Food oral processing: mechanisms and implications of food oral destruction

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Abstract

Background

Food oral processing is a simultaneous process of food destruction and sensory perception. How a food breaks down its structure inside the mouth and what mechanisms control this process are hugely important to our eating experience and sensory perception. A proper understanding of this process is urgently needed by the food industry for better design and manufacturing of quality tasty food.

Scope and approach

This review article analyses research findings from literature and from author's own laboratory in order to identify main controlling mechanisms of food oral destruction. Appropriate experimental evidences are given wherever available to demonstrate the important implications of different destruction mechanisms to sensory perception.

Key findings and conclusions

Three major controlling mechanisms of food oral destruction are identified: the mechanical size reduction, the colloidal destabilisation, and the enzymatic interactions. These mechanisms may be applicable to different food materials either independently or collectively. They could also be applicable through the whole eating process or just at a certain stage of an eating process.

Keywords: food oral processing, food structure, food destruction, sensory perception, eating, saliva

1. Introduction

Eating facilitates two very basic functions for human beings: to gain energy and nutrition and to gain pleasure and enjoyment. The former is for human's physiological and biological needs of proper functioning of human body, while the latter serves to elevate our spirit and mood, a social and psychological function of the food also essential for our well-being. Food structure greatly increases the latter whilst barely affecting the former. Consuming one mouthful solid food, from the first bite till final swallowing, only takes few seconds to up to few ten seconds. For a mouthful fluid food like a beverage, a couple of seconds is usually more than enough for the whole process. However, despite its short oral stay, food experiences a series changes in structure and in physicochemical properties. The drastic food destruction and the food-body interaction at the oral stage create a unique sensory experience which leads to consumers' preference and liking of a food product. There is no doubt that food structure creates most if not all the pleasure of eating. Therefore, a proper understanding of food structural breakdown during eating is critically important not only to our fundamental understanding of the governing principles of eating and sensory perception but more importantly for better design and manufacturing of quality tasty foods. Food industry urgently needs technological support in order to meet ever increasing demand from consumers and to keep competitive advantages in a globalised market.

This paper aims to elucidate the determining mechanisms of food oral destruction. The discussion will focus on how food oral breakdown is regulated and influenced by what factors and more importantly, their implications to our sensory perception. This work is a continuation of author's previous works on the underpinning principles of food oral processing (Chen, 2009, 2014; Chen & Stokes, 2012). Though opinions expressed in this paper are only author's view of the topic, supporting experimental evidences are given to support such views wherever available. While food structure is a main focus of the discussion, how food structure/texture is sensed or assessed is not covered in the review. This is partly to keep the paper in proper length, but more importantly because mechanisms of structure sensation are too complicated to be covered in this short review. For some introductory information about functions of oral mechanoreceptors and structure/texture sensation, readers are referred to other reference sources including Schmidt (1981), Goldstein (2010), and Chen (2014).

2. Structuring and destruction of food

Food making is basically a structuring process. From ingredients selection and mixing to processing, forming, shaping, and storage, the ultimate aim of formulation and processing design is to have the formation of an optimum structure which conveys most desirable sensory experience as well as nutritional quality. All efforts are to ensure component molecules and particles organised in a particular order and microstructure and to preserve and maintain such structures for as long as possible (the shelf life). Main approaches to food structure creation and longer shelf life stability include the use of functional ingredients, innovative processing techniques, optimized processing conditions, modified packaging, and appropriate storage conditions (shown in the left half of Figure 1). Food structuring and structure preservation concern the whole range of food chain, from raw materials till the point of entering the mouth when the food is orally consumed and begins to be digested.

Since food science and technology became a scientific discipline more than half century ago, structuring of food has always been one of the core focuses of scientific research. Every effort has been sought on developing new techniques for most efficient conversion of raw food materials to a product which is welcomed and enjoyed by consumers. Extensive use and exploitation of hydrocolloids is a typical example of optimum food structuring. As a type of structure building ingredients, hydrocolloids are commonly used as a functional ingredient in a wide range of food products for various cases of structure formation, including gelling, thickening, emulsifying, coating, fat replacing, and etc. (Phillips and Williams, 2000; Williams and Phillips, 2014). Food processing technique has also evolved hugely in the effort of optimising food structure and structure preservation. Recently emerged non-thermal processing techniques are typical examples (Sanchez and Bergezac, 2012). Other novel techniques such as high pressure processing, high intensity pulsed electric field, ultrasound, and etc are now available for industrial applications for the purpose of either structure formation or better structure preservation of food materials.

Contrast to great achievements in both technical advances and fundamental understanding of food structuring, very limited understanding has been obtained to the other half of the spectrum of the Figure 1, the food destruction. When food enters the mouth, an opposite process begins, i.e. food starts structural degradation and disintegration. This process continues throughout the whole alimentary channel and could carry on for many hours (Roach, 2012).

With ever growing concerns from consumers on the health and well-being, huge interests have arisen in recent years on what happen to the food inside human body and its impacts to human wellness. Based on anatomy analysis, food alimentary journey could be roughly divided into four different stages: oral, gastric, small intestine, and large intestine. Destruction process is of course very different in nature at different stages along the alimentary journey, and so the controlling mechanisms. The main scope of this paper is about food destruction during the oral stage, the very beginning of food digestion process. The reason we choose food oral destruction as a topic for investigation is because of its uniqueness. Through the whole food journey, food oral processing is the only stage where food–body interactions produce strong and immediate psychological as well as physiological responses.

At the oral stage, food destruction is closely associated with the sensory perception and liking. Once food is swallowed, structural breakdown continues to a further level for digestion and nutrients absorption. Chewing and mastication as well as saliva mixing are the typical phenomena associated with food oral destruction (Figure 1). Lucas et al. (2002) proposed an excellent flowchart to illustrate sequences of an eating process (see Figure 2). The pathway shown in the left side is mostly for fluid food where no mastication is needed. However, for solid and soft-solid food, very different pathway will be needed as shown on the side of the graph. Various oral actions as well as decision making in a sequential order are involved in a single mouthful eating. From the chart, one could imagine that the food at the first grip and the bolus at the point of swallowing are categorically different materials in terms of both physical/textural properties as well as chemical compositions. At the point of swallowing, food is no longer the food as it was on the plate, but becomes a mixture of food particles with body fluid (the bolus). However, people still prefer to refer this mixture as food simply for convenience and this same approach will also be used in this paper. Particle size reduction was shown in the middle of the figure highlighting the destruction nature of the eating. However, the actual destruction and controlling mechanisms are much more complicated than they appear to be. From author's opinion, at least three very different mechanisms are operating at the oral stage, regulating and controlling this destruction process. Details of these mechanisms and their implications are discussed below.

3. Mechanisms of food oral destruction

3.1 Oral mechanical destruction of food

Mechanical destruction is the most common and most important mechanism of food oral breakdown and has been extensively studied. Via this mechanism, food is reduced to a much smaller size through actions of oral mastication in the form of biting and chewing. Jaw closing, teeth involvement, as well as tongue pressing are essential for such a mechanism. As also highlighted in Figure 2, size reduction at oral stage could across few magnitudes of length scale, from initial centimetre scale at the entry to sub-millimetre (or even micrometre) scale at the point of swallowing.

Mechanical size reduction is a must for any solid and most soft solid foods. With the help of saliva participation, this process ensures the conversion of a non-flow-able food to a food bolus so that transportation of the food from the oral cavity to the stomach can be easily performed by a simple swallow action. This is because the design of our oral-pharyngeal-oesophageal tract is only suitable for the transportation of flow-able fluid. The driving force behind this transportation comes from muscle contraction along the alimentary channel, which creates a peristaltic effect to push bolus forward. Any food in solid form must be properly reduced for its size and properly mixed up with saliva to become a flow-able fluid body. Another very important purpose of mechanical oral size reduction is to ensure maximum digestive effect of the food once it reaches inside the stomach. Gastric digestion relies on three factors for food breakdown, the shearing and tearing effect by muscle contraction of the stomach wall, the acid attack by gastric juice, and the enzyme interactions with protein components. All these actions need food particles to be as small as possible to achieve the maximum contact between food and gastric juice for most efficient digestion.

Sensory implications of oral mechanical destruction are immediate and highly significant. In terms of flavour (taste and aroma), hugely increased surface area helps fast release and diffusion of taste and aroma compounds from food interior so that they can be detected quickly by the taste buds inside oral cavity and olfactory receptors inside the nasal cavity. Fast and easy flavour release is necessary for sensory perception. However, too fast and uncontrolled aroma release will often cause quick sensory loss during storage and will significantly reduce the shelf life of the product. Of course, too slow release is also not desirable. In such a case, a large fraction of flavour compounds will remain unreleased and enters the body not being sensed. Therefore, optimum control of aroma and taste release is a big challenge to food manufacturers. This problem has attracted extensive attentions and it was specifically indicated that the intensity of flavour release is strongly influenced by the duration of mastication phase, the microstructure of the food, the air–bolus contacting area, as well as some other parameters (Salles et al., 2011; Doyennette et al., 2014).

Texture appreciation accompanies the whole mastication process. How a food resists the deformation, how it breaks, the size distribution of fractured particles and their geometry, and the surface wetting will all contribute to texture sensation. Bulk deformation or fracture of large particles dominates texture sensation at early stage of eating, where food rheology is believed to be hugely important. However, with continuing size reduction, bulk rheology will become less relevant, but tribological behaviour of food–saliva mixture could become a dominant mechanism of oral textural sensation. The underlying principles of this transition have been explained in detail by Chen and Stokes in a previous article (Chen and Stokes, 2012).

A big challenge to food R&D is how to have a controlled oral destruction or to design a food which has a unique pattern of oral fracturing and breaking. In order to have a reliable method to quantify this destructive process, the concept of Breakage Function has been proposed to measure the fracture of a solid food (Lucas and Luke, 1983). The concept has been tested as feasible to evaluate the extent and ease of food fracture. Dry brittle solid foods such as biscuits, candies, nuts, etc. would normally have a high breakage function, which means less number of chewing cycles is needed to complete an eating process (no matter how hard a food is). However, for some fibrous wet solids such as fruits, vegetables, meat, etc. breakage function is usually low. Such types of foods will need continuous chewing, despite of probably less oral effort per chewing cycle. For the former, a burst of aroma and flavour is usually the case due to the sudden increase of contacting area between food particles and the air/saliva. For the latter, aroma and flavour release would be usually slow and gradual. An extreme example would be the chewing gum which never breaks but only kneads with the saliva.

There is also a gradual mechanism transition of size reduction, from teeth-involving for solid foods to tongue pressing for some soft solid foods. This transition depends on individuals' oral physiological conditions. It has been experimentally confirmed by author's group that tongue muscle strength is the determining factor for this transition (Alsanei et al., 2015). An individual with strong tongue muscle will be much more capable of applying tongue-only for oral breaking of some gel type foods. However, individuals with low tongue muscle strength will have to rely heavily on teeth for size reduction of even softer food. A positive correlation between tongue muscle strength represented by the maximum tongue pressing pressure and the threshold value of gel strength is shown in Figure 3. A correlation factor of 0.71 demonstrates a very significant correlation between the two factors.

3.2 Colloidal destabilisation of food structure

Human saliva is a typical colloidal system. According to Glantz (1997), saliva has four levels of structure: a continuous phase composed of electrolytes in water, a scaffold-like continuous network structure (largely due to the presence of MUC5B protein); less water-soluble protein, salivary micelles or other globular structure inside the saliva network filaments; and lipid materials, bacterial and epithelical cell. The colloidal nature of human saliva has also been positively confirmed by the extensive network observed under the microscope for a sample of freeze dried human saliva (Schipper et al., 2007).

As a unique oral fluid, saliva has some specific functions naturally designed for oral lubrication and protection, maintaining tooth integrity, and antibacterial activity. Despite these oral functions, saliva is also an indispensible fluid for oral consumption of many solid and semi-solid foods. Even for fluid food, saliva participation and mixing could also be inevitable. Saliva functions as buffering, for food mixing, bolus formation and swallowing, oral clearance, as well as for food disintegration and digestion. Once entering oral cavity, food will come into contact immediately with the saliva. Therefore, saliva is an indispensible ingredient for food oral processing and for sensory perception. Strictly speaking, sensory perception perceived during eating is not purely from the food but from the food–saliva mixture.

Colloidal principles of eating and sensory perception have been well documented by van Vliet et al. (2009), Le Reverend et al. (2010), and Salles et al. (2011). By analysing specific sensory (texture) attributes for all three categories of food (solid, semi-solid, and liquid food), van Vliet et al. demonstrated that understanding of the processes in the mouth at colloidal length scales is essential in order to grasp the interplay between perception, oral physiology and food properties (van Vliet et al., 2009). Le Reverend et al. (2010) also applied microstructural approach to the engineering challenge of fat replacement in dairy products such as mayonnaise, cream and sauces. They found that tribological behaviour gave much relevant sensory information about sensory creaminess because of the underpinning colloidal principles behind oral processing of these products. As has been indicated by these researchers, the most important colloidal implications occur to emulsion systems.

Sarkar and Singh (2012) indicated possible oral destabilisation of food emulsions as a result of saliva mixing and oral shear. Salt-induced aggregation, depletion flocculation, bridging flocculation, and coalescence are the four most important mechanisms as illustrated in Figure 4. Of all these mechanisms, depletion flocculation and bridging flocculation are the most likely mechanisms. A depletion flocculation refers to the aggregation of emulsion droplets as a result of osmotic pressure created by the presence of non-adsorbing large molecules in the continuous phase. A bridging flocculation is the case of droplets aggregation due to one large molecule adsorbing (anchoring) simultaneously onto two or few emulsion droplets (Dickinson, 1992). For both mechanisms to occur inside the mouth, the key ingredient is the prolin-rich mucins, a family of high molecular weight, negatively charged (at neutral pH), heavily glycosylated proteins, which are produced by epithelial tissues in most organisms of Kingdom Animalia. Mucins have gel-like characteristic and therefore serves as a key component for surface lubrication (Okumura and Endo, 2013).

For food emulsions, Silletti et al. (2007) assured that charge status is crucial for their oral stability. They demonstrated that strongly negatively charged emulsions will normally remain stable inside mouth, except being diluted by the saliva. The negative charge on droplet surface would normally provide a large enough repulsive force to prevent emulsion droplets from sticking together. Neutral or weakly negatively charged emulsions will likely to become depletion flocculated, due to the osmotic pressure created by the non-adsorbing salivary proteins. On the other hand, positively charged emulsions stand no chance inside mouth. Immediate destabilisation is almost certain due to bridging flocculation caused by simultaneous absorption of mucins and other large salivary proteins to the surface of few positively charged emulsion droplets.

To author's opinion, any oral destabilisation will have significant implication to sensory perception, in particular for beverages where emulsion droplets are often used as flavour carrier as well as texture modifier. Once such a dispersed system is destabilised after oral processing, very different microstructure will lead to a textural experience completely different from that of a stable emulsion. A stable emulsion would normally be perceived as smoothly creamy, but a flocculated emulsion would often be sensed as rough and dry with probably increased thickness sensation (Vingerhoeds et al., 2009). Severe flocculation could even lead to coalescence of oil droplets. In this case, the emulsion could be perceived as greasy or oily. By controlling the surface properties of emulsion droplets, it is possible to have a delicately controlled oral sensation for fluids and beverages. However, potential applications of such an approach have not been fully explored by the food industry.

Another very important but less known oral colloidal destabilisation is the aggregation of salivary proteins with some specific small molecules (e.g. polyphenols). The aggregation leads to depletion of salivary protein from the oral (tongue) surfaces and a significantly reduced oral lubrication (Gibbins and Carpenter, 2013). Astringency perception is the immediate result of this colloidal interaction. This has been confirmed experimentally by authors' group in investigating the astringency of wines. Microscope observation confirmed strong aggregation between wine polyphenols and salivary protein. This leads to protein depletion from the saliva (and possibly tongue surface) and causes a significantly reduced surface lubrication (increased friction) (data to be published separately).

3.3 Biochemical and enzymatic interactions

Apart from mucin and other large molecules, human saliva contains two other very important biopolymers, lipase and α-amylase. The existence of these two enzymes has very important significances because of their interactions with two principal food components: the lipids and starches.

Salivary lipase is secreted from von Ebner’s glands of the tongue. Unlike other mammalian lipases, salivary lipase of human is highly hydrophobic and capable of entering fat globules, hydrolysing medium to long chain triglycerides to form free fatty acids. Mattes and his co-workers believed that oral sensation of fatty/creamy is achieved by the detection of free fatty acids (Chalé-Rush et al., 2007; Tucker and Mattes, 2012), via a two-stage mechanism (Mattes, 2011). Firstly, triglycerides (fat) are hydrolysed into glycerol and respective fatty acids by the interaction of salivary lipase. The fatty acids are then be detected through a number of possible mechanisms: including in particular delayed-rectifying potassium channels, G protein-couples receptors-120 (GPCR120), and CD36 glycoprotein receptors (Akhtar Khan and Besnard, 2009).

Though the hypothesis seems very plausible, reservation remains among sensory scientists. Opposing reason is very simple: the lipase content in human saliva is so low that many suspects that the formation of free fatty acids will not be in high enough concentration for positive detection by fatty acid detecting receptors (if they exist in humans). Instead, some scientists have shown that fattiness is a textural feature which is sensed via a physical (or tactile) mechanism, based on the evidences obtained from neural imaging experiments (Rolls, 2011, 2012). It is not the purpose here to judge which mechanism is the right for fattiness sensation. But one should be aware that interactions between lipase and fat are completely feasible under the oral condition, though how relevant of this enzymatic interaction to sensory perception requires further investigation.

The presence of α-amylase in human saliva is critically important to the sensation of food texture as well as flavour. And this has been confirmed by many experimental evidences, The α-amylase is a calcium metalloenzyme and is abundant in human saliva. Salivary amylase is highly active at neutral pH and oral conditions. It interacts with starch molecules by hydrolysing (1-4) bonds of both amylose and amylopectin to form small sugar molecules of which maltose is the major end-product. This enzyme quickly loses its activity once enters stomach due to unfavoured acidic condition. The α-amylase interaction has at least two important implications to oral sensory experience: the structure breakdown (or significant viscosity decrease) of the food and a hint of sweet taste due to the formation of sugar molecules. The latter can be experienced when consuming rice or other starch food. Despite no sugar addition, a hint of sweetness can often be detected during consumption of such foods.

Oral degradation or oral thinning of starchy food has been observed by many researchers. Hoebler et al. (Hoebler, Karinthi, Devaux, Guillon, Gallant, Bouchet, et al., 1998; Hoebler, Devaux, Karinthi, Belleville & Barry, 2000) found that during a short period of oral processing, about 50 % of bread and 25 % of pasta starch was hydrolysed and transformed into smaller molecules. They concluded that the starch hydrolysis began in the mouth and the different rate of starch hydrolysis was caused by the structural differences of the solid foods. Such observation was further confirmed by an *in vitro* investigation. In a separate study, it was found that in less than 10 second of mixing with the saliva, the viscosity of custard showed almost a ten-fold decrease (Prinz, Janssen & de Wijk, 2007). Janssen et al (2007) also examined the degradation of the gel made from whey protein isolate and tapioca starch. By mixing the samples with water (as a reference) and with saliva *in vitro*, they observed instant viscosity decrease for the sample with the addition of saliva. The time-scale for the observed viscosity reduction was perfectly within the time range of a normal oral eating process.

Amylase interaction was also proved to be very effective to starch emulsifiers, a functional ingredient increasingly used in food formulation in recent years, due to its great functions of emulsifying and stabilising food emulsions. Relatively lower cost compared to traditional food emulsifiers such as milk protein is another great advantage of starch emulsifier. However, food manufacturers must be aware that even though a starch emulsifier provides great long term shelf life stability to food emulsions, it becomes vulnerable once the emulsion comes into contact with the saliva. Oral destabilisation could be inevitable for such emulsions. Amylase interaction with starch chains at the oil droplet surface and causes significant reduction of monolayer protection. Severe droplet flocculation and even coalescence will be highly possible. And this has been confirmed very recently by both *in vitro* and *in vivo* tests conducted in author's lab (data to be published). In this study, two emulsions, one stabilised by purity gum ultra, a modified waxy maize starch emulsifier provided by Ingredion (UK), and one stabilised by sodium caseinate, were prepared with matched properties (oil volume fraction and droplet particle size). Once the emulsions come into contact with saliva, they behaved completely different. As shown in Figure 5, severe flocculation was clearly evident for the starch emulsion when it was mixed with saliva, while the caseinate emulsion remained stable under the same condition. Enzymatic degradation of starch emulsifier by the α-amylase is the only possible explanation in this case.

4. Implications

The oral structural breakdown is an important part of food digestion. To food scientist and technologists, the question is how to make the most of this process for desirable sensory experience. Implications of food oral breakdown can be summarised at least to the following three aspects.

Firstly, the most important implication of food oral breakdown is of course the changing textural properties of the food during an eating process. All three destruction mechanisms will affect the texture of food. Mechanical size reduction leads to reduced relevance of food rheology to food texture sensation. Once food particles become small enough, deformation is no longer about individual food particles but more the food–saliva mixture, for which flow-ability and even tribology would be more relevant to oral processing and sensory perception. Colloidal destabilisation makes food emulsion no longer smooth. Large cluster of emulsion droplets may lead to rough and also watery sensation. Aggregation of salivary protein in the presence of polyphenols leads to specific sensation of astringency. In terms of α-amylase attack, oral thinning is an obvious consequence to a starch food.

Food oral destruction is a dynamic process where textural perception could be from either an instant feeling or an integrated opinion through the whole process. Consequently, traditional static approach of *in vitro* texture characterisation might be little relevant to the real oral sensation. A new strategy for instrumental assessment of texture perception is really needed.

Secondly, the active presence of salivary enzymes means continuous molecular and structural degradation for some particular foods, e.g. fatty and starch food. A fatty food is vulnerable to lipase degradation, while a starch food is vulnerable to α-amylase interaction. The former leads to the formation of free fatty acids, though whether its quantity is high enough for sensory impact is still questionable. The latter leads to the formation of sugar molecules and possibly an altered taste of the food (enhanced sweetness).

Thirdly, mechanical size reduction is essential for swallowing. The formation of a food bolus and the initiation of bolus swallowing depend largely on the speed of size reduction as well as the rate of saliva secretion. Proper size reduction and proper flow-ability are essential to ensure a comfortable and safe swallowing.

It should also be noted that above mentioned mechanisms of food oral destruction could occur separately as well as simultaneously. For example, three mechanisms could all be applicable to the oral destruction of a starch emulsion gel. The question is, in this case, what will be the sensory implication. Though little is known, but definitely much more complicated.

5. Summary

Food oral processing is a dynamic process during which food will be broken down structurally both for the purpose of easy transportation to the stomach for further digestion and for the purpose of sensory enjoyment. This dynamic process is controlled by three very different mechanisms: physical/mechanical, colloidal, and biochemical/enzymatic. The mechanical process dominates early stage of the oral mastication of solid and soft solid foods. Size reduction and hugely increased food–saliva contacting area enable simultaneous sensation of texture and flavour release. Colloidal interaction between salivary proteins and food emulsion could lead to instant destabilisation. Colloidal interaction could also occur in the presence of some specific small molecules such as polyphenols which leads to the depletion of protein from the saliva and consequently astringency. Enzymatic interaction occurs mostly to starch food where the attack of α-amylase to starch molecule leads to significant oral thinning as well as mildly altered sweetness. These mechanisms should be further explored for better food design and formulation in order to produce quality food which is not only healthy but also sensory desirable.

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Captions

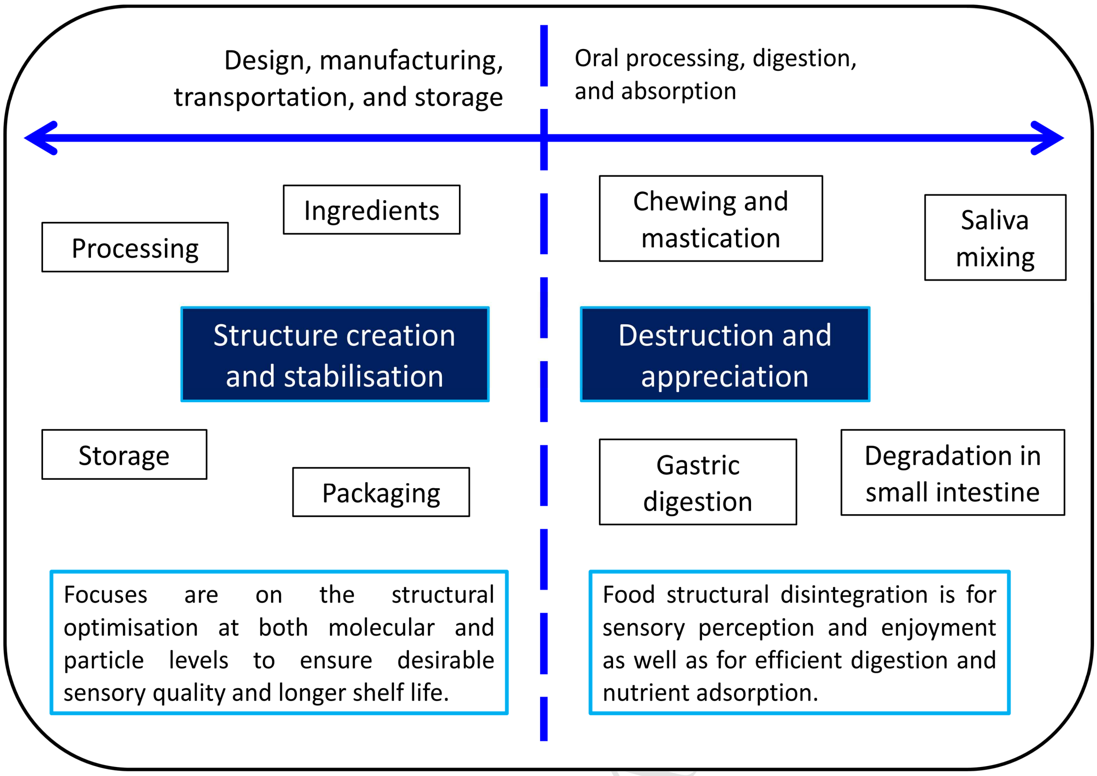
Figure 1. The structuring and destruction of food as separated by the point when the food enters the mouth, serving for very different purposes and also regulated by very different mechanisms.

Figure 2. The flowchart of food oral processing highlights various oral decisions and sequential oral actions starting from the first grip till the swallowing (Modified from Lucas et al., 2002).

Figure 3. A positive correlation is clearly observable (R^2 = 0.71) between one's tongue muscle strength (represented by the maximum isometric tongue pressure) and the maximum elasticity of food gel for tongue-only oral breaking.

Figure 4. Differently charged food emulsions will have a very different oral behaviour due to different colloidal interactions with salivary proteins.

Figure 5. Microscopic observation of food emulsions mixed with fresh human saliva. Higher amount of saliva leads to increased aggregation for the starch emulsion, but a caseinate emulsion remains stable at the same condition. Results demonstrate the enzymatic attack to starch emulsions leads to significantly reduced stability.



Focuses are on the structural optimisation at both molecular and particle levels to ensure desirable sensory quality and longer shelf life.

Food structural disintegration is for sensory perception and enjoyment as well as for efficient digestion and nutrient adsorption.

Figure 1. The structuring and destruction of food as separated by the point when the food enters the mouth, serving for very different purposes and also regulated by very different mechanisms.

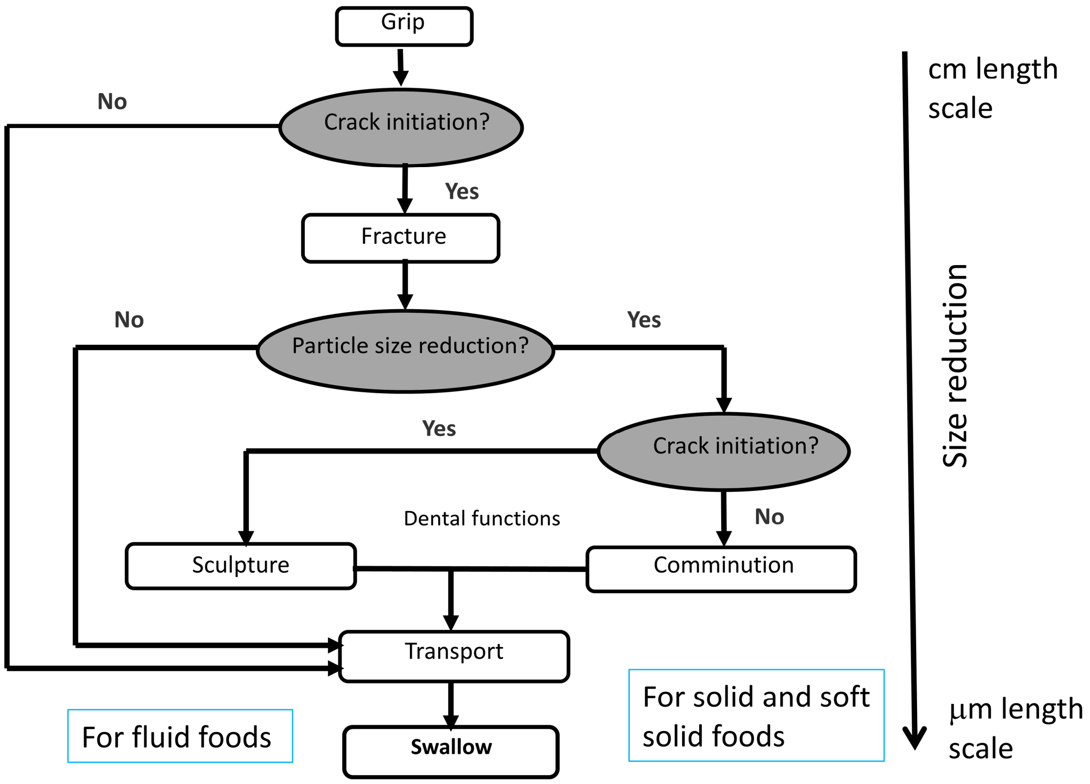


Figure 2. The flowchart of food oral processing highlights various oral decisions and sequential oral actions starting from the first grip till the swallowing (Modified from Lucas et al., 2002).

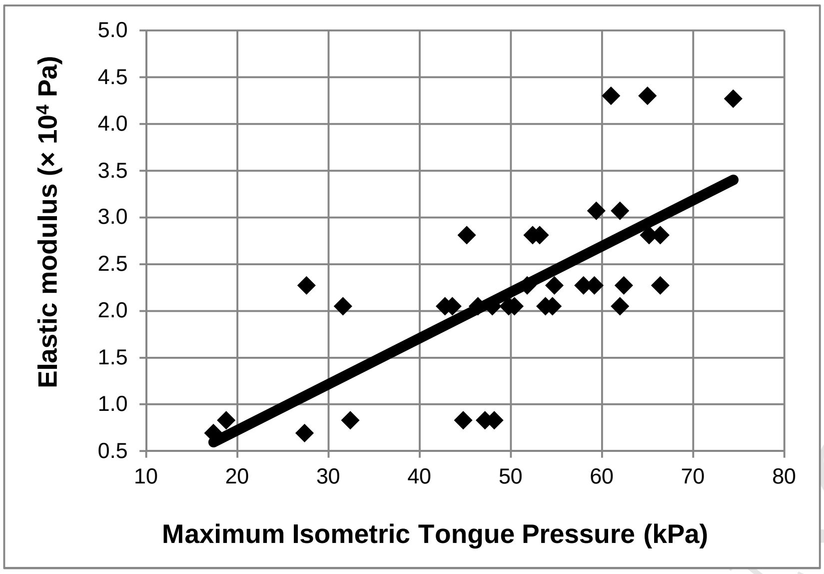


Figure 3. A positive correlation is clearly observable (R^2 = 0.71) between one's tongue muscle strength (represented by the maximum isometric tongue pressure) and the maximum elasticity of food gel for tongue-only oral breaking. Mechancal strength of lab-constituted veggie gels was tested using a Texture Analyser and the tongue muscle strength of subjects was measured using IOPI device (Alsanei and Chen, 2014).

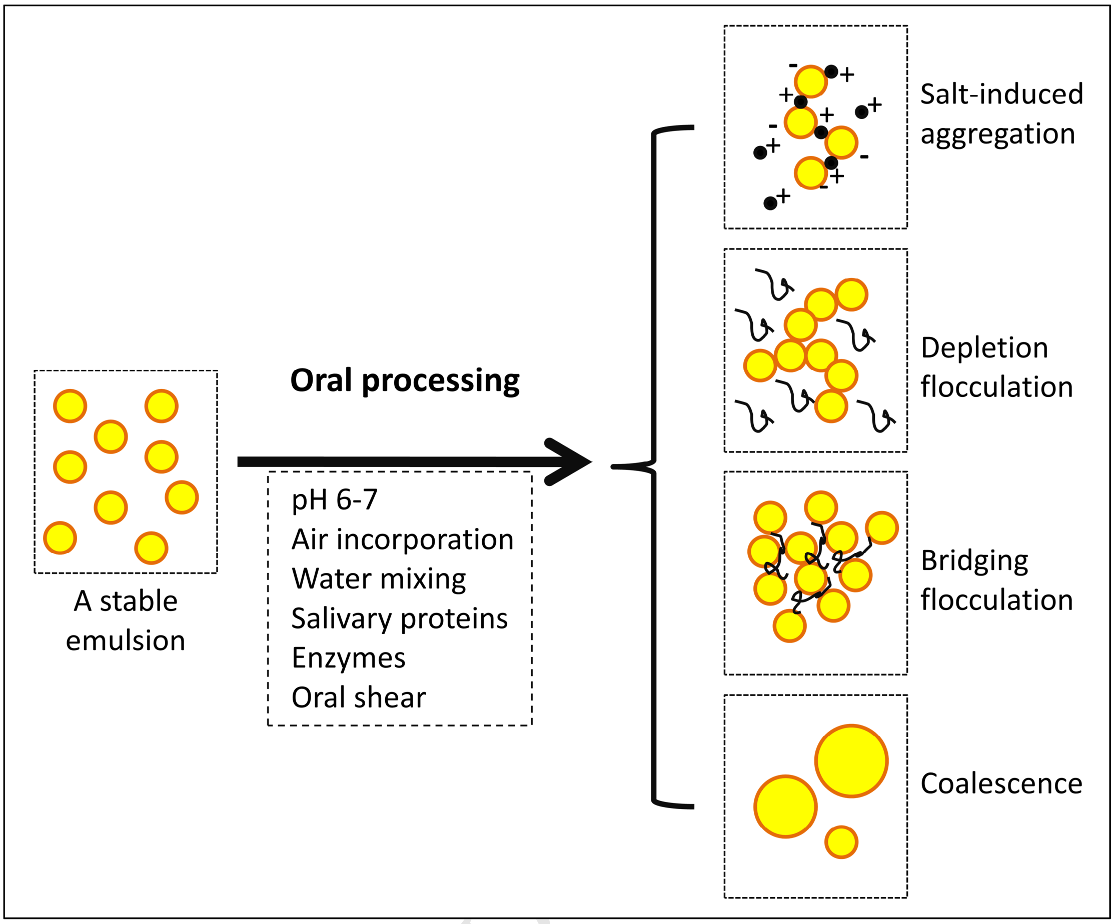


Figure 4. A schematic illustration of the possible destabilization mechanisms of food emulsions after oral processing.

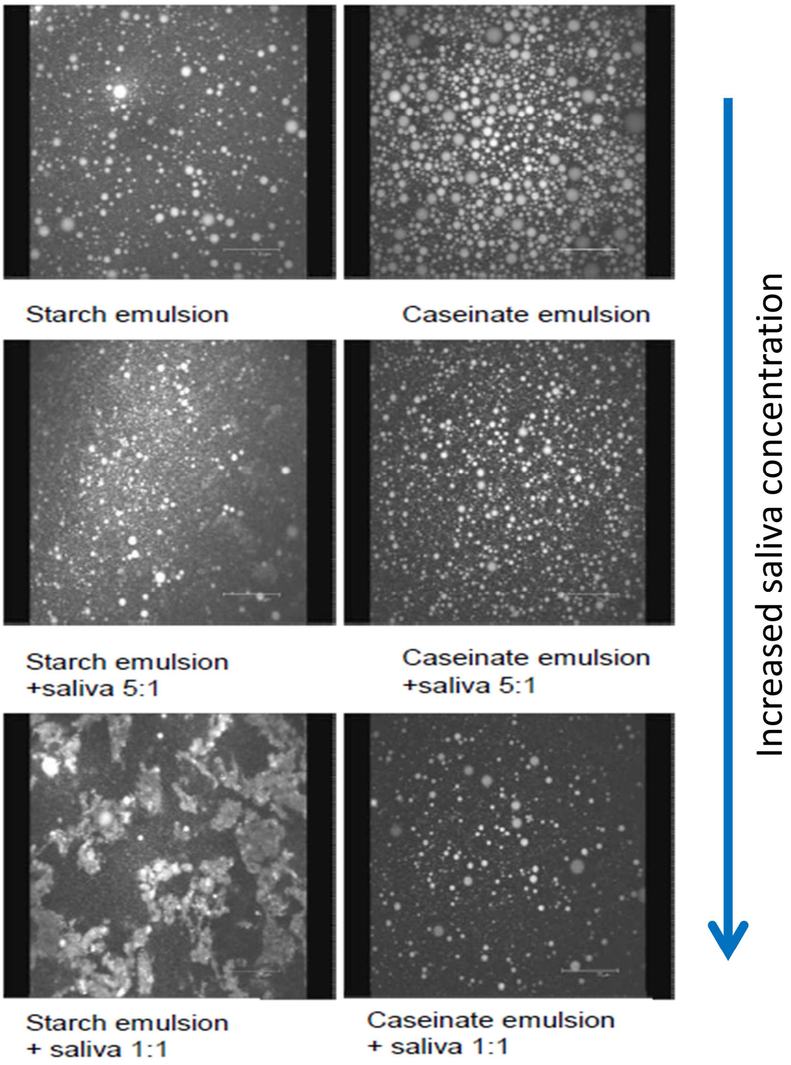


Figure 5. Microscopic observation of food emulsions mixed with fresh human saliva. Emulsions were made with 20 vol. % corn oil and 2 wt. % modified waxy maize starch emulsifier or 1 wt. % sodium caseinate. Initial mean droplet size was 0.3 µm for both emulsion systems. Higher amount of saliva leads to increased aggregation for the starch emulsion, but a caseinate emulsion remains stable at the same condition. Results demonstrate the enzymatic attack to starch emulsions leads to significantly reduced stability.

Highlights

- Food oral processing is a dynamic process of food destruction and sensory perception
- Sensation of food texture and flavor are closely related to how a food is broken down inside the mouth
- Food oral destruction could be controlled by mechanisms of mechanical size reduction, colloidal destabilisation, and enzymatic interactions
- Different mechanisms of food oral destruction imply different oral experience