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Effect of commercial konjac glucomannan and konjac flours on textural, rheological and microstructural properties of low fat processed cheese

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ABSTRACT

Hydrocolloids are used in food systems as emulsifiers, texturizing and stabilizers agents. Its use is also associated with health benefits such as reducing the risk of cardiovascular diseases. Beta-glucans and konjac glucomannan are commercially important examples. Konjac glucomannan is a polysaccharide extracted from konjac tuber (*Amorphophallus konjac* K. Koch) and is authorized as food additive in Europe and classified as Generally Recognized as Safe by the FDA. Due to its technological and nutritional applicability, it can be used in food as fat mimetic. Dairy food consumption has increased worldwide due to its functional and sensory properties. Processed cheese is a stable oil-in-water emulsion containing dairy protein, fat, emulsifying salts and other ingredients. There are few studies investigating the supplementation of low fat processed cheese with hydrocolloids. Low fat processed cheese was produced with 0.5% of commercial konjac glucomannan (CKG) or konjac flour (KF) with fat reductions of 25, 50, 75 and 100%. Physicochemical, color and texture profile analyzis were conducted. Rheological properties (G′, G″, tan δ) and microstructure were determined on selected samples. Processed cheese with 50% fat reduction with added CKG (CKG50) showed the highest hardness value (327 g) and a strong elastic behavior. Fat reduction altered processed cheese color and melting properties. The standard sample (S) melted at 28 °C, while low fat cheeses with CKG or KF did not melt showing a more stable structure.

1. Introduction

Dairy food consumption has increased worldwide due to its functional and sensory properties (Gopinath et al., 2014). Processed cheese is described as stable oil-in-water emulsion, which contains dairy protein, fat, emulsifying salts and other ingredients. It is prepared by heating and mixing to create a homogeneous product (Hosseini-Parvar, Matia-Merino, & Golding, 2015). Its fat content is high when compared to other dairy foods such as yogurt and white cheese.

It is known that the consumption of high-fat foods with low fiber content can cause serious health problems. Thus, food industries have invested in research to develop low fat foods with acceptable taste and physical properties (Li, Wang, Jin, Zhou, & Li, 2014). Processed cheese is commonly used as ingredient and the fat content is mainly responsible for its texture, color and taste (Hennelly, Dunne, O'Sullivan, & O'Riordan, 2005, 2006; Hosseini-Parvar et al., 2015; Liu, Xu, & Guo, 2008).

Food hydrocolloids are widely used in food formulations to compensate physicochemical changes due to fat reduction. They can be extracted from algae, bacteria and plants (Alam et al., 2005; Glover, Ushida, Phillips, & Riley, 2009; Krstonošić, Dokić, Nikolić, & Milanović, 2015). Guar gum, konjac glucomannan, pectin, inulin, carrageenan and xanthan gum are examples of hydrocolloids used as fat mimetic (Hennelly et al., 2006; Hladká et al., 2014; Krstonošić et al., 2015; Liu et al., 2008; Ruiz-Capillas, Triki, Herrero, Rodriguez-Salas, & Jiménez-Colmenero et al., 2012; Sołowiej, Cheung, & Li-Chan, 2014; Swenson, Wendorff, & Lindsay, 2000).

Konjac glucomannan is a polysaccharide extracted from konjac

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tuber (*Amorphophallus konjac* K. Koch), a plant native from Asia where it is used for its detoxifying properties (Chua et al., 2012). It is composed of β-1,4 linked D-mannose and D-glucose, authorized as a food additive in Europe and classified as GRAS (Generally Recognized as Safe) by the FDA (Food and Drug Administration) (Jimenez-Colmenero, Cofrades, Herrero, Solas, & Ruiz-Capillas, 2013). The ratio of mannose and glucose is about 1.6:1 with some branching points at the C-3 position of the mannoses (Chua et al., 2012). This polysaccharide is extracted from the tuber by an extraction or purification process (Prawitwong, Takigami, & Phillips, 2007). Several techniques to extract glucomannan from konjac flour can be adopted, but most of these processes are costly and complex (Nakajima & Matsuura, 1997; Tatirat & Charoenrein, 2011; Xu et al., 2014; Ye et al., 2014).

The gelation behavior of Konjac glucomannan is related to the limited presence of the acetyl group in the chain. Due to its emulsifying and water binding capacity, it has been used in foods, cosmetics, drugs and biodegradable biofilms (Prawitwong et al., 2007). Studies have shown its efficiency as fat replacer in pork meat, sausages and mortadella (Jiménez-Colmenero, Cofrades, Lópes-Lópes, Ruiz-Capillas, Pintado, & Solas, 2010, 2013; Ruiz-Capillas & Triki, 2012).

Other food products made with konjac glucomannan, such as mayonnaise and UHT-treated skim milk, were successfully developed and studied (Li et al., 2014; Tobin, Fitzsimons, Kelly, & Fenelon, 2011). There are no studies investigating the supplementation of low fat processed cheese with konjac glucomannan or konjac flour.

In addition to the technological functions, some studies have proven its effectiveness in obesity treatments, modifying the intestinal metabolism and lowering cholesterol (Chua et al., 2012; Zhou et al., 2013). The aim of this study was to evaluate the effect of commercial konjac glucomannan or native konjac flour (without extraction process) on the physicochemical, rheological properties and microstructure of fat reduced processed cheese.

2. Materials and methods

2.1. Material

Commercial konjac glucomannan (CKG) was imported from China by Fagron® (São Paulo, Brazil). Emulsifying salt (sodium polyphosphates), sodium chloride and chymase rennet were purchased from Ipê Amarelo Ingredientes Alimentícios Ltda (Minas Gerais, Brazil). Native konjac flour (KF) was prepared by drying konjac tuber (*A. konjac*) at 55 °C during 15 h to constant weight and grinding to ≤ 300 mm particle size. Konjac tuber was obtained from a small farm in South of Brazil (23° 28′ 17.639″ S 51° 49′ 32.642″ W). Butter and pasteurized whole cow's milk were purchased from a local supermarket. All other reagents were of analytical grade.

2.2. Manufacturing procedure of the processed cheese

In preliminary experiments, commercial konjac glucomannan (CKG) was used to determine appropriate concentrations of CKG or KF used in low fat processed cheese formulations. Processed cheese formulation without added fat (as butter) were manufactured with 0.0, 0.25, 0.5, 0.75, 1.0 and 1.25% of CKG. Optimal CKG concentration was chosen based on texture profile analysis (TPA) parameters: hardness, adhesiveness and cohesiveness. The objective was to obtain a processed cheese without added fat and supplemented with CKG with a texture profile similar to a whole fat standard (S) processed cheese (25± 1% fat and 60± 1% moisture). The selected CKG concentration (0.5% w/w) was then used in the formulation of low fat processed cheeses with various fat content.

Low fat processed cheese formulations (ingredients g/100 g) studied are shown in Table 1. The samples were manufactured in laboratory scale from fresh cheese curd (16.76% fat, 16.01% protein, 58.2% moisture). Pasteurized whole milk, calcium chloride and rennet were used to produce cheese curd. Firstly, milk was heated to 45 °C and rennet was added. After clotting (30 min), the curd was drained, molded and pressed. The ingredients (except butter and CKG or KF) were mixed (3600 rpm) into a stainless steel trough and heat to 85 ± 2 °C. When the mixture reached the temperature of 85 °C (±15 min) butter (86% fat, 0.4% protein) was added and mixed (3600 rpm) during 2 min. After homogenization and 15 min cooking (reached about 90 °C), CKG or KF was added and mixed for 2 min (3600 rpm). A standard (S) processed cheese with 25± 1% total fat and 60± 1% moisture content, without the addition CKG or KF was prepared. The standard (S) formulation was chose based on a Brazilian typical processed cheese called *Requeijão Cremoso*, which must have a maximum moisture content of 65% and a minimum fat content of 55% on a dried weight basis. The formulations under study were produced with 25 (CKG25 or KF25), 50 (CKG50 or KF40), 75 (CKG75 or KF75) and 100% (CKG100 or KF100) of fat reduction from standard (S) (considering fat added) and supplemented with 0.5% (w/w) of CKG or KF. The samples were placed in white plastic pots of 40 mL and stored at 4 ± 1 °C for 24 h before analysis.

2.3. Chemical composition and caloric values of processed cheese

Processed cheese samples were analyzed for nitrogen by Kjeldahl method, protein, fat, ash content and moisture (AOAC, 1990). The pH was determined using a digital pH-meter (Tecnopon®) in a solution with water at 60 °C (1:5). A nitrogen-to-protein conversion factor of 6.38 was applied. The moisture content was determined by the oven drying method (AOAC, 1990). Carbohydrate content was determined by subtracting the sum of moisture, protein, fat and ash percentages from 100%. Caloric values kcal/100 g were estimated according to the equation (1) (Li et al., 2014). All analyzes were performed in triplicate.

$$\text{Caloric values} = 4 \times \text{protein} + 4 \times \text{carbohydrate} + 9 \times \text{fat} \quad (1)$$

2.4. Color measurements

Color parameters L* (lightness), a* (redness) and b*(yellowness) of the processed cheese samples were evaluated on a Chroma Meter CR-400 (Konica Minolta Business Technologies, Inc., Tokyo, Japan). The colorimeter was standardized using the white calibration plate. Nine determinations were performed from each sample and results were expressed as average values.

2.5. Texture profile analyzis

Texture profile analyzes (TPA) were performed using a CT3 Texture Analyzer (Brookfield Engineering Laboratories, Inc., Middleboro, USA) using a cylindrical acrylic probe (d = 35 mm). The processed cheese samples were placed into plastic pots with 55 mm diameter and 60 mm length. The analyses were carried out at 10 °C with 15 mm of deformation extent. The data for force as a function of time were obtained for the two compression–decompression cycles using the TPA function. Texturometer was fitted with a 5.0 kg load cell and deformation rate was 2.00 mm s^{-1}. The following textural parameters were determined: hardness (g), adhesiveness (J) and cohesiveness according to