product development.

Figure 3: Correlation from instrumental measurements to oral processing stages (top for beverages, and bottom for semi-solid/solid products). Techniques are not restricted to those mentioned above.

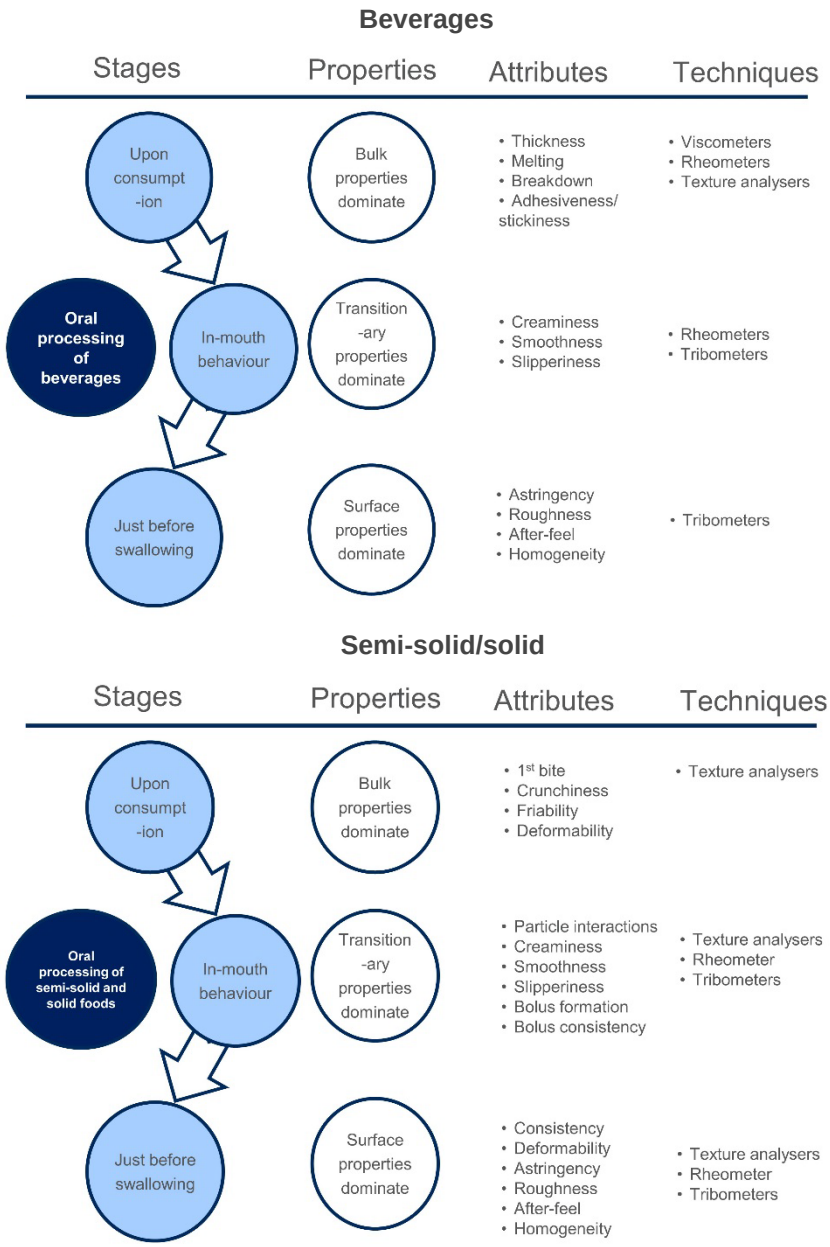
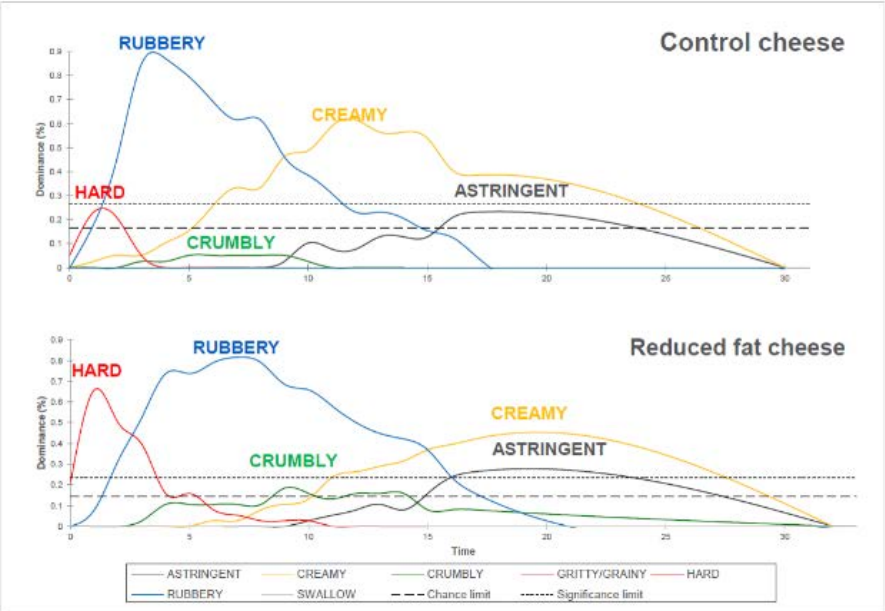


Figure 4: TDS carried out on standard and low-fat cheese (same samples as in Figure 1).



How Leatherhead can help?

Leatherhead has many years of experience and expertise in application, interpretation and correlation of rheology and microscopy, along with other complementary techniques, to map the deconstruction of food & beverage products in-mouth, and working backwards to ingredient selection and product design. Balancing the instrumental analysis, Leatherhead has dedicated trained panels to provide sensory feedback on critical attributes, therefore offering a comprehensive and science-focused approach to use of oral processing science in development of products with desirable texture and mouthfeel characteristics.

About the author

Pretima graduated with a BSc (Hons) in Food Technology at University of Reading and obtained her PhD in the area of rheological characterisation of food biopolymers/hydrocolloids at Cranfield University. She continued to develop her skills in this area over several years while working at the Institute of Food Research, Norwich and at DuPont Cereal Innovation Centre, Cambridge, before joining Leatherhead Food Research in 2001. Pretima is now a Senior Consultant within the Science & Innovation department, and manages several Confidential Contract Research projects. Pretima has many years' experience in physico-chemical characterisation of ingredients, interim products and final products, focusing on the textural and microstructural properties and their effect on product quality and stability, as well as their role in oral processing. Pretima is a Fellow at the Institute of Food Science and Technology (FIFST).

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Leatherhead Food Research provides expertise and support to the global food and drinks sector with practical solutions that cover all stages of a product's life cycle from consumer insight, ingredient innovation and sensory testing to food safety consultancy and global regulatory advice. Leatherhead operates a membership programme which represents a who's who of the global food and drinks industry. Supporting all members and clients, large or small, Leatherhead provides consultancy and advice, as well as training, market news, published reports and bespoke projects. Alongside member support and project work, our world-renowned experts deliver cutting-edge research in areas that drive long-term commercial benefit for the food and drinks industry. Leatherhead Food Research is a trading name of Leatherhead Research Ltd, a Science Group (AIM:SAG) company.

help@leatherheadfood.com T. +44 1372 376761 www.leatherheadfood.com

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info@sciencegroup.com

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