PS10.02 Texture and satiety; Simulation of gastrointestinal digestion for the development of novel satiety concepts 84.00

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The epidemic of overweight and obesity necessitates the design of foods that suppress appetite to guard the balance between energy consumption and expenditure. A multidisciplinary approach, combining principles from sensory science of flavors and textures, gastrointestinal physiology, ingredient technology, and texture design enables the engineering of such food products. This lecture will focuses on the textural properties of proteins and polysaccharides during gastrointestinal transit and their concomitant effects on satiety. An *in-vitro* digestion method in combination with rheometry has been developed to enable fast screening of textural effects under physiological conditions. Examples will be given of fast and slow proteins and gelling polysaccharides from different sources.

Keywords: Satiety, texture, protein, rheometry, in-vitro digestion

1 INTRODUCTION

The war against overweight and obesity requires multiple approaches. One of the possibilities for food industry is to develop products that affect food intake, either by directly terminating food intake (termed satiation) or - on a longer timescale – by prolonging inter-meal intervals (satiety). There are several ways by which food influences the satiating feeling and meal termination (see Fig. 1). There are sensory effects induced by flavour and mouth feel, a full feeling by stomach distension, hormone release and post-absorptive appearance of food metabolites in the blood circulation due to intestinal nutrient absorption [1-3].

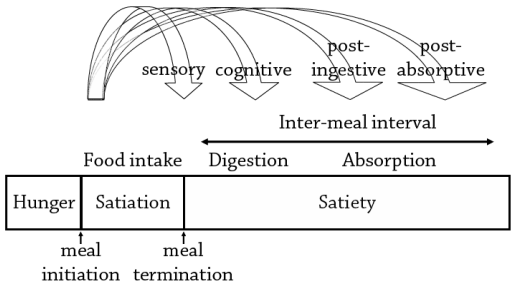

Figure 1: Schematic overview of the food intake cycle and satiety cascade with related terminology (adapted from [1]).

It is known from several studies [4-5] that there is a correlation between texture and satiety. From a food technological point of view there is, however, little room to alter food texture in existing products unnoticeably. Since minor textural changes will not have a profound effect on satiety, the focus of this study is on textural changes during gastrointestinal passage. Stomach distension and delayed gastric emptying may be induced by high gelling ingredients such as proteins and polysaccharides. On the other hand, moving downstream from the stomach, the appearance of peptides and amino acids may induce satiety by specialized sensing mechanisms and/or transport of nutrients (amino acids) into the blood. Hence, in this area there are two protein technological solutions of influencing satiety by engineered textures: “fast roteins” will travel with high speed through the stomach delivering their peptides and amino acids in the small intestine, while “slow proteins” will remain in the stomach for a longer period [6]. Ultimately slow proteins, in analogy to gelling polysaccharides [7], can induce satiety by increasing the resistance during gastric grinding. Measuring satiety properly requires extensive human and sensory trials. To accelerate product development, a fast *in-vitro* method has been designed that enables the monitoring of hysicalchemical properties of ingredients and food structures under gastrointestinal conditions. It is based on an *in-vitro* model simulating gastrointestinal digestion (termed SIMPHYD) combined with in-line measurements of the physical parameters using a controlled stress rheometer with vane geometry operating under physiological conditions.

The aim of this paper is to demonstrate the well known satiating effects of proteins and alginates from human studies in a model *in-vitro* system by measuring their physical properties under gastric conditions. Moreover, understanding the relationship between results from human studies and *in-vitro* studies will provide tools for engineering of textural properties that contribute to satiation during gastrointestinal passage of food (ingredients).

2 MATERIALS AND METHODS

2.1 Equipment

An *in-vitro* digestion model SIMPHYD (simulation of physiological digestion) has been adapted for texture measurements during the simulated digestion process. The viscosity measurements were performed using a controlled stress rheometer (TA Instruments, AR-2000) equipped with a stainless steel vane geometry (stator inner radius 26.85 mm, rotor outer diameter 24.50 mm, height, 73.00 mm), which was operated under physiological parameters present in the stomach

(presence of enzymes, salts, dynamics of acidification, enzyme secretion, mixing, etc.). Protein samples were tested under steady shear conditions (continuous ramp, 37°C, 3h at 75 s-1), whereas alginates were tested under dynamic conditions (37°C, 135 min at 50% strain, 1 Hz). Within the first 15 min. of the experiment the solution was acidified from pH 7
towards gastric pH (i.e. ~ pH 2), after which gastric enzymes were added. For the dynamic tests an
initial 5 min. delay time was applied before starting acidification.

2.2 Materials

The typical fast and slow proteins whey (WPI) and casein (Na-caseinate), respectively and alginates (Manucol DM) were used to validate the methods developed. A commercially available casein hydrolysate was utilized in this study to determine the effects of casein hydrolysis. Furthermore, casein was modified by using coupling of food grade biopolymers. Whey protein was aggregated rendering a more viscous whey product that is able to gel upon reduction of pH.[8].

3 RESULTS & DISCUSSION

Fig. 2 shows the results of viscosity measurements using the controlled stress rheometer operated under simulated gastric conditions. Clearly, casein showed a higher viscosity under these conditions than whey protein. Where whey remained soluble, casein coagulated and precipitated under gastric conditions (see insert in Fig. 2) giving rise to an increase in viscosity during and after acidification in the first 15 min. of the experiment. Physiologically, these differences would result in an altered gastric transit as previously reported in human trials [6]. After obtaining maximum viscosity, a decrease in viscosity was evident, most likely as a result of proteolysis of the aggregates/lumps by proteolytic enzymes present in the simulated gastric fluids. On the other hand, the fast whey protein gave a clear solution, in which all proteins were dissolved, making them well accessible for proteases. No viscosity changes were observed during acidification of the whey protein even while proteolysis of the whey proteins may induce minute changes in viscosity.

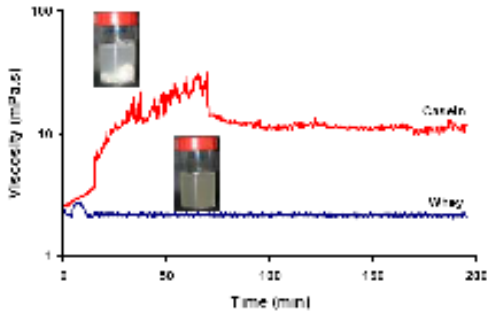

Figure 2: Viscosity changes with time under simulated gastric conditions for whey protein and casein. Samples were taken after 15 minutes to judge appearance (photographs)

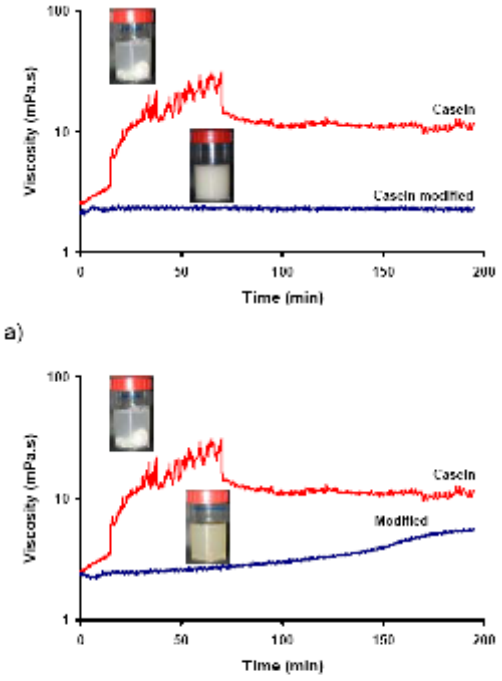

Figure 3: Viscosity changes with time under simulated gastric conditions for casein. a) Hydrolyzed casein vs. untreated casein, and b) Modified casein vs. untreated casein. Samples were taken after 15 minutes to judge appearance (photographs).

In Fig. 3 two examples are given displaying the effect of modifications of casein on its behavior under gastric conditions. Fig 3a shows the viscosity pattern for untreated casein and for the casein hydrolysate. Hydrolysis resulted in a profile associated with typical fast proteins (whey) most likely because coagulation and aggregation was prevented. Fig 3b shows casein modified by addition of food grade polymers. This modification rendered an ingredient that had an intermediate viscosity pattern between that of casein and whey.

Fig. 4 shows the viscosity pattern for whey protein, both native and modified by controlled heat-induced aggregation [8]. This particular form of whey modification resulted in a profile representing a slower protein.

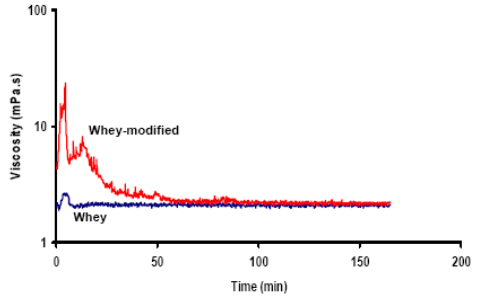

Figure 4: Viscosity changes with time under simulated gastric conditions for native whey protein and aggregated whey protein.

Alginates have been reported to induce a feeling of fullness in human studies [7]. The underlying mechanism likely includes gellation under gastric conditions, leading to an increased resistance during gastric grinding. Fig. 5 shows the gelling behaviour of alginates under gastric conditions. Clearly, a plateau in G' and tanδ was reached soon after acidification, and a completely gelled rheometer content was observed. No breakdown was observed, since, tuned to *in vivo* specification, the simulated gastric fluid did not contain enzymes that hydrolyse polysaccharides.

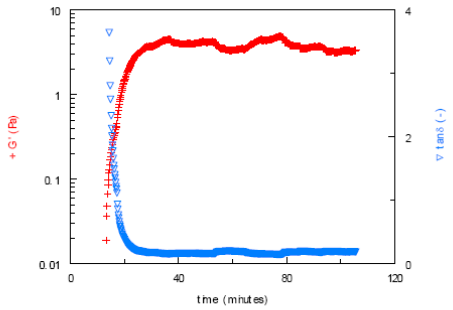

Figure 5: Dynamic measurements in time under simulated gastric conditions for alginate.

4 CONCLUSION

The results in this study clearly demonstrate that the *in-vitro* digestion method combined with rheometry provides an efficient tool to screen ingredients and food products with various textures for their potential satiety effects. It will therefore facilitate the engineering of weight management products. Although the total satiety cascade is influenced by many factors, including sensory aspects and nutritional composition, novel approaches may include the modification of ingredients (proteins or others) to tune their properties to the desired effect during gastrointestinal transit.

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