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Rheological characterization of raw and roasted green gram pastes

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ABSTRACT

Rheological properties of raw and roasted green gram pastes have been determined at different moisture contents (52–56 g/100 g) and temperatures (10–40 °C). These pastes exhibit shear-thinning behavior and possess yield stress. Cross model is suitable ($0.986 \le r \le 0.999$, $p \le 0.01$) to explain the flow characteristics of the pastes. The Cross model parameters such as zero-shear viscosity and relaxation time are sensitive to concentration of solids in the paste as well as temperature of measurement, and vary widely between raw and roasted samples. The effect of temperature on the apparent viscosity follows the Arrhenius type relationship ($r \ge 0.961$, $p \le 0.01$). The viscoamylographic indices and trypsin inhibitor content are also different for raw and roasted samples. The roasted pastes show a smooth and cohesive microstructure. The optimized sample of roasted flour having a moisture content of 55 g/100 g is suitable as bread spread with appropriate stickiness and spreadability.

1. Introduction

Butter and margarine are popular spreads throughout the world. Non-dairy and reduced fat/calorie spreads are becoming important for health conscious people who are seeking attractive products from different sources. Low-fat spreads/pastes have been studied and categorized into three main groups. These are carbohydrate-based (Khatoon, Sreerama, Raghavendra, Bhattacharya, & Bhat, 2009; Wang, Sun, Zeng, & Lu, 1999), protein-based (Kampf & Peleg, 2002), and lipid-based fat substitutes (Akoh, 1998). Fat reduction and the replacement of fat with an appropriate fat substitute of a spread product affect the sensory and rheological characteristics. However, a detailed investigation on the flow behavior of products is needed for their characterization, selection of processing conditions, product development and consumer acceptance. Legume and oilseed cakes can serve as the base raw materials with added advantages of lower price of products and increased protein content. Chickpea and soy protein concentrate based spreads have been reported (Kampf & Peleg, 2002).

Green gram is one of the major legumes and is frequently used in Asian countries. It is widely used in making *dhals* (decorticated split halves), infant foods, snacks, etc. In Southeast Asian countries, many traditional foods are also made from green gram after blending with cereals though it is popularly consumed as cooked thick gruel which is part of major meals. Rheology of maize-green gram blend extrudate pastes has been investigated (Balasubramanian, Singh, Ilyas, and Wanjari, 2006). Sindhu and Khetarpaul (2005) have reported green gram based food blend after fermentation with probiotic organisms. Several green gram blended products have also been reported (Anu-Sehgal, & Kwatra, 2006; Geethalakshmi & Prakash, 2000). Walde, Tummala, Laskhminarayan, and Balaraman (2005) have studied the effect of pasting and particle size distribution of green gram dried batter. However, there is scope to further study the suitability of green gram in various formulations.

Rheological characterization of selected low-fat pastes/spreads from sesame (Razavi, Habibi Najafi, & Alaee, 2008), soy (Choi, Chang, & Yoo, 2008), pistachio butter (Taghizadeh & Razavi, 2009), tomato (Bayod, Willers, & Tornberg, 2008), and chickpea (Ravi & Bhattacharya, 2006) is available. A number of spreads including fat substitute pastes are covered by patents (Budiman and Adato, 2007; Reiling, 2001). Legume and oilseed cakes are possibly an alternative for manufacturing low-fat spreads in terms of cost-effectiveness as well as increased protein content. Knowledge of the rheological properties of green gram flour pastes both raw and cooked can thus widen the use of green gram in manufacturing different types of foods including low-fat spreads. Understanding of the flow behavior of pastes at different processing conditions is thus needed in addition to searching for an appropriate mathematical model that can help process scale-up and quality control.

The objectives of the present paper are to (a) characterize the rheological properties of raw and roasted green gram pastes as affected by concentration of solids and temperature of measurement, (b) examine viscoamylographic behavior and (c) suitability of model explaining flow behavior.

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2. Materials and methods

2.1. Preparation of flour

Green gram (GG) *dhal* (dehusked split halves) was procured from the local super market and cleaned manually. It was roasted in a laboratory model coffee roaster at 100 °C for 20 min when characteristic roasted flavor was detected. The raw and roasted *dhal* were pulverized in a laboratory model grinder keeping the temperature of material below 40 °C during grinding by cooling the material (about 10 °C) prior to grinding. The ground powder thus obtained was passed through a 120 μm aperture sieve and used for further studies.

2.2. Physico-chemical properties

The proximate composition of the raw and roasted flour was determined following AOAC (2002) methods. Trypsin inhibitor activity (TIA) was estimated using the procedure developed by Hamerstrand, Black, and Glover (1981). *In-vitro* protein and carbohydrate digestibility of the pastes was determined according to Walter and Mark (1964). Water holding capacity (WHC) of the GG flours was determined following the procedures of Sirelkhatim, Elhardallou, and Walker (1993). The results are expressed in ml of water absorbed per g of dry flour. All determinations were replicated thrice.

2.3. Viscoamylograph

Viscoamylography of green gram (raw and roasted) flours was carried out by following the method of AACC (2000) by employing a Micro-Viscoamylograph (model # 803202, Brabender, Duisburg, Germany) using a dispersion containing 10 g/100 g flour solids on a dry basis. The sample was heated from 30 °C upto 92 °C at the rate of 5 °C/min, held at 92 °C for 5 min and finally cooled to 30 °C at 5 °C/min. The runs were triplicated for each sample.

2.4. Rheological measurement

Dispersion containing desired levels of moisture content (52–56 g/100 g) was prepared by adding the required amount of water to flour and the mixture was stirred for 2 min to obtain a smooth paste. The flow behavior of dispersions was determined employing a rotational viscometer (model IM7287, Rheolab QC, Ostfildern, Germany) with a concentric cylinder attachment. Shear-rate was linearly increased from 0.1 to 500 s^{-1} in 3 min to obtain 50 data sets comprising shear-rate, shear-stress and apparent viscosity. A circulatory water bath was used to maintain the desired temperature during the measurement. Apparent viscosity (η_{100}) was taken as the ratio of shear-stress and shear-rate the latter being taken as 100 s^{-1}. Apparent viscosity was reported as the mean ± standard deviation of three replicates. The yield stress was determined by employing the stress relaxation procedure (Bhattacharya and Bhattacharya, 1996). Yield stress was reported as the mean ± standard deviation of four replicates.

2.5. Suitability of rheological model

Data on shear-rate/shear-stress were fitted to several common rheological models such as Herschel-Bulkley, Casson and Cross equations employing the software provided by the equipment manufacturer. The suitability of individual model was judged by the correlation coefficient (r); the statistical significance of r values were judged at $p = 0.01$.

2.6. Sensory assessment

The non-oral sensory assessment of paste samples were performed by 10 trained panelists by using their fingers to determine the sensory attributes such as spreadability and stickiness (Bhattacharya, Bhattacharya, and Narasimha, 1999) based on a 9-point scale (9: extremely sticky or hard to spread, and 1: least sticky or extremely easy to spread). Spreadability was defined as the ease of spreading of sample by using a blunt kitchen knife. Stickiness was the extent of difficulty to fore finger while releasing the finger after touching the paste gently. Ten judges from the Institute participated in the analysis who had previous experience in descriptive sensory analysis. Each panel members participated in one-hour training session for familiarization of the definitions and the standards used. For evaluation, 10 ml of sample was served in a 50 ml beaker, coded with three digit random numbers. Groundnut oil was assigned as 1 while peanut butter was taken as 9. The sample paste was kept in a covered container in a water bath, maintained at the specific temperatures. Spreadability was assessed by spreading on a slice of bread (Daubert, Tkachuk, & Truong, 1998). The desirable

Table 1
Properties of raw and roasted green gram flour.

Properties		Raw green gram	Roasted green gram
Proximate composition	Moisture (g/100 g)	10.2 ± 0.4[b]	5.5 ± 0.3[a]
	Fat (g/100 g)	1.2 ± 0.2[a]	1.3 ± 0.2[a]
	Protein (g/100 g)	22.2 ± 0.9[a]	23.4 ± 0.6[a]
	Ash (g/100 g)	2.2 ± 0.2[a]	2.4 ± 0.2[a]
	Carbohydrate (by difference) (g/100 g)	64.2	67.4
Nutritional and functional properties	Trypsin inhibitor (TIU/mg)	57.8 ± 1.5[b]	3.8 ± 0.3[a]
	Starch digestibility (g/100 g)	45.9 ± 0.8[a]	65.5 ± 1.4[b]
	Protein digestibility (g/100 g)	55.8 ± 1.1[a]	68.2 ± 2.0[b]
	Water holding capacity (ml/g)	1.1 ± 0.1[a]	1.4 ± 0.1[b]
Pasting characteristics	Gelatinization temperature (°C)	72.7 ± 0.3[a]	73.6 ± 0.4[b]
	Peak viscosity, A (BU)	307 ± 3[b]	85.7 ± 2[a]
	Breakdown viscosity, B (BU)	0 ± 1[a]	21 ± 1[b]
	Setback viscosity, C (BU)	411 ± 5[b]	159 ± 2[a]
	Final paste viscosity, D (BU)	718 ± 6[b]	378 ± 4[a]
	Set back ratio (C/A)	1.34 ± 0.12[a]	1.85 ± 0.04[b]
	Breakdown ratio (D/A)	2.34 ± 0.31[a]	4.41 ± 0.22[b]

Values in the same row with different superscripts differ significantly at $p \leq 0.05$.