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Development and parameter optimization of health promising extrudate based on fenugreek oat and pea

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ABSTRACT

The purpose of this study was to develop health promoting extruded snack products. Extruded snacks were prepared using a blend of oat, green pea and fenugreek seed flour and leaf powder. Effect of feed moisture (12–16% wet basis), barrel temperature (90–110 °C) and screw speed (100–200 rpm) on the product properties like lateral expansion (LE), bulk density (BD), water absorption index (WAI), water solubility index (WSI) and hardness was investigated. The product responses were significantly affected by changes in moisture, temperature and screw speed. The regression models for product responses like LE, BD, and hardness were highly significant ($P \leq 0.0001$), whereas WAI and WSI were significant at a ($P \leq 0.001$) respectively. Desirable extruded products were obtained at moisture of 12%, 110 °C temperature and 200 rpm screw speed. It was revealed that fenugreek, oat and dried green pea can be used to produce snack products with desirable quality characteristics.

1. Introduction

Modern life is characterized by lot of work and limited time, which has moved us for consumption of ready-to-eat products. Additionally, youngsters throughout the world are attracted to several ready-to-eat snack products because of their taste and ease of consumption. Consequently, the industries of food have increased the production of ready-to-eat products by using various processes. One of the processes is extrusion that is a high temperature-short time and is characterized by continuous cooking, kneading, mixing and forming processing and finally into direct expanded product with high quality characteristic (Ding, Ainsworth, Plunkett, Tucker, & Marson, 2006). Extrusion produces wide variety of new products, for example cereal snack foods, breakfast cereals, baby foods, bakery products, pastas and so on. Extrusion involves thermo-mechanical cooking in a screw-barrel assembly by a combination of temperature and pressure in order to mechanically shape and shear (Rodriguez-Miranda et al., 2011) and extruded products undergo many chemical and structural changes. The process conditions are the factors on which the final products' quality depends on, for example, screw speed of extruder, moisture of feed material, the temperature profile in the barrel sections, the feed rate and finally the extruder type (Thymi, Krokida, Pappa, & Maroulis, 2005).

These days there is an increasing trend for the eating of high-value food products. Peoples have become conscious about their health, which has raised their interest for consumption of nutrient enriched as well as functional foods. High consumption of these nutrient rich foods and functional foods reduces risks of various kinds of diseases like heart disease, protection against many cancers (Satia, Kristal, Patterson, Neuhouser, & Trudeau, 2002) and other malnutrition. So, it is important to have functional foods as well as nutritionally enriched foods in the diet of children.

Fenugreek seed flour has a great potential, because of its high and good quality protein (20–25%) and dietary fibres (soluble 20%). Fenugreek has been reported to have hypocholesterolemic effect (Sharma, 1986) and hypoglycemic effect (Neeraja & Rajyalakshmi, 1996). Fenugreek leaves are rich in vitamin C, vitamin K and potassium, calcium and iron and also rich in good dietary fibre. In ancient periods the leaves of fenugreek were found to be a powerful herb. Consuming fenugreek leaves regularly improves tone of nervous, respiratory, reproductive and neuromuscular system (Sharangi & Guha, 2013). Fenugreek has been used to develop extruded snack products of acceptable physical and sensory properties (Wani and Kumar, 2015a, 2015b; Shirani & Ganesharanee, 2009). Studies on incorporation of fenugreek seed flour in extruded snack products are little.

Pulses have long been recognised as highly nutritious because of their good protein quality (Boye, Zare, & Pletch 2010) and abundant nutrients (Wani and Kumar, 2015c). It has been found that eating pulse rich diet daily reduces serum cholesterol (Ha et al. 2014). Pulses provide protein, fibre and a rich source of minerals and vitamins, minerals like magnesium folate, zinc, and iron. In order to have these nutrients in your diet experts suggests

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having a half a cup of peas or beans per day. Additionally, presences of phytochemicals, tannins and saponins found in pulses have *anti*-carcinogenic and antioxidant effects, showing that pulses may have significant anti-cancer effects (Mudryj, Yu, & Aukema 2014). It is necessary to know the composition of the dried green pea flour, which has been used as one of the ingredients in the present study. Dried green pea has 23% protein content, 2.8% ash, 1.9% fat, 4.9% fibre and 57.9% carbohydrate, Wani and Kumar (2015c).

Oats are a uniquely nutritious food as they contain a good lipid profile and greater quantity of soluble fibre as compared to other cereal grains. Oats are good sources of functional ingredients such as β- glucan; findings reveal beneficial effects of oat on health (Wani et al., 2014). Oats have been used as a food ingredient in number of products like breakfast cereals, bread, ready-to-eat and snacks (Decker, Rose, & Stewart, 2014). The most common way to eat oats is oatmeal. Extrusion has been found to improve the functional properties of oat bran, leading to higher temperature for gelatinisation, higher swelling capacity, higher solubility, increased apparent viscosity and a decrease in the flow behaviour index (Zhang, Bai, & Zhang, 2011). The last two changes have been suggested to be beneficial because they could contribute to a slower gut transit and the perceived 'fuller for longer' of satiety effect (Clemens & van Klinken, 2014). In oats, extrusion has been found to alter β-glucan's ability to decrease serum cholesterol (Wolever et al., 2010). Oats have other many physiological benefits like increased hypoglycemic effect (Jenkins, Jenkins, Zdravkovic, Wursch, & Vuksan, 2002). Oats flour can be used as functional ingredients in variety of processed food products to improve the nutritional quality and provide beneficial health effects.

The extrusion cooking is common process, but the incorporation of nutrient rich ingredients on the extruded snack product has not been extensively studied. So, development and consumption of such extruded snack products having health and nutritious benefits would help to increase the health status of the population. Additionally, the effect of process conditions on the properties of extruded snacks' product will be determined. Hence, current study involves the investigation of the effect of process conditions on the properties of extruded snacks produced with fenugreek seed flour, leaf powder, dried green pea and oat flour.

2. Materials and methods

The raw materials used (dried green pea flour, oats flour, fenugreek seed powder, fenugreek leaf powder and composite flour of rice and corn) were procured from local market Sangrur, India. Fenugreek leaves were blanched at 90 °C for 4 min and they were then kept in a drier at 60 °C over night in the trays. After drying the leaves were ground in a grinder. All the raw materials were packed and kept in dry condition until their use.

Composition of ingredient used are the results of optimization of previous experiments (21.72% oat flour, 8.62% dried green pea flour, 0.66% fenugreek leaf powder and 1.78% fenugreek seed powder) and remaining percentage was composite flour (rice+corn:80+20) (Wani and Kumar, 2016). Extrusion of samples was done using a twin-screw extruder (Basic Technology Pvt. Ltd., Kolkata, India). The die diameter used in this study was selected at 4 mm as recommended by the manufacturer for such type of products and recommended by Stojceska, Ainsworth, Plunkett, Ibanoglu, and Ibanoglu (2008). Control panel displayed the temperature of barrel as well as the screw speed. The effect of extrusion condition viz. feed moisture content, barrel temperatures and screw speed (Table 1) were used to study their effects on the quality parameters of extruded products. Sharp knife was used to cut the extrudates (approx. 8 cm long) as they come out from the die. The extrudates were cooled to room temperature and laminated bags were used for storage of extrudates until used for analysis.

Table 1
Coded level for independent variables used in developing experimental data.

Independent Factors	Coded level	Levels				
		-α (−1.68)	−1	0	+1	+α (−1.68)
Feed moisture content (%, wet basis)	X_1	11	12	14	16	17
Barrel temperature (°C)	X_2	83	90	100	110	117
Screw speed (rpm)	X_3	66	100	150	200	234

2.1. Experimental design and data analysis

Response surface methodology (RSM) was adopted in the design of experimental combinations. The central composite rotatable design for three independent variables of moisture content, temperature and screw speed was selected. Each independent variable was used according to preliminary trials and literature. The outlines of experimental design are presented in Table 2. Second order polynomial model was applied for three factor design which is given as.

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i\neq j=1}^{3} \beta_{ij} X_i X_j + \in$$

where Y is the predicted response, β_0, β_i, β_{ii} and β_{ij} are the constant and coefficient for linear, quadratic and interaction terms. X_i and X_j are the coded values of the process variables and ε the residual error (Diamante, Savage, & Vanhanen, 2012). In the current study dependent variables were lateral expansion (LE), bulk density (BD), water absorption index (WAI), water solubility index (WSI) and hardness (HD) of the extruded product. The production of response surface plots and statistical analysis was carried out using statistical software Design-expert, verson-6.0.10 (Stat-Ease Inc., Minneapolis, USA).

2.2. Quality analysis of extruded product

2.2.1. Lateral expansion (LE)

Lateral expansion was determined by using vernier caliper as per methods described by Meng, Threinen, Hansen, and Driedger (2010). The basic formula used for calculation of lateral expansion is given in Eq. (1).

$$LE = \frac{(\text{diameter of extrudate} - \text{diameter of die opening})}{\text{diameter of die opening}} \times 100 \tag{1}$$

2.2.2. Bulk density (BD)

Bulk density of the expanded products was estimated as per method suggested by Alvarez-Martinez, Kondury, and Karper (1988) and calculated using the formula given in Eq. (2).

$$BD = \frac{4m}{\pi d^2 L} \tag{2}$$

m is mass (g); length L (cm); d is diameter (cm) of extruded snack product.

2.2.3. Water absorption index (WAI) and water solubility index (WSI)

The method described by Anderson (1982) was used to determine WSI and WAI. The basic formulas used for calculation of WAI and WSI are given below (Eqs. (3) and (4)).