Food Bioscience 14 (2016) 28–33

Contents lists available at ScienceDirect

Food Bioscience

journal homepage: www.elsevier.com/locate/fbio

Development of functional yoghurt via soluble fiber fortification utilizing enzymatically hydrolyzed guar gum

Deepak Mudgil [a,*], Sheweta Barak [a], B.S. Khatkar [b]

[a] Department of Dairy and Food Technology, Mansinhbhai Institute of Dairy and Food Technology, Mehsana, Gujarat 384002, India
[b] Department of Food Technology, GJUS&T, Hisar, Haryana 125001, India

ARTICLE INFO

Article history:
Received 14 November 2015
Received in revised form
2 February 2016
Accepted 17 February 2016
Available online 19 February 2016

Keywords:
Yoghurt
Soluble dietary fiber
Partially hydrolyzed guar gum
Water holding capacity
Viscosity

ABSTRACT

The purpose of this research was to investigate the effect of enzymatically/partially hydrolyzed guar gum (PHGG) level (1–5%), culture level (1.5–3.5%) and incubation time (4–8 h) on functional and sensory property of yoghurt using response surface methodology. Central composite design was used to study the effect of processing variables on pH, viscosity, titratable acidity, water holding capacity and overall acceptability (OA) of yoghurt. The coefficients of determination for all the responses were greater than 0.8896 (except OA, 0.7833). Regression analysis showed that PHGG level was the most important factor that affected quality of yoghurt ($p < 0.01$). Optimum value for PHGG level, culture level and incubation time obtained from response surface modeling were 2.02%, 2.33% and 5.28 h, respectively. Results revealed that partially hydrolyzed guar gum could be potentially used for soluble fiber enrichment of yoghurt with acceptable functional and sensory quality.

1. Introduction

Increased awareness in health issues leads to increased consumption of functional dairy products containing nutritional supplements. Traditional and staple foods fortified with dietary fiber often results in healthy products with calories, cholesterol and fat. Dietary fiber incorporation may also improve the functional properties in food products (Elleuch et al., 2011). Plant carbohydrate polymers including both oligosaccharides and polysaccharides, which are undigestable in the human small intestine with complete or partial fermentation in the large intestine, are considered as dietary fiber. These are classified into two types: soluble and insoluble dietary fiber. Soluble fibers include pectic substances, gums, mucilage and inulin, whereas insoluble fibers include cellulose, hemicellulose and lignin. Dietary fiber, when consumed in diet, can perform one or more functions such as increase in faecal bulk, stimulation of colonic fermentation, reduction of blood glucose and reduction of cholesterol levels (AACC, 2001). Guar gum is considered as soluble dietary fiber due to its water solubility. It is obtained from the endosperm portion of the seed of guar plant (*Cyamopsis tetragonolobus*). Guar gum is composed of linear chain of (1→4)-linked β-D-mannopyranosyl units with (1→6)-linked α-D-galactopyranosyl residues as side chains hence guar polysaccharide is known as galactomannan. This galactomannan, when consumed in the diet, remains undigested in human intestinal tract making it a functional dietary fiber. Gums can perform beneficial functions in human physiology such as reduced glycemic response and plasma cholesterol (Barak & Mudgil, 2014). When dissolved in hot or cold water, guar gum gives highly viscous solution even at low concentration. Due to this unique property, it is used as an additive in variety of processed food products such as tomato ketchup, ice cream, beverages, bakery and confectionery products (Mudgil, Barak, & Khatkar, 2011, 2012a, 2014a). Due to its high viscosity, guar gum cannot be used as dietary fiber source, as it deteriorates the product sensory as well as processing properties when incorporated at higher concentration. Hence enzymatic hydrolysis of guar gum is carried out for the production of partially hydrolyzed guar gum (PHGG). Studies proved that PHGG show resemblance in basic molecular structure with native guar gum (Yoon, Chu, & Juneja, 2008). PHGG obtained after enzymatic hydrolysis is a very low viscosity water soluble gum. During enzymatic hydrolysis of guar gum viscosity reduction is achieved via reduction in chain length and molecular weight of guar gum (Mudgil et al., 2012b, 2012c, 2014b). In past few decades, there is growing interest in fortification of food products with soluble dietary fiber to meet the daily requirements of fiber intake (Mudgil & Barak, 2013). PHGG is reported as tasteless, odorless and low viscosity water soluble dietary fiber (Yoon et al., 2008).

Yoghurt is a fermented dairy product widely consumed for its nutritional and health value. Food scientists have tried to improve nutritional properties of yoghurt by incorporation of protein, fiber

* Corresponding author.
E-mail address: dsmudgil@yahoo.com (D. Mudgil).

http://dx.doi.org/10.1016/j.fbio.2016.02.003
2212-4292/

and fiber source in yoghurt and evaluate the functional and sensory characteristics of yoghurt (Domagalla, Sady, Grega, & Bonczar, 2005, 2006; Ghasempour, Alizadeh, & Bari, 2012; Kaur, Mishra, & Kumar, 2009; Yang & Li, 2010). Quality of yoghurt can be analyzed by evaluating physicochemical and sensory properties (Lunardello, Yamashita, Benassi, & Barros-De-Renesis, 2011). Optimum quality of yoghurt fortified with soluble fiber could only be achieved by understanding technological functions of ingredients and process variables. Negative impact on products' functional properties restricts application of dietary fiber fortification in food products (Leeds & Avenell, 1985).

Response surface methodology (RSM) is a useful statistical and mathematical approach used for cost reduction and efficient process development. It finds applications in optimization, development and improvement of processes. Regression models generated in RSM help in describing the interrelationship between processing variables and responses (Montgomery, 1984; Myers & Montgomery, 1995). The effect of the independent variables on the processes can also be analyzed using RSM technique. The present research was carried out to investigate the effect of PHGG level, culture level and incubation time on pH, viscosity, titratable acidity, water holding capacity and overall sensory acceptability of yoghurt. To study the relationship among independent variables and for their optimization, second order polynomial models were developed to obtain yoghurts with optimum physicochemical and sensory properties.

2. Material and methods

2.1. Materials

The precious gift of food grade guar gum sample was obtained from Hindustan Gums and Chemicals Ltd., Haryana, India. Sieving of guar gum sample through 200 mesh sieve was done to obtain a uniform particle size fine powder. The guar gum sample was then stored under refrigerated conditions (8 ± 2 °C) until used. All chemicals (AR grade) were obtained from Central Drug House, India. Cellulase enzyme (*Aspergillus niger*) was obtained from USB Corporation, USA. Milk and skim milk powder (SMP) were procured from local market Hisar, India.

2.2. PHGG preparation and analysis

Native guar gum was subjected to enzymatic hydrolysis to prepare partially hydrolyzed guar gum having low viscosity. Hydrolysis of guar gum was done using cellulase (*Aspergillus niger*) at pH 6 and the temperature was maintained at 50 °C (Mudgil et al., 2014b). After enzymatic hydrolysis, the resultant aqueous solution of guar gum showed a low viscosity. It was then filtered, freeze dried and ground to powder. It was passed through 200 mesh sieve to obtain uniform size powder, before analysis. Moisture, protein, fat and ash content were determined using standard method of analysis (AOAC, 1990). Total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) of PHGG was determined by enzymatic method (James & Theander, 1981).

2.3. Preparation of yoghurt

SNF (solids nonfat) of milk was first set to 10% (w/v) with skim milk powder and then was heated to 43 °C for set-type yoghurt preparation. Selected concentrations of partially hydrolyzed guar gum were added to the milk and mixed with a mechanical stirrer. The milk was heated in a flat bottom container (with lid) on hotplate (with magnetic stirrer) at 90 °C for 10 min with occasional stirring. Milk was cooled to 43 °C after pasteurization treatment. Inoculation of milk fortified with different levels of partially hydrolyzed guar gum was done with selected concentrations of culture. Incubation of milk was then carried out at 43 °C for 4–8 h. After incubation, the yoghurts were cooled to 10 °C and stored in sealed container at 4 ± 1 °C before physicochemical and sensory analysis was done. Effect of culture level (1.5% to 3.5%) and incubation time (4–8 h) on yoghurt supplemented with PHGG (1% to 5%) was studied using response surface methodology.

2.4. Physicochemical analysis of yoghurt

pH of the yoghurt samples was measured using a pH meter (pHTestr 30, Eutech Instruments, Malaysia). The titratable acidity of the yoghurt was determined by modified method of Purwandari, Shah, and Vasiljevic (2007). It was determined as % lactic acid by titrating with NaOH (0.1 N), using phenolphthalein as an indicator. Viscosity of yoghurt samples was analyzed using viscometer (Brookfield, USA) with spindle no. 2 at 20 rpm and 4 °C temperatures. Water-holding capacity (WHC) of yoghurt was determined using a centrifuge. 10 g of yoghurt (X) sample was centrifuged at 3000 rpm for 20 min at 4 °C. The whey (Y) separated was removed and weighed. The water-holding capacity was calculated as.

$$\text{Water Holding Capacity } (\%) = [(X - Y)/X] \times 100 \quad (1)$$

2.5. Sensory analysis of yoghurt

Sensory characteristics of yoghurts were evaluated by a panel of ten semi-trained sensory panel members (Gajera, Kapopara, & Patel, 2010; Yadav, Yadav, & Dhull, 2012). The panelists were trained for descriptive analysis for sensory evaluation yoghurt. Panelists evaluated the appearance, taste, aroma, mouthfeel and texture. Twenty yoghurt samples were evaluated in four sessions spread over four days, five samples on each day. Freshly prepared yoghurt samples were removed from the refrigerator 1 h before the beginning of every evaluation session. Serving temperature range for samples was 10–12 °C. Each yoghurt sample was presented in a 100-g plastic cup fitted with lid and labelled with a 3-digit code. Order of presentation of samples was randomized. Water and expectoration cups were also presented to each panelist to rinse their mouths between samples. Overall acceptability of yoghurt samples was estimated by taking average of all the above sensory parameters. Evaluation of sensory attributes of yoghurt was done using a nine-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely).

2.6. Experimental design for PHGG yoghurt

Response surface methodology (RSM) was employed for the optimization of processing variables for production of partially hydrolyzed guar gum fortified yoghurt. It involves the design of experiments, selection of higher and lower levels of variables in experimental runs, mathematical models fitting and selection of optimized levels of variables with respect to optimized responses. Central composite design (CCD) was used to study the effect of three independent variables at five different levels on response pattern and for the determination of the optimum combination of variables. The present study was conducted to study the effect of processing variables such as PHGG level (X_1, 1–5%), culture level (X_2, 1.5–3.5%) and incubation time (X_3, 4–8 h) on pH (Y_1), viscosity (Y_2), titratable acidity (Y_3), water holding capacity (Y_4) and overall