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Characterization of eating difficulty by sensory evaluation of hydrocolloid gels

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ABSTRACT

Eating difficulty was evaluated by sensory analyses of hydrocolloid gels as a food model. Twenty sample gels were created with a wide range of textures. Twelve panelists rated the eating difficulty for each gel on an unstructured line scale. Subsequently, they also evaluated six texture attributes including firmness, cutting effort, elasticity, extensibility, adhesiveness, and melting rate in the mouth. A principal component analysis characterized the texture attributes of the sample gels on axes of resistance to fracture (principal component 1) and stickiness and flexibility (principal component 2). The contour of the resulting eating difficulty scatter diagram revealed that resistance to fracture and stickiness and flexibility were critical determinants of eating difficulty.

1. Introduction

Texture is a key determinant of food quality. Therefore, numerous approaches have been adopted to evaluate food texture and improve food quality (Foegeding et al., 2011). Because texture is a sensory property (Szczesniak, 2002), a sensory evaluation is the most direct method for evaluating and understanding texture (Foegeding et al., 2011; Nishinari et al., 2008). Descriptive sensory analyses by well-trained panelists are effective for analyzing sensory properties such as texture (reviewed by Murray, Delahunty, & Baxter, 2001).

The importance of food texture to eating safety has recently received attention (Nishinari, 2009). Mastication and swallowing functions deteriorate remarkably with age, and the absence of natural teeth is associated with decreased acceptability of hard foods (Garcia, Perlmuter, & Chauncey, 1989). Reduced difficulty during eating is a key to producing pleasant food texture for the elderly. In addition, aspiration often causes pneumonia in elderly and dysphagic patients. Therefore, food products that can be chewed and swallowed easily are increasingly required. As a result, development of methods to characterize and quantify eating difficulty are also urgently required (Funami, 2011).

The measurement of eating difficulty initially relies on human perception data derived from a sensory evaluation. The sensory data can then be used to develop physiological and instrumental methods to estimate eating difficulty and design food products that can be easily processed in the oral cavity. However, obtaining numerical sensory data concerning eating difficulty is not easy. Eating difficulty should be analyzed by a sensory evaluation; however it has been rarely studied. A characterization of swallowing difficulty has been gradually achieved in several studies. Moritaka and Nakazawa (2009, 2010) assessed swallowing difficulty by sensory analysis with a panel of young women testing rice starch samples (nonglutinous rice starch, 6%–24%; glutinous rice starch, 6%–30%) or hydrocolloid gels (0.2%–0.8% agar and 0.8%–2.4% gelatin gels). They concluded that the samples became more difficult to swallow with increasing hydrocolloid concentration. Takahashi, Nitou, Tayama, Kawano, and Ogoshi (2003) conducted a sensory evaluation of three semiliquid samples with markedly different physical properties using a healthy young adult panel. They revealed that the sample which demonstrated lower viscosity was recognized as easier for swallowing. Ishihara, Nakauma, Funami, Odake, and Nishinari (2011) investigated swallowing profiles of polysaccharide gel from either low acyl gellan gum or mixture of low acyl gellan and psyllium seed gum in relation to bolus rheology by dynamic viscoelasticity measurements as well as a sensory evaluation by healthy adult subjects. They concluded that swallowing ease of bolus is determined by cohesiveness and surface lubricity, which can be achieved by manipulating the viscous components (i.e., addition of psyllium seed gum) of polysaccharide gel. Although these studies have contributed in the characterization of

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swallowing difficulty, issues concerned with eating difficulty still remain. Because eating difficulty is perceived during all of oral processing, characterizing and quantifying eating difficulty, including the process before swallowing, are required to produce pleasant food texture for the elderly. Furthermore, as Takahashi et al. (2003) indicated, humans predict swallowing difficulty from their textural perception in the early stage of oral processing. Characterizing eating difficulty before swallowing is a necessary step to understand swallowing difficulty.

Unfortunately, swallowing difficulty sensory data in previous studies (Igarashi et al., 2010; Ishihara, Nakauma, Funami, Odake, et al., 2011; Ishihara, Nakauma, Funami, Tanaka, et al., 2011; Moritaka & Nakazawa, 2009, 2010; Takahashi et al., 2003) were limited because the data were not obtained numerically (i.e., by ranking method or rating on a categorical scale). Numerical sensory data are needed for investigating food texture precisely; however, sensory evaluations of eating difficulty are complicated by multidimensionality and individual variation. Therefore, a reliable method for an eating difficulty sensory evaluation remains to be established.

Biopolymer gels provide excellent model systems for investigating food texture (Çakir et al., 2012), and hydrocolloid gels are frequently used as semi- and soft-solid food models (Ishihara et al., 2013; Moritaka & Nakazawa, 2010). Indeed, varying mixtures of hydrocolloid gels provide a wide range of textures that can be used to mimic the texture of real foods, despite their compositional simplicity and homogeneity. Moreover, because hydrocolloids are used as thickening and gelling agents in various food products, data obtained from hydrocolloid gels may be directly applied to food design for the elderly.

The objective of this study was to characterize eating difficulty using a sensory evaluation of hydrocolloid gels as a food model. Therefore, eating difficulty was quantified by a descriptive panel using a line scale. Texture profiles of the sample set were subsequently examined to characterize eating difficulty using descriptive sensory evaluations.

2. Materials and methods

2.1. Preparation of hydrocolloid gels

Various hydrocolloids were used to design 20 different gels mimicking a wide variety of food textures. All ingredients for the gel samples were provided by San-Ei Gen F.F.I. Inc. (Osaka, Japan). Nine types of food grade hydrocolloids were used. These included κ-carrageenan (CARRAGEENAN CS-606), ι-carrageenan (CARRAGEENAN CS-599), locust bean gum (VIS TOP® D-2050), low acyl gellan gum (KELCOGEL®), low methoxyl pectin (VIS TOP® D-2242), xanthan gum (VIS TOP® D-3000-C), gelatin (SAN SUPPORT® P-100), agar (GEL UP® J-3531), and high acyl gellan gum (KELCOGEL® LT-100). The compositions of the samples were designed to cover as wide a range of textures as possible. The hydrocolloid and salt contents of each gel are shown in Table 1. Because some samples had unpleasant flavor, 0.1% (w/v) food grade sucralose sweetener (SAN SWEET® SU-100) was added to all 20 gels.

Gelling agents and sucralose were dissolved in de-ionized water at 80 °C (#1, #2, #3, #4, #5, #6, #9, #10, #11, #12, #13, #14, #15, and #16) or 90 °C (samples containing gellan gum; #7, #8, #17, #18, #19, and #20). Potassium chloride or calcium lactate was added if necessary. Solutions were further heated to 85 °C for 30 min in a container (60 mm in diameter and 25 mm in height) with cylindrical molds (20 mm in diameter and 10 mm in height) and cured at 8 °C for 2 h to form gels. The gels were stored at 5 °C.

The sample gels were molded into specimens measuring 20 mm in diameter and 10 mm in height for both the instrumental tests and sensory evaluations and were stored at 20 ± 2 °C for 1 h before use. The heights of some samples were <10 mm because of deformation by their own weight.

2.2. Instrumental measurements

The mechanical properties of the hydrocolloid gel samples were characterized by a puncture test, a compression test, and two-bite texture profile analysis (TPA) using a TA XT-2i texture analyzer (Stable Micro Systems, Surrey, UK). The puncture test was conducted using a stainless plunger (3 mm in diameter) at a crosshead speed of 1 mm/s at 20 ± 2 °C to determine fracture properties. The force and distance at the fracture point were measured. For the compression test, gels were compressed using an aluminum flat plunger (100 mm in diameter) at the same speed and temperature as those used for the puncture test. The clearance, namely the distance from the sample stage to the plunger at the end of compression, was set to 1 mm, and the stress and strain at the fracture point were measured. Stress was estimated by dividing the force by the initial cross-sectional area of the cylindrical molded gel (20 mm in diameter). Strain was obtained by dividing the distance

Table 1
Contents of gelling agents and salt of sample gels.

No.	Hydrocolloids	% (w/v)	Hydrocolloids	% (w/v)	Hydrocolloids	% (w/v)	Salt	% (w/v)
1	κ-Carrageenan	0.50					Potassium chloride	0.1
2	κ-Carrageenan	1.00					Potassium chloride	0.1
3	κ-Carrageenan	0.50	Locust bean gum	0.50				
4	κ-Carrageenan	1.00	Locust bean gum	1.00				
5	ι-Carrageenan	2.00						
6	ι-Carrageenan	3.00						
7	Low acyl gellan gum	0.15					Calcium lactate[a]	0.2
8	Low acyl gellan gum	0.30					Calcium lactate[a]	0.2
9	Low methoxyl pectin	2.00					Calcium lactate[a]	0.3
10	Low methoxyl pectin	3.00					Calcium lactate[a]	0.3
11	Locust bean gum	0.25	Xanthan gum	0.25				
12	Locust bean gum	0.50	Xanthan gum	0.50				
13	Gelatin	2.00						
14	Gelatin	3.00						
15	Agar	0.50						
16	Agar	1.00						
17	High acyl gellan gum	0.50						
18	High acyl gellan gum	1.00						
19	High acyl gellan gum	1.50						
20	κ-Carrageenan	1.00	Locust bean gum	0.50	High acyl gellan gum	1.00		

[a] Pentahydrate.