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Commercial thickeners used by patients with dysphagia: Rheological and structural behaviour in different food matrices

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ABSTRACT

In order to achieve a safe swallowing in patients with dysphagia, liquids must be thickened. In this work, two commercial starch based thickeners dissolved in water, whole milk, apple juice and tomato juice were studied. The thickeners were Resource®, composed of modified maize starch and Nutilis®, composed of modified maize starch and gums. They were formulated at two different concentrations corresponding to nectar- and pudding-like consistencies. Influence of composition, concentration and food matrix on rheological properties and structure of the resulting pastes were analysed. Viscoelastic measurements and microscopic observations of the thickeners dissolved in water revealed structural differences due to the presence of gums. When the thickeners were dissolved in the other food matrices significant statistical interactions were found between the matrix and the thickener-type in both the viscoelastic and flow parameters. The most relevant differences were observed for the nectar-like consistency with Nutilis® thickener in milk and apple juice. These samples had lower zero viscosity values and higher loss tangent values, that corresponded to weaker structured systems. Light microscopy images showed that the matrix formed by swollen starch granules was interrupted by the presence of gums. The structure of the matrices in pudding-like formulations became more continuous irrespectively of the matrix employed, and also differences in viscoelasticity among samples diminished. Although differences were observed in zero shear viscosity values among samples, the viscosity of the beverages at 50 s^{-1} – commonly used as a reference for swallowing – was similar for all samples regardless of the matrix used.

1. Introduction

Dysphagia is defined as a difficulty or inability in swallowing. This disorder can be caused by anatomical or physiological abnormalities that can have a neurological or structural basis such as stroke, Motor Neuron disease, Parkinson's disease, head and neck cancer and others (Logemann, 2007). People with dysphagia, find the turbulent and fast flow of liquids difficult to control during passage through the pharynx, resulting in impaired airway protection (Cichero, 2013). The consequences of dysphagia can result in reduced oral intake and related malnutrition, dehydration, aspiration and aspiration pneumonia (Andersen, Beck, Kjaersgaard, Hansen, & Poulsen, 2013).

A variety of interventions are used in the management of dysphagia, including texture modified food and thickened fluids, which have the purpose of making the swallowing process slower and thereby safer and more efficient (Andersen et al., 2013; Cichero, 2013). Thickened fluids are classified into several levels of different consistency, or classes. The terminology used to describe them varies depending of the country (Andersen et al., 2013; Cichero, 2013; Payne, Methven, Fairfield, & Bell, 2011) but there is a certain agreement about establishing at least three levels of fluid thickness: nectar-syrup (mildly thick or stage 1), custard-honey (moderate thick or stage 2) and spoon-pudding (extremely thick

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or stage 3). Consistencies are classified on the basis of a range established for the values of viscosity measured at 50 s^{-1}, which is the shear rate considered to be representative of the swallowing process; although actually there is a large range of shear rates (from 1 to 1000 s^{-1}) involved in the whole oral process of the bolus (National Dysphagia Diet Task Force, 2002; Payne et al., 2011; Sopade, Halley, Cichero, & Ward, 2007; Zargaraan, Rastmanesh, Fadavi, Zayeri, & Mohammadifar, 2013).

Food thickeners are commercially available as powders that can be added to any drink. Modified maize starch (pre-gelatinised) and natural gums (such as xanthan gum or galactomannans) are the polysaccharides normally used (Cichero, 2013; O'Leary, Hanson, & Smith, 2010; Sopade, Liang, Halley, Cichero, & Ward, 2007). Physical treatment of starch makes it able to form a paste even in cold liquids, so it swells and behaves as an instant thickener (National Dysphagia Diet Task Force, 2002). The recent review by Cichero (2013) indicated composition of the thickeners could have influence on hydration and absorption of medication. Starch is broken down through all phases of digestion, while galactomannans tend to pass relatively untouched until the intestines. Starch granules just swell, while gums produce networks of entanglements where water is lodged. Some authors have suggested that viscosities of starch-based thickened beverages are different from those of gum-based thickened beverages, mainly due to this different thickening process (Mertz-Garcia, Chambers, Matta, & Clark, 2005; Sopade, Halley, Cichero, Ward, Liu, et al., 2008).

According to several studies, the commercial thickeners employed to treat dysphagia present distinct properties when mixed in different liquids (Adeleye & Rachal, 2007). Pelletier (1997) suggested that specific recipes should be developed for each thickener and liquid to be thickened when studying sensory aspects of five commercial thickeners dissolved in apple juice, milk, and black coffee. Lotong and coworkers also described some sensory characteristics of four beverages (water, milk, orange juice, apple juice) thickened with 4 commercially starch-based thickeners, and the main results showed that all the thickeners imparted a starchy flavour and some of them imparted off-flavours (Lotong, Chun, Chambers, & Mertz Garcia, 2003). The same results regarding starchy and off-flavours were found by Matta, Chambers, Mertz Garcia, and Helverson (2006).

Regarding the physical properties, Mertz-Garcia et al. (2005) compared the viscosity of five different liquids thickened to nectar- or honey-like consistencies with a variety of thickening products based on starch and gums. The viscosity of a nectar- or honey-like liquid was found to be highly dependent on the type of thickening product and variability in viscosity measurements also was noted within a product line for thickening various liquids. The rheological characterisation of six food thickeners marketed in Australia for the management of dysphagia was carried out in various media as water and cordial (Sopade, Halley, et al., 2007), milk (Sopade, Halley, Cichero, Ward, Hui, et al., 2008) and fruit juice (Sopade, Halley, Cichero, Ward, Liu, et al., 2008). Other works researched more in deep the rheological properties of gum-based thickeners (Cho, Yoo, & Yoo, 2012). The above-cited authors suggested that the differences in mechanical properties may be due to interactions of the macromolecules of thickeners with components of thickened liquids. Little literature has been found on the structure of all these systems.

Recently the necessity of studying viscoelastic properties of dysphagia-oriented products has been pointed out, as not only viscosity, but also elasticity and other rheological parameters are important in swallowing process (Zargaraan et al., 2013). Moreover, dynamic spectra obtained by small amplitude oscillation sweeps provide information related to internal structure of the substances (Payne et al., 2011). However, little information is available on dynamic rheological properties (Cho et al., 2012; Payne et al., 2011; Quinchia et al., 2011) as well as on microstructural properties of thickened beverages. These studies will allow an improvement on the understanding of the mechanical behaviour and the interactions between the major molecules of the thickened beverages.

The objective of this work was to analyse the structure and rheological properties of two commercial thickeners with different composition (Resource® – modified starch – and Nutilis® – mixture of modified starch and gums), when dissolved in four food matrices: water, whole milk, apple juice and tomato juice. Two concentrations corresponding to nectar- and pudding-like consistencies were considered.

2. Materials and methods

2.1. Materials

Two commercial starch based thickeners, specially designed for the management of dysphagia were studied: Nutilis® (Nutricia, Milupa GmbH., Fulda, Germany) and Resource® (Resource, Nestlé Portugal S.A., Linda-a-Velha, Portugal). Both products are presented as white powder easily able to dissolve and instantly thicken clear liquids. Nutilis® is composed of maltodextrin, modified maize starch (E-1442), tara gum, xanthan gum and guar gum while Resource® contains only modified maize starch (E-1442). In both cases the modified starch used was hydroxypropyl distarch phosphate.

Both thickeners were dissolved in four different food matrices: deionised water, whole milk (Central Lechera Asturiana, Corporación Alimentaria Peñasanta S.A., Asturias, Spain), apple and tomato juices (Eckes-Granini Ibérica SA, Barcelona, Spain).

2.2. Sample preparation

Following manufacturers' guidelines, two concentrations of commercial thickeners were chosen as representatives for the extreme consistencies used for dysphagia management: 0.05 g/mL for nectar-like consistency and 0.09 g/mL for pudding-like consistency.

The thickener powder was slowly poured into the liquid and stirred 3 min at 400 rpm (Heidolph RZR2021, Heidolph Instruments GmbH & Co. KG, Schwabach, Germany). The thickened beverages rested for 30 min prior to measurements. All samples were prepared twice in different days.

2.3. Rheological properties

Rheological measurements were carried out with a controlled stress rheometer (Rheostress RS1, ThermoHaake, Germany) equipped with Rheowin 4.0 software and an HK10 thermostatic bath for temperature control. A titanium cone/plate (60 mm/2°) for flow curves, and serrated plate–plate (60 mm) for oscillatory tests were used. After loading the sample, a rest time of 900 s prior to measurement was established for sample relaxation and temperature equilibration. Edges of the samples were covered with silicon oil in order to avoid evaporation. All the measurements were made in duplicate at 25 °C, so four different values were obtained for each sample.

Step flow curves (30 s/step) in controlled stress mode were performed. Different ranges of stresses, σ, were applied, depending on the consistency of the preparation, in order to be able to measure viscosity between very low shear rates (close to rest) and approximately at 100 s^{-1} in all cases.

Oscillatory frequency sweeps between 0.01 Hz and 10 Hz (0.063 and 62.8 rad/s) were performed at constant stress amplitude within