Food Chemistry 124 (2011) 1620–1626

Contents lists available at ScienceDirect

Food Chemistry

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

A comparative study of the effects of three galactomannans on the functionality of extruded pea–rice blends

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ARTICLE INFO

Article history:
Received 14 February 2010
Received in revised form 29 June 2010
Accepted 12 August 2010

Keywords:
Galactomannans
Extrusion
Pea
Physical
Sensory
Nutritional characteristics

ABSTRACT

The present study evaluated the effects of three galactomannans on the physical and nutritional characteristics, and sensory acceptability of pea–rice based extruded products, targeted as nutritional snacks. A base blend of 70:30 pea and rice fortified with guar gum (GG), locust bean gum (LBG) and fenugreek gum (FG), at 5%, 10%, 15% and 20%, was extruded at pre-determined optimum processing conditions. All three gums resulted in good expanded products. Increasing the inclusion levels of gums, however, had no effect ($P > 0.05$) on the degree of expansion. Addition of 5% GG and LBG reduced ($P < 0.05$) the hardness, while the inclusion of GG and LBG at levels higher than 5%, and all inclusion levels of FG, increased ($P < 0.05$) the hardness of extruded products. Relative to other treatments, FG produced extrudates that were harder and crispier. The mean scores of sensory evaluation indicated that all products containing gums up to 15% were within the acceptable range. Extrusion increased ($P < 0.001$) the soluble fibre content and decreased the insoluble fraction; the magnitude of these changes were greater in GG and FG. The addition of 15% gums in the pea–rice blend reduced ($P < 0.05$) the glycaemic index to less than 55. Overall, the data suggest that all three galactomannans could be incorporated up to 15% in a pea–rice blend to develop nutritious, organoleptically acceptable, extruded snack products with low glycaemic index.

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1. Introduction

The low incidence of diseases related to blood circulation in Asian population is ascribed, in part, to a relatively high consumption of legumes (Kahlon, Smith, & Shao, 2005). However, legumes are an underutilised commodity in most regions of the world due to the length of time needed to prepare a legume-based meal and, the belief that legumes are of low nutritive value due to the presence of flatulence and anti-nutritional factors (Adsule, Lawande, & Kadam, 1989). However, legumes are potentially valuable dietary components due to a protein content between 20% and 50%, and the presence of complex carbohydrates, especially dietary fibre and water soluble polysaccharides, which give them low glycaemic potency. Field peas (*Pisum sativum* L.) are widely cultivated and readily available as dry products. They represent an inexpensive source of protein and energy, and are well-suited to meet the demands of health-conscious customers. Pea can be an effective component for formulating foods with low glycaemic index (GI) and high protein content.

All processing methods tend to modify the composition and availability of nutrients in raw materials. Among the various technologies, short-time high-temperature extrusion cooking is a well known cost-effective industrial process. Extrusion combines high pressure with a moderately high-temperature and usually high shear for a short period of time. Extrusion processing completely gelatinises the starch and partially or completely destroys anti-nutritional factors present in many legumes (Melcion & van der Poel, 1993). New developments in twin-screw extrusion processing technology have given snack and breakfast cereal processors a practical tool to incorporate gums into grain-based products.

Starch is the primary component of expanded snack products and is responsible for most of their mechanical properties. But inclusion of galactomannan gums can also affect the mechanical, physico-chemical and micro structural properties, and may lower the GI of the food. Two commercially popular galactomannans are guar gum (GG) and locust bean gum (LBG), which differ in their mannose:galactose ratios. In a previous study in our laboratory (Gamlath & Ravindran, 2009), it was found that the extrusion of mixtures of fenugreek (*Trigonella foenum-graecum* L.) polysaccharide blended with chickpea and rice flours resulted in expanded snacks with low GI and organoleptic properties that were not compromised. Fenugreek gum (FG) is a water soluble galactomannan that is extracted from the fenugreek seeds, a member of the legume family, and is known for its medicinal benefits. In descending order of galactose to mannose ratios, the three gums are ranked 1:4 (LBG); 1:2 (GG) and 1:1 (FG). No research has been conducted thus far on how gums behave in extrusion cooking or the effect of

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0308-8146/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2010.08.030

including these hydrocolloids into cereal–legume blends, in relation to the overall functional properties of the snack products. The choice of rice flour was due to its bland taste, its low protein content that could limit the non-enzymatic browning reaction rate and its good capacity of expansion (Gamlath & Ravindran, 2009).

The aims of the present work were to compare the functional characteristics of FG, GG and LBG in extruded pea–rice blends and to determine the effects on the functional properties of expanded snack products. The properties investigated included physical characteristics related to organoleptic properties, such as expansion rate, bulk density (BD), true density (TD), hardness, texture, and sensory characteristics. Additionally, the nutritional properties, such as macronutrients, trypsin inhibitor activity (TIA), *in vitro* protein digestibility (IVPD) and GI, were investigated to determine their suitability as healthy snack products. Other physical properties studied included water solubility index (WSI) and water absorption index (WAI).

2. Materials and methods

2.1. Raw materials

Yellow pea flour and rice were purchased from local commercial suppliers. Fenugreek gum (FenuLife®), a debittered fenugreek polysaccharide comprising 85% dietary fibre, was supplied by PhytoHealth Pty Ltd., Hornsby, NSW, Australia. Guar gum (78% dietary fibre) and locust bean gum (80% dietary fibre) were obtained from Hawkins Watts Ltd., Auckland, New Zealand and Roeper, Hamburg, Germany, respectively. Rice was ground in a hammer mill (Bisley's Farm Machinery, Auckland, New Zealand) to pass through a 1.0 mm screen.

2.2. Extruder

A Clextral BC 21 (Firminy Cedex, France), co-rotating, twin-screw extruder with length/diameter ratio of 25 was used for the work. The screw configuration (from feed section to die) used to process the ingredients consisted of three sections with forward elements, in a sequence of 4, 5 and 5 screw elements, each 50 mm in length, with pitches of 13, 10 and 7 mm respectively. The total length of the screw was 700 mm. The extruder was equipped with a volumetric feeder (KTRON T20, Niederlenz, Switzerland), a single round die of 2.5 mm diameter, and an automated cutter.

2.3. Extrusion processing

2.3.1. Experimental

Based on the results of previous studies (Gamlath & Ravindran, 2009), a blend of 70:30 pea and rice flour was chosen as the base formulation. The three gums were added to the base formulation at levels of, 5%, 10%, 15% and 20% w/w. Prior to extrusion, the ingredients were thoroughly mixed in a small commercial food mixer (model: ARM-02, Thunderbird, Canada). Studies were conducted at optimum processing conditions; the temperatures of the seven zones of the extruder from feed to die were set to 50, 50, 70, 110, 150, 150 and 160 °C, respectively, and the die temperature was 118 °C. The screw speed was maintained at 306 rpm and the motor torque was 6.5 for GG, 6.1 for LBG, and 7.1 Nm for FG. The input feed rate was 11.5 kg/h and the water feed rate was adjusted at 0.39 l/h. The cutter speed was maintained at 200 rpm to obtain spherical shaped products.

Extrudates were collected over a period of 3–5 min, during which time, the torque and screw speed were stable. The extruded products were collected and allowed to cool to room temperature. Two replicates of each product were made, and stored at room temperature in sealed polyethylene bags. Representative samples were then obtained and ground to pass through a 0.5 mm sieve for chemical analyses.

2.4. Determination of characteristics leading to organoleptic properties

2.4.1. Expansion ratio

It was calculated from the diameter of the extrudates to the diameter of the die. The diameter of the extrudates was determined as the mean of 20 random measurements made with a Vernier caliper (Mitutoyo, Tokyo, Japan). The percent expansion of the extrudates was calculated as follows:

$$\%\text{Expansion} = \text{extrudate diameter} \times 100/\text{die diameter}$$

2.4.2. Bulk density

It was calculated from the weight of 1 l of extruded product in duplicate and recorded as g/l.

2.4.3. True density

The true density of the extruded products was determined by the mustard seed displacement method (Heaton, Daniell, & Moon, 1982). True density was determined using the following equation.

$$\text{True density}(\text{kg/m}^3) = \frac{\text{Sample weight}(\text{g}) \times 1000(\text{ml/L}) \times 1000(\text{L/m}^3)}{\text{Sample volume}(\text{ml}) \times 1000(\text{g/kg})}$$

2.4.4. Texture profile analysis

Texture profile analysis of the extruded puffs was performed in triplicate using a Texture analyser (TA.XT PLUS, Canners Machinery Ltd., Simcoe, Ontario, Canada). Hardness and crispiness were determined using 20 g samples. Each sample was tested for hardness in an Ottawa cell with a solid base plate (Instron Corporation, Canton, MA). The sample in the cell was compressed to a distance of 30 mm (trigger force = 0.3 N) with a 30 mm square probe, at a speed of 5 mm/s, in two replicate runs. The pre-speed and post-speed were set at 1.0 mm/s and 10 mm/s, respectively. The data acquisition rate was 400 pps. Hardness, an estimation of the force required to compress a food between molars, was calculated as the maximum peak force from the two compression cycles obtained using the texture expert software.

2.4.5. Sensory evaluation

The sensory assessments were conducted in a purpose-built, 10-booth sensory evaluation laboratory. Thirty panelists, who were regular snack consumers and aged between 18 and 37, were randomly selected for the consumer panel. The panelists were naïve to the project objectives. In the first stage, samples incorporated with 5%, 10%, 15% and 20% gums were used in the evaluation. Samples were coded using random three-digit numbers and served following standard sensory evaluation methodology. Panelists were provided with written instructions and asked to evaluate the products for acceptability based on its flavour, texture, colour and overall acceptability using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely) following the procedure of Meilgaard, Civille, and Carr (1999). Samples were scored by the panel on two separate occasions.

2.5. Nutritional properties

The unextruded raw materials and the extruded snack products containing 15% added gums that were selected as organoleptically acceptable were analysed for macronutrient composition, TIA and,

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