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Effect of hydrocolloid type on texture of pureed carrots: Rheological and sensory measures

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ABSTRACT

This research is an investigation of the effect of selected hydrocolloids on the texture of pureed foods. Modified starch, xanthan, carrageenan, carboxymethyl cellulose, pectin, gellan, and two proprietary hydrocolloids were added to pureed carrots and textural properties were examined. ThickenUp®, a commonly used modified corn starch thickener used when making pureed foods, was used as a reference. Rheological measurements, texture profile analysis (TPA), and sensory testing were employed to characterize the texture of the purees. It was hypothesized that hydrocolloids have no effect on texture and sensory properties of pureed carrots once the viscosity is matched at a shear rate of 50 s^{-1}. The results indicated clear differences in the behaviour of hydrocolloids under small and large deformation measures. Carrageenan had a very stiff structure, which was susceptible to fragmentation, while CMC with a weak gel structure was easy to form a swallow-able bolus. It was observed that although pectin had a strong gel structure at rest, it had a high cohesiveness when subjected to large deformation. Trained panel sensory results indicated textural similarities amongst a starch-gum blend, xanthan and CMC. Viscosity at 10 s^{-1}, yield point (rheology) and gumminess (TPA) correlated well with three sensory attributes amongst the five tested by the panel.

1. Introduction

Pureed foods are a class of modified texture foods, which are mainly prescribed for oropharyngeal dysphagia – a condition where the oral and motor muscles related to biting and chewing are weakened (Keller, Chambers, Niezgoda, & Duizer, 2012). Pureeing is intended to aid in oral manipulation of food and contribute to a swallowable bolus in order to minimize the risk of choking, a common occurrence in individuals with dysphagia. Pureed foods are soft, smooth and semi-solid. They are mechanically altered with or without the addition of texturizing agents and/or liquids such as water, milk, juice, or gravy (Keller et al., 2012).

Preparation of pureed foods often involves the use of hydrocolloids for product stability and texture. These are high molecular weight water soluble polysaccharides used for their thickening and water-binding ability. Also known as texture modifiers, hydrocolloids are added to these foods to give desired textural properties with appropriate flow characteristics, which include increased viscosity (thickening), water retention, firmness and smoothness (Funami, Ishihara, & Nakauma, 2012a; Hayakawa et al., 2014; Morris, Kirby, & Gunning, 1999). An in-depth rheological characterization of hydrocolloid behaviour is of great use to enable modulating texture as per the desired requirements for a food (Arancibia, Costell, & Bayarri, 2013; Fernández, Canet, & Álvarez, 2009; Tárrega, Martínez, Vélez-Ruiz, & Fiszman, 2014). Although hydrocolloids are used extensively in pureed foods, understanding their impact on textural changes of such foods is still in its infancy (Ilhamto, 2012). Risk of aspiration differs with the type of thickener used, so selection of thickener and appropriate texture is critical in the dysphagia diet (Leonard, White, McKenzie, & Belafsky, 2014).

Starch-based thickeners are the most common hydrocolloids used in commercial dysphagia foods and in the preparation of in-house pureed foods in long-term care homes (Cichero, 2013; Dewar & Joyce, 2006; Garcia, Chambers, Matta, & Clark, 2008; Ilhamto, 2012). This may be because they are inexpensive, easily available and easily dispersed. However, starch thickeners have been shown to increase post-deglutition residue (which increases the risk of post-swallowing aspiration in dysphagia patients) and, in general, are not well accepted by patients (Rofes, Arreola,

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Mukherjee, Swanson, & Clave, 2014). Xanthan is the most studied hydrocolloid in dysphagia diets next to starch. It possesses a range of desirable properties for dysphagia food formulation including: high viscosity at low shear rates (also high yield stress) and low viscosity at high shear rates; stable viscosity within a wide range of pH, temperatures and salt content; clear weak gel-like liquid that can be applied in a variety of foods (Funami et al., 2012a). Carrageenan and carboxymethyl cellulose (CMC) are mainly used in milk-based products, but are now finding applications in dysphagia foods as well (Cichero, 2013; Hayakawa et al., 2014; Tashiro, Hasegawa, Kohyama, Kumagai, & Kumagai. 2010). While kappa-carrageenan forms firm, brittle gels, iota carrageenan forms soft, elastic gels in the presence of certain ions and lambda carrageenan does not gel (Imeson, 2009). CMC gives clear and odorless solutions of high viscosity (Murray, 2009). Gellan has been used in commercial pureed foods and is commonly used in Japan to study swallowing mechanisms (Funami, Ishihara, Nakauma, Kohyama, & Nishinari, 2012b; Hayakawa et al., 2014). Low acyl gellan forms hard, non-elastic, brittle gels and high acyl gellan gels are soft, elastic and non-brittle (Sworn, 2009). Pectin is also being investigated for use in special modified-foods (Damodhar, 2011). High methyl ester pectins gel in the presence of sugars and other co-solutes, and at low pH. The gel strength and setting temperature depend on the concentration and type of sugar, the rate of cooling and pH (Endres, Fox, & Christensen, 2009, pp. 274–297).

The behaviour of hydrocolloids when added to pureed foods can be examined using both instrumental and sensory measures. A number of thickened pureed food matrices such as commercial pureed baby foods, pureed sweet potatoes, fresh/frozen pureed vegetables with cryoprotectants, and pureed and mashed potatoes with single/mixed hydrocolloids have been examined using rheological measures (Ahmed & Ramaswamy, 2007; Downey, 2002; Fernández, Álvarez, & Canet, 2008; Truong & Walter, 1994; Álvarez, Fernández, Olivares, Jiménez, & Canet, 2013; Álvarez, Jiménez, Olivares, Barrios, & Canet, 2012). Similar studies on dysphagia-specific thickened beverages have shown differences in the final product based on type of thickener, type of product (pre-thickened or thickened at time of serving with instant food thickeners), serving temperature, type of beverage used in the sample and time gap between preparation and consumption of fluid (Adeleye & Rachal, 2007; Dewar & Joyce, 2006; Garcia et al., 2008). However, to date, no such studies have been conducted on pureed foods for older adults with swallowing disorders. Rheological and mechanical behaviour of hydrocolloid gels have been studied from a 'safe-swallow' perspective for dysphagia, but the impact of hydrocolloid addition to pureed food matrices is still at a conceptual stage despite its great importance in product development for the health care industry (Funami et al., 2012a; Ishihara, Nakauma, Funami, Odake, & Nishinari, 2011; Nakauma, Ishihara, Funami, & Nishinari, 2011; Rao, 2013).

Sensory properties detail the in-mouth perception and associated reasoning of acceptance or rejection of food. Descriptive Analysis (DA) provides quantitative data, which can be compared with instrumental measurements to help formulate safe foods combined with desired sensory properties. Sensory characterization of pureed foods for individuals with dysphagia is a relatively recent area of research (Wendin et al., 2010; Ettinger & Duizer, 2014; Ilhamto, Keller, & Duizer, 2014). Differences in firmness and chewing resistance were observed in commercial solid foods available for management of dysphagia (Wendin et al., 2010). A study by Ettinger and Duizer (2014) revealed that commercial pureed foods are significantly different in aroma, colour and perceived thickness. Small variations in liquid added during pureeing led to significant differences in perceived textural attributes of pureed turkey (Ilhamto et al., 2014). Different thickeners added to pureed carrots change the appearance as well as the textural attributes (Ilhamto et al., 2014).

The objective of this research was to understand the impact of different hydrocolloids that provide a diverse range of rheological and functional characteristics on the textural properties of a pureed food matrix. Differences in textures were measured using both small and large deformation tests, in order to get an insight of changes occurring to the samples. At the present time, viscosity is the parameter considered to be important in the design of dysphagia oriented food, however other rheological properties may differ when viscosity is held constant (National Dysphagia Diet Task Force, 2002; Zargaraan, Rastmanesh, Fadavi, Zayeri, & Mohammadifar, 2013). In this work, pureed carrot matrices with a similar value of viscosity at a specific apparent shear rate were prepared, and further examined to understand how matrices containing different hydrocolloids, but exhibiting similar viscosity could differ in rheological and sensory properties that may be relevant to the quality of product for dysphagia.

2. Materials and methods

Carrots were purchased from local supermarkets (Guelph, Ontario). The hydrocolloids used in this study were: gellan gum (KELCOGEL® LT100, CP Kelco, Atlanta, GA, USA), xanthan gum (KELTROL®—521, CP Kelco, Atlanta, GA, USA), a high ester pectin (GENU® BETA, CP Kelco, Lille Skensved, Denmark), carboxymethyl cellulose (CEKOL®50000P, CP Kelco, Äänekoski, Finland) and carrageenan (GPI006, GPI, New Market, Ontario, Canada). KELCOGEL® LT100 is a high acyl unclarified gellan (Sworn, 2009). Two commercially dysphagia-specific proprietary thickeners — a modified corn starch — Uni-Pure® D2560, abbreviated in this paper as MCS and a starch-gum blend Uni-Pure® Dys-sperse, abbreviated in this paper to SGB, were supplied by Ingredion Inc. (Bridgewater, New Jersey, USA). Thicken Up® (Nestle Health Science) specifically designed for dysphagia and used prominently in in-house pureed food preparation was store-bought and used as reference. In addition, a commercial carrot puree dysphagia product (Puree Essential Carrot - PE#21734, Marsan Foods, Toronto, ON, Canada) was included as a basis for comparison.

2.1. Sample preparation

To prepare purees, peeled and sliced carrots were cooked in a steamer for 30 min and pureed at 1750 rpm using a kitchen mixer (Kitchen Aid Food Chopper KFC3511). The hydrocolloids were added while pureeing (3–5 min) to achieve uniform dispersion during shearing, at a temperature between 40 and 45 °C. Samples were prepared 24 h before testing, refrigerated at 5 °C and, either warmed up to 55 °C (the serving temperature of pureed foods in long-term care centers) in a water-bath for rheological and sensory testing or to room temperature (~20 °C) for instrumental texture profile analysis (TPA).

2.2. Rheological properties

2.2.1. Viscosity

All purees were formulated to obtain a value of viscosity similar to that of ThickenUp® used as a reference sample. The concentration of ThickenUp® and the method of making pureed carrot samples was adopted from Ilhamto (2012). The concentration of each selected hydrocolloid was determined by ensuring that the apparent viscosity in the shear rate range of 41–50 s^{-1} of each hydrocolloid was close to the average and fell within the standard deviation of the reference. Concentrations of each hydrocolloid used and resulting viscosities are shown in Table 1. Viscosity was