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Optimization of textural properties of noodles with soluble fiber, dough mixing time and different water levels

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A B S T R A C T

Partially hydrolyzed guar gum as soluble fiber source has been investigated for fiber fortified noodles with health benefits. The study investigated the effect of soluble fiber level (1–5 g/100 g of flour), water level (30–40 ml/100 g of flour) and mixing time (2–6 min) on textural properties such as hardness, adhesiveness, cohesiveness, chewiness and resilience. The addition of soluble fiber in flour for noodles making was found to have a significant effect on all the hardness, adhesiveness, cohesiveness, chewiness and resilience whereas water level and mixing time showed significant effect on hardness, adhesiveness and cohesiveness of noodles. The optimized values for soluble fiber level, water level and mixing time were 3.4 g/100 g of flour, 36.0 ml/100 g of flour and 5 min, respectively. Results revealed that fortification of noodles with PHGG (3.4%) increased the soluble fiber content to 3.62% as compared to control noodles (1.07%).

1. Introduction

Modern life style including low physical activity and poor food habits leads to health problems such as increased obesity, diabetes mellitus and cardiovascular diseases (Sayago-Ayerdi et al., 2011). The addition of dietary fiber to traditional and staple foods can solve these health related problems (Slavin and Lloyd, 2012). Dietary fiber is the edible plant portions or analogous carbohydrates which are undigestable and absorbable in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber may include polysaccharides, oligosaccharides, lignin, and associated plant substances which undigestable and absorbable in human digestive tract. Beneficial physiological functions performed by dietary fiber may include laxation, blood cholesterol attenuation and blood glucose attenuation (AACC, 2001). Guar gum is galactomannan obtained from seed endosperm of guar plant known as *Cyamopsis tetragonolobus*. Guar gum is used as thickening and stabilizing agent in many processed food products such as tomato ketchup, ice cream, beverages, bakery and confectionery products (Mudgil et al., 2011, Mudgil et al., 2012a). Complex carbohydrate i.e. galactomannan can perform beneficial functions in human physiology. It lowers the cholesterol level, control diabetes and regulate bowel digestive system in human beings (Mudgil et al., 2014a). Guar galactomannan composed of galactose and mannose units. When incorporated in diet the galactomannan serve as a dietary fiber because it is not digested by our intestinal secretions and due to its water solubility, it is termed as soluble dietary fiber. Native guar gum forms a very viscous solution when dispersed in water and contributes to the high water absorption and viscosity of the system. In food applications native guar gum is used as thickener at very low concentration i.e. 0.50% maximum. This is the reason why it cannot be incorporated at higher concentration as such in food products as it affects the product sensory as well as processing properties (Mudgil et al., 2012b). Hence enzymatic hydrolysis of guar gum is done to produce partially hydrolyzed guar gum (PHGG). Enzymatic hydrolysis of native guar gum reduces mannose chain length in guar galactomannan which leads to the reduction of degree of polymerization from 3295 to 29 (Mudgil et al., 2012c). The reduction in degree of polymerization results in low viscosity of PHGG (5 cps) as compared to native guar gum (5500cps) (Mudgil et al., 2014b).

Studies showed that PHGG is similar in basic molecular structure to native guar gum. Enzymatic hydrolysis of guar gum primarily causes the reduction in chain length of polysaccharide and thus reduces the molecular weight and viscosity of guar gum. Fortification of food products with soluble fiber is in considerable

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interest as it could contribute to increasing demand of daily recommended fiber intake. In past studies it has been reported that PHGG is tasteless, odorless and give transparent solution in water with low viscosity upto 10 mPa s. These properties made it a unique source of water soluble dietary fiber (Greenberg and Sellman, 1998).

In Asian countries, noodles constitute an integral part of the diet. Noodles are processed from refined wheat flour (Zhang et al., 2010). Attempts have been made by scientists to improve nutritional properties of food products (Singh et al., 1996; Ellis, 1985). Researchers have tried to incorporate nutritionally significant material such as fiber and fiber source in noodles and evaluate the textural and sensory characteristics of noodles with composite wheat flour (Izydorczyk et al., 2005; Mohamed et al., 2005; Lagasse et al., 2006).

Understanding of technological functions of ingredient and process variables would be a need for industrial production of soluble fiber enriched noodles in order to attain optimum textural quality. Fortification of dietary fiber in food products involves a major problem that negatively affects the product's functional properties (Shukla and Srivastava, 2014). Response surface methodology (RSM) is a statistical and mathematical approach used for development, improvement, and optimization of processes. It can also be applied to processes for cost reduction and efficient process development. It relates the processing variables to regression equations which describe the interrelationship between processing variables and responses (Brennan and Samyue, 2004). RSM can be applied to study the effect of the independent variables, alone or in combination, on the processes. In addition, it also generates a mathematical model which describes interrelations between independent variables and dependent variables (Montgomery, 1984; Myers and Montgomery, 1995).

Owing to its high viscosity, native guar gum cannot be used as a source of dietary fiber at higher concentration in the wheat products as it hampers the dough handling and processing properties. Thus, partially hydrolyzed guar gum was prepared and used for high fiber noodle formulation as it does not affect the dough properties due to its low viscosity. The present study was employed to understand the effect of processing parameters such as PHGG level, water level and mixing time upon the textural properties such as hardness, adhesiveness, cohesiveness, chewiness and resilience of noodles. To study the interrelationship among processing variables and for their optimization, second order polynomial models were developed to obtain noodles with optimum textural properties such as hardness, adhesiveness, cohesiveness, chewiness and resilience of noodles.

2. Material and methods

2.1. Materials

Guar gum was obtained from Hindustan Gums and Chemicals, Haryana, India. To obtain a uniform particle size fine powder guar gum sample was passed through 200 mesh sieve and was stored under refrigerated conditions before analysis. All chemical of Analytical Reagent (AR) grade were obtained from Central Drug House, New Delhi, India. Cellulase enzyme (*Aspergillus niger*) was obtained from USB, Cleveland, Ohio, USA. Refined wheat flour and salt were procured from local market Hisar, India.

2.2. PHGG preparation

Native guar gum was subjected to enzymatic hydrolysis to prepare partially hydrolyzed guar gum. Hydrolysis of guar gum was carried out using cellulase from *Aspergilus niger* (1.0 mg/g) at pH 6 in aqueous solution maintained at 50 °C. Partially hydrolyzed guar gum aqueous solution obtained after enzymatic hydrolysis showed a viscosity of 5cps. The solution was then filtered, freeze dried and ground to powder. Before analysis it was passed through 200 mesh sieve to obtain uniform particle size fine powder as that of native guar gum (Mudgil et al., 2014b).

2.3. Analysis of wheat flour, native guar gum and PHGG

Moisture, fat, protein and ash content of wheat flour, native guar gum and PHGG was determined following standard method of analysis (AOAC, 1990). Enzymatic method of Furda was employed to determine total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) in native guar gum and PHGG (Furda, 1981). Aqueous solution of guar gum (GG) and partially hydrolyzed guar gum (PHGG) at 1% concentration (w/w) were used for viscosity estimation. Viscosity of gum solutions was analyzed using viscometer (Brookfield, USA) with spindle no. 4 (GG) and 2 (PHGG) at 20 rpm and 25 °C temperature. Average molecular weight (Mv) of guar gum and partially hydrolyzed guar gum was determined from intrinsic viscosity using Mark-Houwink's equation, $[\eta] = k\,Mv\alpha$ with $\alpha = 0.732$ and $k = 3.8 \times 10^{-4}$ (Robinson et al., 1982).

2.4. Experimental design

In the present study, response surface methodology was employed for the optimization of variables. It involves the design of experiment, selection of variables levels in experimental runs, mathematical models fitting and selection of optimized levels of variables with respect to optimized response levels. A central composite design (CCD) was used to investigate the effect of three independent variables at five different levels on response pattern and to determine the optimum combination of variables. Twenty experiments were conducted for the present research work. Present study was conducted to study the effect of processing parameters such as PHGG level, water level and mixing time on textural properties of noodles such as hardness, adhesiveness, cohesiveness, chewiness and resilience. The independent variables optimized were X_1(PHGG level), X_2 (water level), X_3 (mixing time) for dependent response Y_1 (hardness), Y_2 (adhesiveness), Y_3 (cohesiveness) Y_4 (chewiness) and Y_5 (resilience). The minimum and maximum values for PHGG level was set at 1% and 5%. Maximum level of PHGG fortification in noodle was fixed at 5% on the basis of results obtained from screening trails which reveal that PHGG fortification in noodles above 5% leads to unacceptable higher cooking loss due to its water solubility. Another reason for selecting maximum limit of PHGG at 5% level was its fiber content; PHGG fortified noodles at 5% level can provide around 8 g of fiber per serving (serving size 200 g). Water levels varied from 30% to 40% as the optimum water requirement for noodle making is 35% (Barak et al., 2014). The mixing time was varied from 2 min to 6 min as the optimum mixing time for noodle making was 4 min as described in section 2.5. Twenty combinations of complete design (including central points = 6, star points = 6, number of factorials = 8 & alpha = 1.682) were performed in random order (Table 1). The model proposed for responses was

$$Y = b_0 + \sum_{i=1}^{i=3} b_i X_i + \sum_{i=1}^{i=3} b_{ii} X_{ii}^2 + \sum_{i<j=2}^{i=3} b_{ij} X_i X_j + e \qquad (1)$$

where b_0 is the value for the fixed response at the central point of the experiment; and bi, b_{ii} and b_{ij} are the linear, quadratic and cross-product coefficients, respectively.