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Pasting and rheological properties of oat products dry-blended with ground chia seeds[☆]

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ABSTRACT

Oat products containing β-glucan are documented for lowering blood cholesterol that could be beneficial for preventing coronary heart disease. Oat products (oat flour, oat bran concentrate, and Nutrim) were dry-blended with ground chia (*Salvia hispanica* L.) that contains omega-3 polyunsaturated fatty acids for improving nutritional and functional qualities. The pasting and rheological properties of oat–chia composites with 10, 20, and 50 g chia/100 g were characterized using Rapid Visco Analyzer followed by an advanced rheometer. Shear thinning properties were observed for all the composites. The pasting and rheological properties of oat products were not greatly influenced by 10 g or 20 g chia/100 g replacements but were improved at the 50 g/100 g replacement level. Also, these composites had improved water holding capacities compared with their starting oat products from 5 g to 250 g water/100 g, respectively. Also, whole chia seeds currently used in food products on the market are not easily utilized by the human body because of an extremely hard coat. These fine particle composites of oat products with ground chia were prepared by a feasible procedure for producing composites having improved nutritional value, texture quality, and functional food applications.

1. Introduction

It is recognized that oat products such as whole oat flour (WOF), oat bran concentrate (OBC) contain β-glucan which has beneficial health effects for coronary heart disease prevention by the reduction of serum cholesterol and postprandial serum glucose levels (Klopfenstein, 1988). Therefore, several oat hydrocolloids including Nutrim were developed from OBC using mechanical shearing and steam jet-cooking to increase the β-glucan content in oat products (Inglett, 2000; 2011). In addition to β-glucans, oat phenolic and other antioxidant compounds also provide health benefits as demonstrated for oat and barley (Inglett & Chen, 2012; Inglett, Chen, & Berhow, 2011; Madhujith & Shahidi, 2007). At equivalent β-glucan concentrations in solutions, the viscosity for oat β-glucan was found to be ~100 fold higher than for barley β-glucan indicating a direct viscosity dependence on β-glucan content regardless of amount and composition of α-glucan impurities (Mikkelsen et al., 2010). Oat hydrocolloid products containing β-glucan have numerous functional food applications to reduce fat content and calories in a variety of foods (Lee, Inglett, & Carriere, 2004); control the rheology and texture of food products (Rosell, Rojas, & Benedito de Barber, 2001); modify starch gelatinization and retrogradation (Rojas, Rosell, & Benedito de Barber, 1999; Lee, Warner, & Inglett, 2005); and also provide freezing/thawing stability (Lee, Baek, Cha, Park, & Lim, 2002). It was reported that a 5% dispersion of Nutrim had the same consistency as coconut cream when used in several Thai desserts (Maneepun, Boonpunt, & Inglett, 1998). In addition, fat in muffins and frozen desserts could be replaced with Nutrim, and the effect on their flavor and texture was evaluated (Warner & Inglett, 1998). A recent study showed that shortening in cakes could be substituted up to 40% of Nutrim without loss of cake quality (Lee et al., 2004). Rheological and physical evaluation of jet-cooked oat bran has been studied in low calorie cookies by replacing 20% of the shortening with oat β-glucan hydrocolloids (Lee & Inglett, 2006). The cookies containing C-Trim20, another oat hydrocolloid, exhibited reduced spreading characteristics and increased elastic properties compared with the

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control. The study suggested that the replacement should be limited to less than 50% of the substitute for butter and coconut cream in bakery products (Inglett, Maneepun, & Vatanasuchart, 2000).

Chia (*Salvia hispanica* L.) is an annual herbaceous plant that belongs to the Lamiaceae family which is native of southern Mexico and northern Guatemala (Capitani, Spotorno, Nolasco, & Tomás, 2012). Chia was among the principal crops grown by ancient Mesoamerican cultures for thousands of years (Reyes-Caudillo, Tecante, & Valdivia-López, 2008). Chia, also known as chia sage and Spanish sage, was an important staple food such as gruel with roasted and ground Chia seeds; flavorings; oil source such as body emollient; painting oil; and folk medicine for treating eye obstructions, infections and respiratory malaises (Lu & Foo, 2002; Reyes-Caudillo et al., 2008). The seeds soaked in water or fruit juice are consumed in some regions as refreshing drinks (Cahill, 2003). The chia plant produces numerous small white and dark seeds that mature in autumn. The seed has a high unsaturated oil content that has gained attention as a dietary component (Ayerza, 1995). Recent studies have shown that chia has a high content of oil (32%) that is rich in polyunsaturated fatty acids, particularly omega-3 linolenic acid (54–67%) and omega-6 linoleic acid (12–21%) which has great benefits for human and animal health (Ixtaina, Martínez et al., 2011; Rosamond, 2002); dietary (soluble and insoluble) fiber (over 30% of the total weight), both important components of the human diet; and proteins of high biological value (around 19% of the total weight; Muñoz, Cobos, Diaz, & Aguilera, 2012; Taga, Miller, & Pratt, 1984). In addition, the seed contains natural antioxidants such as phenolic glycoside-Q and K, chlorogenic acid, caffeic acid, quercetin and kaempferol (Reyes-Caudillo et al., 2008) which protects consumers against some adverse conditions, such as some cardiovascular diseases and some types of cancer; as well as supplying vitamins and minerals (Ayerza & Coates, 2001a, 2004; Craig & Sons, 2004). Also, chia seeds contain 5–6% mucilage that can be used as dietary fiber (Ayerza & Coates, 2001b; Reyes-Caudillo et al., 2008). Defatted chia has 22% fiber and 17% protein, similar to other oilseeds, and has currently been used in the food industry and animal feed (Ayerza & Coates, 1999). The protein content of chia is higher than that of other traditional crops such as wheat, corn, rice, oat, barley and amararanth (Ayerza & Coates, 2005). Chia protein contained high amounts of glutamic acid (123 g/kg raw protein), arginine (80.6 g/kg raw protein) and aspartic acid (61.3 g/kg raw protein). Its amino acid profile has no limiting factors in the adult diet, but threonine, lysine and leucine were the limiting amino acids in a preschool child's diet (Olivos-Lugo, Valdivia-López, & Á.Tecante, 2010).

The quality and composition of some minor constituents of chia seed oils were influenced by the extraction process, as well the oil yield. Solvent extraction obtained about 30% more oil than by pressing. The main fatty acids ranked in the following order of abundance: α-linolenic acid (α Ln) > linoleic acid (L) > oleic acid (O) ≈ palmitic acid (P) > stearic acid (S) for both extraction systems (Ixtaina, Martínez et al., 2011). An optimized microwave-assisted extraction (MAE) method was efficient for extracting lignans from the plant matrix, and it achieved significantly higher extraction yields than the two established reference methods (Names & Orsat, 2011). The oil extraction from chia seeds using supercritical CO2 appears to be a good alternative because it operates at low temperature with good mass-transfer rates and with no solvent residual in the final product (Uribe, Perez, Kauil, Rubio, & Alcocer, 2011). Also, SC–CO_2 extraction was of interest because it was possible to achieve a chia oil yield close to that obtained by conventional extraction with a similar fatty acid composition by using an environmentally friendly process (Ixtaina, Mattea et al., 2011).

Whole oat flour, OBC, and Nutrim were used in this study to produce unique composites containing β-glucan in combination with chia containing its distinctive omega-3 oil. Also, there is a need to search for an alternative method to improve its functional performance since the viscosity and cohesion of ground chia is fairly low for food applications. The oat component appears to be helpful in absorbing chia oil and improving physical properties such as water holding capacity. RVA tests were used to describe the changes of the viscosities of composites on the heating and cooling. The rheological test discloses the elastic and solid properties and the changes in viscosity of composites during increased shearing. Thus, the purpose of our study was to explore information on the pasting and rheological characteristics of dry blended ground chia with Nutrim, OBC and WOF that could be valuable for processing and developing potential new functional food products having desirable texture and health benefits.

2. Materials and methods

2.1. Preparation of oat–chia composites

Black chia seeds (chia) were purchased from Chia Seed Growers (Cuernavaca, Mexico). Organic whole oat flour colloidal fine (WOF) was provided by Grain Millers (Eugene, OR). Oat bran concentrate (OBC) was supplied by Quaker Oats, Chicago, Illinois (Lot 18608408). Nutrim (Lot 35503475N170) was provided by VDF FutureCeuticals (Momence, Illinois). Nutrim was prepared by steam jet-cooking OBC, sieving, and drum-drying (Inglett, 2000).

Black chia seeds were ground for 40 s using a Kinfete 1095 grinder (Foss Analytical AB, Sweden). Ground chia seeds were mixed with corresponding oat by a N-50 Hobart mixer (Hobart Canada INC., Ontario, Canada) for 1 min. The mixtures were ground again with a Kinfete 1095 grinder for another 40 s for additional mixing to obtain the desired composites.

2.2. Measurement of water-holding capacity

The water-holding capacities of the oat–chia samples were determined according to the procedure of Ade-Omowave, Taiwo, Eshtiaghi, Angersbach, & Knorr (2003) with minor modifications. Samples (2 g) were mixed with 25 g of distilled water and vigorously mixed using a vortex for 1 min a homogenous suspension and then held for 2 h, followed by centrifugation at 1590 × g for 10 min. Each treatment was replicated twice. Water-holding capacity was calculated by the following equation:

$$\text{Water holding capacity}(\text{g}/100\text{ g}) = [\text{water add}(\text{g}) - \text{decanted water}(\text{g})]/\text{dry sample weight}(\text{g})*100$$

2.3. Pasting property measurement

The pasting properties of samples were evaluated using a Rapid Visco Analyzer (RVA-4, Perten Scientific, Springfield, IL). Samples (2.24 g dry basis) were made up to a total weight of 28 g with distilled water in a RVA canister (8 g solids/100 g w/w). The viscosity of the suspensions was monitored during the following heating and cooling stages. Suspensions were equilibrated at 50 °C for 1 min, heated to 95 °C at a rate of 6.0 °C/min, maintained at 95 °C for 5 min, and cooled to 50 °C at rate of 6.0 °C/min, and held at 50 °C for 2 min. For all test measurements, a constant paddle rotating speed (160 rpm) was used throughout the entire analysis except for 920 rpm in the first 10 s to disperse sample. Each sample was analyzed in duplicate. The results were expressed in Rapid Visco Analyser units (RVU, 1 RVU = 12 cP).