RESEARCH ARTICLE

Effects of Extrusion Operating Conditions and Blend Proportion on the Expansion Properties of Sorghum-Barley-Chickpea blend Extruded Products

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ABSTRACT

Extrusion cooking is a versatile and well-established food process that is used to make ready-to-eat snack foods. In this study, Response surface methodology was used to evaluate the effect of feed parameters i.e., moisture content (8-16%), blend ratio of sorghum:barley:chickpea flours (70:15:15 to 50:35:15) and machine parameters i.e., barrel temperature (120-200 oC) and screw speed (120-200 rpm) on expansion propertiesi.e., longitudinal expansion index (LEI) and volumetric expansion index (VEI) of extrudates developed by twin screw extruder. The results showed that LEI ranged from 0.64 to 1.46 mm and VEI ranged from 1.17 to 3.38 mm. The results reveals that extrudates characteristics were significantly influenced by feed moisture content and barrel temperature, with feed moisture content having the greater impact.

Keywords: *Extrusion cooking, longitudinal expansion, ready-to-eat, response surface, volumetric expansion.*

INTRODUCTION

Extrusion cooking is a versatile and well-established food process that is used to make extended snack foods, pastes, modified starches, flat breads, meat and cheese analogues, ready-to-eat cereal dishes, and porridge all over the world [16]. Extrusion's main purpose is to promote dietary variety by creating a variety of products with diverse shapes, textures, colours, and flavours from basic ingredients [4]. One way to make textured snack food is to use extrusion cooking which is high-temperature short-time (HTST) procedure. Extrusion cooking differs from other processes in that it operates at high temperatures, pressures, and shears while maintaining low-intermediate moisture content and provides ingredient modification in the feed mixture [13]. Through the utilization of temperature, moisture, shear, and mixing conditions, it is excellent for the production of fiber-rich foods [12] and [1].

After rice and wheat, sorghum (Sorghum bicolor) is India's third most major essential cereal. Sorghum's chemical constituents are similar to those of maize and wheat. It is also said to be a possible source of nutraceuticals such as cholesterol-lowering waxes and antioxidant phenolics [15]. Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides and fat [3]. Sorghums are preferred for many foods such as flat bread, thick and thin porridges, snacks and other products [14]. However, low protein content and quality limit the widespread applications of sorghum in human foods. Thus, there is a need for sorghum-based foods with higher protein content and digestibility.

Barley (Hordeum vulgare) is one of the most ancient of the cereal crops. After wheat, rice and corn, it is the world's fourth most important cereal [10] For today's consumers, barley is a new and unique flavour alternative. The ability of barley to support good consumer health through nutritional components

such as fibre (particularly *β*-glucan), antioxidants and B vitamins has piqued interest recently. *β*-glucans, which are essential contributors to dietary fibre and have significant blood cholesterol-lowering benefits, are abundant in barley. Chickpeas (*Cicer arietinum L.),* often known as garbanzo beans, are an ancient world pulse (i.e., edible seeds) in the legume family, that have long been used in a variety of culinary inventions due to its nut-like flavour and sensory versatility [2]. Chickpeas are available in two varieties: light seeded Kabuli and tiny dark Desi (8). Pulses differ from other plant foods in that they have higher protein content (17%–30% by dry weight). Chickpeas are a low-cost and significant source of protein for vegetarians and others who cannot afford animal protein [6]. Chickpea consumption helps to maintain good health by regulating fatty acid levels in humans.

MATERIALS AND METHODS

Material

The ingredients used for production of ready-to-eat extruded snacks were sorghum, barley and chickpeaand were procured from the Raichur local market, Karnataka, India.For preparing the samples,all the raw materials were grinded in a hammer mill separately, to reduce the size into fine particles.

Preparation of samples

The samples were prepared using process parameters such as five distinct sorghum, barley and chickpea blends (70:15:15, 65:20:15, 60:25:15, 55:30:15, 50:35:15) at feed moisture content (8, 10, 12, 14, 16%) and extruder operational parameters such as barrel temperature (120, 140, 160, 180 and 200 °C) and screw speed (120, 140, 160, 180 and 200 rpm). All of the flours were weighed and the moisture content was adjusted by sprinkling water into the flours and mixing them together to make a homogeneous mixture. After mixing, the samples were kept at room temperature for 12 to 24 hours in aluminium laminated polyethylene bags. The samples were sieved and placed into a feed hopper, where they were extruded with a 7 mm die diameter and collected at the die end.

Statistics design

Central composite rotatable design (CCRD) was used to analyze the influence of four independent variables i.e., Moisture Content of Feed (%), Blend Ratio (%), Barrel Temperature (°C) and Screw Speed (rpm) on expansion properties of extrudates i.e., longitudinal expansion index (LEI) and volumetric expansion index (VEI). A second order polynomial equation was used to fit the measured dependent variables (LEI, VEI) as a function of independent extrusion variables.

Expansion properties of extrudates

Longitudinal Expansion Index

The Longitudinal Expansion Index is the ratio of the exiting velocity of the extrudate after expansion to its velocity in the die orifice expressed by the following equation:

$$LEI = \left(\frac{\pi D^2}{4}\right) L_w \rho_d \, X \frac{1-M_d}{1-M_e} \qquad \text{eqn. 1}$$

Where,

D = Diameter of die
L_w = Specific length of extrudates
ρ_d = Density of dough/melt(assumed 1400 kg/m^3)
M_d = Moisture content of dough/feed (wb) in decimal
M_e = Moisture content of extrudates (wb) in decimal

Volumetric Expansion Index

The Volumetric Expansion Index is the product of SEI and LEI, and it represents the extrudate's overall expansion in both radial and longitudinal directions and it is expressed as

VEI= SEI*LEI eqn. 2

RESULTS AND DISCUSSION

Longitudinal Expansion Index

The Longitudinal Expansion Index is the ratio of the exiting velocity of the extrudate after expansion to its velocity in the die orifice. From the experiment, the longitudinal expansion index (LEI) of extrudates measured for all the samples ranged from 0.64 to 1.46 mm. The effect of extrusion parameters on longitudinal expansion index of extrudates are shown in 3-D surface plots (Fig. 1 to 3).

The coefficient of determination (R^2) of various regression models for predicting the longitudinal expansion index of extrudates was 0.95. The following second order model provides a multiple regression equation that represents the effect of processing factors on longitudinal expansion index in coded values.

Longitudinal Expansion Index = + 2.37490 – 0.14490 x MC – 0.036125 x BR + 0.00153125 x SS + 8.09896E – 003 x MC^2 eqn.3

Positive coefficients of the first order terms of BT, SS, interaction terms and quadratic terms in equation 3 indicate an increase in longitudinal expansion index (LEI) as these variables are increased, whereas negative coefficients of the first order terms of MC,

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BR, quadratic terms and interaction terms indicate a decrease in longitudinal expansion index of extrudates as these variable is increased.

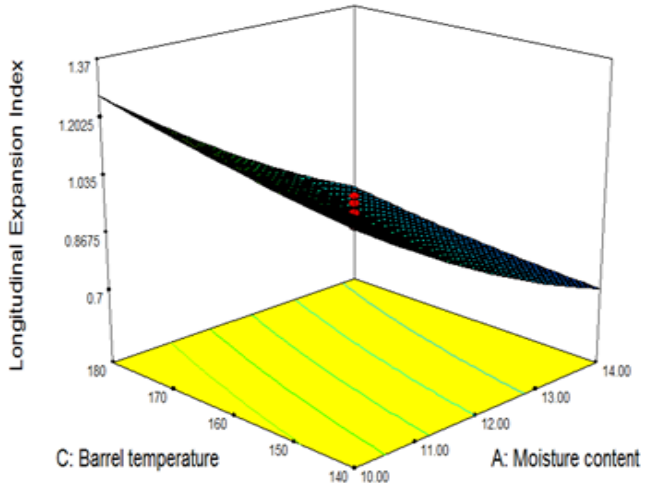

Fig. 1: Effect of moisture content and barrel temperature on longitudinal expansion index of extrudates

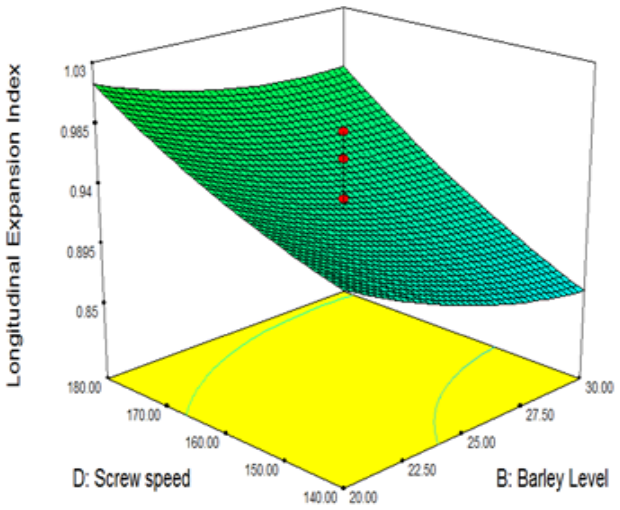

Fig. 2: Effect of barley level and screw speed on longitudinal expansion index of extrudates

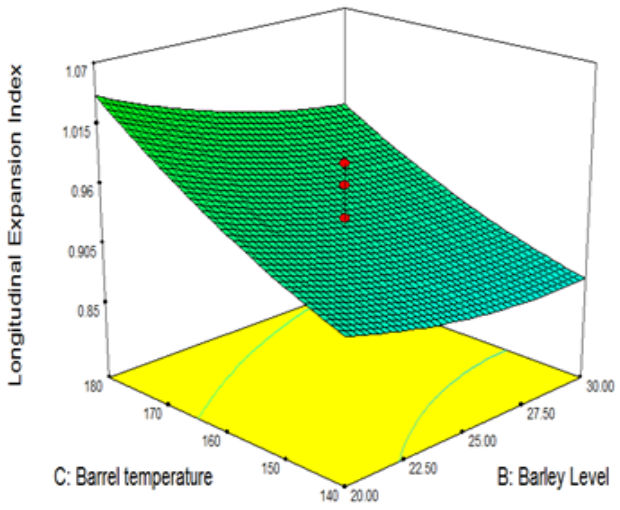

Fig. 3: Effect of barley level and barrel temperature on longitudinal expansion index of extrudates

As shown in fig. 1 higher moisture content of feed led to a significant reduction in the longitudinal expansion index. Fig. 2 and 3 shows that higher percentage of barley flour in blend ratio decreased the longitudinal expansion index (LEI) of extrudates. Fig. 1 and 3 shows that longitudinal expansion index increased with increase in barrel temperature. [5] also reported that with an increase in barrel temperature, the value of expansion also increases, because of the stretching of the molecules at higher temperature, thereby enhancing the degree of gelatinization. From fig. 2 it can be depicted that longitudinal expansion index of extrudates increased with an increase in screw speed. [7] also mentioned that increasing the screw speed can increase the longitudinal expansion of extrudates.

Volumetric Expansion Index

Volumetric expansion index (VEI) is the product of sectional expansion index and longitudinal expansion index. So, it indicates the extrudate's overall expansion in both radial and volumetric directions. From the experiment, volumetric expansion index (VEI) of extrudates measured for all the samples ranged from 1.17 to 3.38 mm. The effect of extrusion parameters on volumetric expansion index of extrudates are shown in 3-D surface plots (Fig. 4 to 6).

The coefficient of determination (R^2) of the various regression models for predicting the volumetric expansion index of extrudates was 0.90. The following second order model provides a multiple regression equation that represents the effect of processing factors on volumetric expansion index of extrudates in coded values.

Volumetric Expansion Index = -1.23271 + 0.50646 x MC - 0.37675 x BR - 0.036542 x BT + 0.074042 x SS + 0.002875 x MC x BR – 0.00121875 x MC x BT – 0.00296875 x MC^2 + 0.00362500 x BR^2 eqn.4

Positive coefficients of the first order terms of MC, BT, SS, interaction terms and quadratic terms in equation 4 indicate an increase in volumetric expansion index (VEI) as these variables are increased, whereas negative coefficients of the first order terms of BR, quadratic terms and interaction terms indicate a decrease in volumetric expansion index of extrudates as these variable is increased.

As shown in fig. 4 the volumetric expansion index (VEI) was increased up to 14%, above this temperature VEI was decreased significantly. Figures 8 and 9 shows that higher percentage of barley flour in blend ratio decreased the volumetric expansion index of extrudates. Due to the high dietary fiber content, barley flour has been observed to create low expansion [11]. From fig. 4 and 5 it can be observed that volumetric

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expansion index was increased with the increase in barrel temperature. In the extruder, the viscosity of melt and degree of superheating of water could have been reduced by the high barrel temperature, resulting in greater expansion [9]. It can be noted from the fig. 6 that with an increase in screw speed, there was an increase in volumetric expansion index of extrudates.

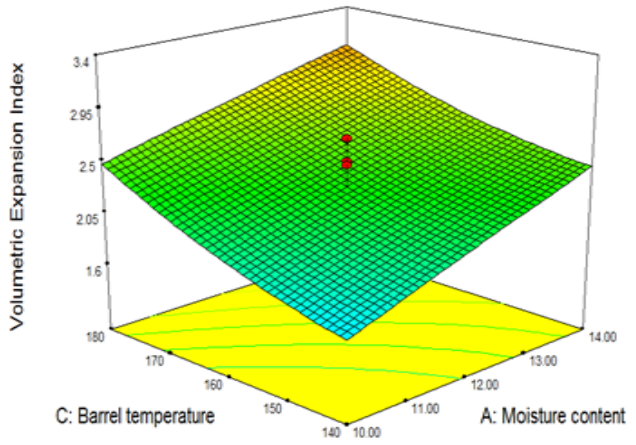

Fig 4: Effect of moisture content and barrel temperature on volumetric expansion index of extrudates

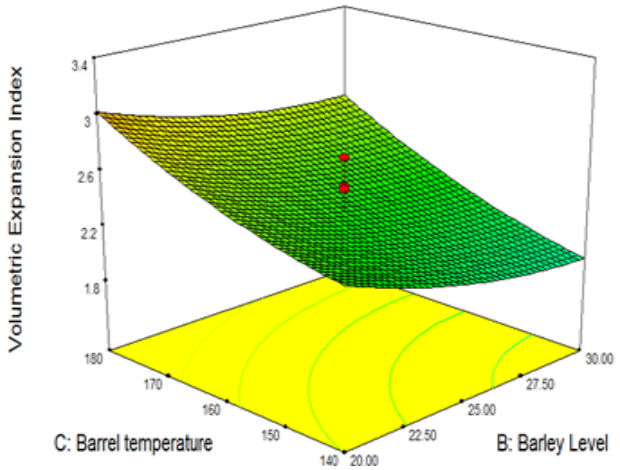

Fig. 5: Effect of barley level and barrel temperature on volumetric expansion index of extrudates

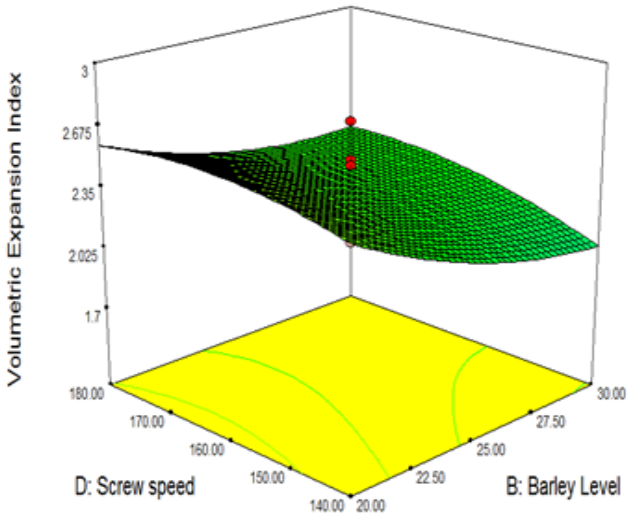

Fig. 6: Effect of barley level and screw speed on volumetric expansion index of extrudates

CONCLUSION

The study revealed that expansion properties of sorghum-barley-chickpea extrudates on twin screw extrusion process were dependent on the process parameters. The results showed that maximum LEI (1.46 mm) was observed with the blend ratio 65:20:15, having 10% moisture content (w.b) extruded at 180 °C barrel temperature and a screw speed of 180 rpmand the VEI of extrudates was found maximum (3.38 mm) at 12% moisture content, 60:25:15 blend ratio, 200 °C barrel temperature and 160 rpm screw speed. The results acquired in this investigation revealed that there was a positive correlation of expansion properties with barrel temperature and screw speed, and a negative correlation with moisture content and barley level.

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