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Twin-screw extrusion of barley–grape pomace blends: Extrudate characteristics and determination of optimum processing conditions

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ABSTRACT

The barley flour–grape pomace blends were extruded in a 30 mm APV co-rotating twin-screw extruder. Response surface methodology using a central composite design was used to evaluate the effects of independent variables, namely die temperature (140–160 °C), screw speed (150–200 rpm) and pomace level (2–10%, db) on product responses (expansion, bulk density, texture and color). Sensory analysis was carried out for selected extrudates for appearance (color, porosity), taste (bran flavor, bitterness and sweetness), off-odor, texture (hardness, crispness and brittleness) and overall acceptability. Multiple regression equations were obtained to describe the effects of each variable on product responses. The product responses were most affected by changes in temperature, pomace level and to a lesser extent by screw speed. Blends of 2% grape pomace extruded at 160 °C, 200 rpm and 10% grape pomace extruded at 160 °C, 150 rpm had higher preference levels for parameters of appearance, taste, texture and overall acceptability. However, graphical optimization studies resulted in 155–160 °C, 4.47–6.57% pomace level and 150–187 rpm screw speed as optimum variables to produce acceptable extrudates. The results suggest that grape pomace can be extruded with barley flour into an acceptable snack food.

1. Introduction

Extrusion cooking technology, high temperature-short time processing being used increasingly in the food industries for the development of new products such as cereal-based snacks including dietary fiber, baby foods, breakfast cereals and modified starch from cereals (Sebio and Chang, 2000). The thermal energy generated by viscous dissipation during extrusion with combination of shearing effect cooks quickly the raw mixture so that the properties of the materials are modified by physico-chemical changes of the biopolymers (Thymi et al., 2005).

There is a growing interest in the evaluation of the residues generated by the food industry. In particular, in the zones of grape and wine production, a great quantity of residues are generated whose storage, transformation or elimination pose problems in economic terms. For this reason, the recovery of the antioxidant compounds present in these by-products could represent an interesting advance in the maintenance of the environmental equilibrium (Alonso et al., 2002).

Grape pomace is the press residue remaining when grapes are processed for wine-making. The pomace consists of pressed skins, disrupted cells from the grape pulp, seeds and stems. Among fruits, grapes constitute one of the major sources of phenolic compounds and pomace is particularly rich in phenols (Meyer et al., 1998). Numerous studies have demonstrated the antioxidant and health promoting effects of phenolic compounds present in grapes and wine, particularly in relation to cardiovascular diseases (Scalbert et al., 2005). Grape pomace therefore represents a potentially valuable source of phenolic antioxidants that may have technological applications as functional food ingredients and possible nutritional benefits. Grape pomace is also characterized by a high content of dietary fiber and associated polyphenols (Valiente et al., 1995) and could be used as a potential ingredient for dietary fiber-rich supplements (Martín-Carrón et al., 2000).

With the growing awareness of the beneficial effects of healthy diet on the quality of life as well as on cost-effectiveness of health care, the food industry is facing the challenge of developing new products with special health enhancing characteristics. To meet this challenge, it must identify new sources of nutraceuticals and other natural and nutritional materials with the desirable functional characteristics. Although less common in food formulations than other cereals, barley has the ability to promote good consumer health through its nutritional components such as fiber (both soluble and insoluble fiber), antioxidants and B-vitamins.

Therefore, the aim of this research was to investigate possibilities of grape pomace utilization through the production of barley based snack food using extrusion process. The target was also to optimize processing conditions for production of extruded snack food from barley flour and grape pomace by RSM.

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2. Materials and methods

2.1. Materials

Barley flour used in these experiments was supplied from Bob's Red Mill Natural Foods (Milwaukie, OR, USA). The particle size distribution of the barley flour is shown in Table 1. Barley flour was stored at 4 °C until use. Thompson seedless grape pomace was provided by Department of Viticulture and Enology, UC Davis pilot plant. Grapes were conveyed into stemmer and crusher by screw conveyor. They were pressed immediately after crushing. The resulting juice was separated from pomace and processed for wine-making. Grape pomace was frozen as sheet in a blast freezer (Model FB27-5-5 ST S, Conrad, Michigan, USA) at −63.9 °C for freeze drying. The pomace was freeze-dried (Model 50-SRC-5, Virtis, Gardiner, NY, USA) at 8 Pa pressure for 72 h. The condenser temperature was approximately −40 °C. Freeze-dried grape pomace was finely ground and stored in polyethylene bags at −20 °C for further usage. The moisture content of dried grape pomace was between 3.9% and 6.3% (wb).

Analyses of proximates, dietary fiber and starch of the raw materials were performed by Silliker Inc. (Modesto, CA, USA). The moisture content, ash, protein (Kjeldahl, protein factor: 6.25), starch (Ewers starch) and total dietary fiber were performed according to approved methods described in AOAC (1995). The carbohydrate content was calculated by difference. The composition of grape pomace (on dry basis) was 4.1%, 86.6%, 2.4% and 6.9% for ash, carbohydrates, fat and protein, respectively. The starch and fiber contents (on dry basis) were 0% and 12.3%, respectively.

2.2. Feed preparation for extrusion

Grape pomace was mixed thoroughly with barley flour to the ratio of 0, 2, 6, 10 and 12.73% (w/w, db). The moisture content of the blended samples for extruder feed was adjusted to 21.66 ± 0.49% (wb) by mixing continuously at medium speed in a mixer (Mod. F-30T, Blakeslee, Chicago, IL, USA) with calculated amounts of water being sprayed onto each blend. After that, the samples were put in buckets and stored at 4 °C overnight to reach homogeneous moisture distribution. Before extrusion, the feed was allowed to come to ambient temperature (~25 °C) and mixed again after checking the moisture content. Moisture content of samples was determined by halogen moisture analyzer (Model HR83 and HR83P, Mettler-Toledo GmbH, Greifensee, Switzerland) at 105 °C.

2.3. Extrusion process

Extrusion was performed in a laboratory-scale co-rotating twin-screw extruder (MPC/V-30, APV, Staffordshire, England) of 30 mm in barrel diameter and 13:1 its length to diameter ratio (L/D) with a System9000 torque rheometer (Haake Buchler, Paramus, NJ) that provided computer control and data acquisition. The slit die (Haake Buchler, Paramus, NJ, USA) was used with dimensions of 20 mm × 1.47 mm × 150 mm. The barrel zone temperatures were kept constant at 30, 60, 100 and 130 °C throughout the experiments but die temperature varied according to the experimental design. The screws were composed of screw elements and lope-shaped paddles which could be assembled on the hexagon-shaped shafts to give different screw configurations. The extruder screw consisted of three pieces of 1.5 D twin lead feed screws, two 1 D twin lead feed screws, nine kneading paddles set at 30° feed forward, one 1 D single lead feed screw followed by nine kneading paddles set at 30° feed forward and 1 D discharge screw. Extruded products were immediately dried at 52 °C overnight in a forced-air drier (Model # R-4, Commercial Dehydrator System Inc., Eugene, OR, USA). The final dried samples contained a maximum of 5.7% (wb) moisture. Dried samples were stored in polyethylene bags at room temperature and used for further analysis. The figure of screw configuration and the details of extruder were given elsewhere (Altan et al., 2008).

Table 1
Particle size distribution of barley flour used

	Sieve size	%
Retained on	Mesh 40	12.1
	Mesh 60	42.9
	Mesh 80	38.9
	Mesh 100	5.5
	Mesh 120	0.4
Passed through	Mesh 120	0.2

2.4. Product properties

2.4.1. Expansion

The sectional expansion index (SEI) of extrudates was determined as described by Alvarez-Martinez et al. (1988). The width and thickness of 15 pieces of extrudate taken at random were measured with a digital caliper and SEI was calculated as the ratio of cross-sectional areas of the extrudate to that of the slit die and averaged.

2.4.2. Bulk density

The bulk density of the extrudates was determined by displacement method using the glass beads of 1.00–1.18 mm diameter (Hwang and Hayakawa, 1980; Sokhey et al., 1997). The values were average of four measurements.

2.4.3. Texture

The peak force as an indication of hardness was measured with a TA-XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA) using 3-point bend test with a sharp-bladed probe (55 mm wide, 40 mm high, 9 mm thick). The test speed was 2 mm/s and the distance between two supports was 22 mm. The curve was recorded and analyzed by Texture Exponent 32 software program (version 3.0). The slope (N/mm) and distance (mm) at which a product breaks were measured from force–distance curve and evaluated as crispness and brittleness, respectively (Jackson et al., 1996; Texture Technologies, a). Ten measurements were performed on each sample.

2.4.4. Color

Color is an important characteristic of extruded foods. Color changes can give information about the extent of browning reactions such as caramelization, Maillard reaction, degree of cooking and pigment degradation that take place during the extrusion process. The color of the raw materials and ground extrudates were measured in a HunterLab LabScan XE (Hunter Associates Laboratory Inc., Reston, Virginia, USA) as lightness (L), redness (a), and yellowness (b). The extrudates were ground in a laboratory grinder and passed through a 60 mesh sieve prior to color analysis. For each sample, four measurements were taken and averaged. The total color change (ΔE) was calculated as

$$\Delta E = \sqrt{(L - L_o)^2 + (b - b_o)^2 + (a - a_o)^2} \quad (1)$$

where the subscript 'o' indicates initial color values of the raw material.

2.5. Sensory analysis

A semi-trained panel of 35 students and from faculty from the Food Engineering Department at the University of Gaziantep