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Research Article

PRODUCTION OF VALUE ADDED SNACKS FROM RICE BROKEN AND OKARA BY EXTRUSION COOKING TECHNOLOGY

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Abstract- Extrusion Cooking Technology is used to produce snacks from various raw materials, including by-products. In this study extruded snacks were prepared through Okara, a by-product of soya milk, blending with broken rice, a by-product of rice milling industry, using a single-screw extruder to assess their suitability as snack food. Response surfaces generated by CCRD were used to evaluate the significance and effects of extrusion process variables on various physical properties of extruded product. The combined effect of moisture content (14-22%), feed blend ratio of broken rice: okara (70:30-90:10), barrel temperature (120-160^{0}C), and screw speed (50-90 rpm) of extruder on physical parameters of extrudate (bulk density, specific length and sectional expansion index) were studied. The product properties were found to be dependent on feed moisture, blend ratio and barrel temperature. The presence of okara content in blend ratio contributed to decrease the sectional expansion index, specific length and to increase in bulk density.

Keywords- Broken rice, Okara, Extrusion Cooking, Physical properties, Response surface methodology.

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Introduction

One viable method for the utilization of by-products of food industry into useful products is extrusion processing due to its versatility, high productivity, relative low cost, energy efficiency, and lack of effluents [1]. At present, technological advances in processing techniques and diversity in the marketplace and consumer culture have increased over time, and this has brought increasing demand for their conversion into useful products for preventing pollution of the environment as well as for economic motives and the utilization of valuable constituents from food processing waste. Besides a major disposal problem for the industry concerned, food processing waste has the potential to be converted into useful products.

In this study Okara (soy pulp) and rice broken was used for manufacturing of extruded snacks. Okara is a by-product obtained from soymilk production. Okara is low in fat, high in fiber. Okara contains high moisture about 75-80% (wb) and on a dry weight basis 24% protein, 8 to 15% fats, 12 to 14.5% crude fiber. It contains 17% of the protein from the original soybeans [2]. Okara fiber usually imparts a gritty texture in products, which may be one of the reasons limiting its scope of application. Okara is rich in nutrients content but majority of it is still being discarded, causing environmental problems [2]. Hence, okara has potential to develop a nutritious product that will be beneficial for human health.

Among all kind of raw material, cereal starches play a key role during extrusion cooking. Starch undergoes several significant structural changes such as starch gelatinization, melting, and fragmentation [3]. Rice contains high starch percentage, which is above 80% depending on rice cultivars [4]. Rice is the second largest produced worldwide next to wheat only [5]. In modern rice, milling industry 3.50% rice broken is found as by product [6], which is sold in cheaper price in market. Rice broken contains approx 5-6% protein, 0.09% fat, 0.07% ash contain, 22-23% amylose content and pH 4-5 [7].

The extent of molecular destruction of starch mainly depends on extrusion parameters like temperature, feed moisture, feed rate, screw speed [8] and feed composition [9]. According to [10] the role of shear, temperature, moisture and feed composition are significant in the transformation of starch by extrusion. Effects of extrusion parameters on physical properties of extrudate were analyzed using central composite ratable design with response surface methodology. RSM is a rapid procedure with less number of experiments and efficiency to the general vicinity of the optimum. This method of optimization i.e., RSM is preferred because it can simultaneously consider several factors at many different levels and corresponding interactions among these factors using a small number of observations [11]. The analysis of response surfaces is generally carried out graphically by drawing contour plots in a plane or computing surfaces in three-dimensional space. Based on above facts, in this investigation, the effect of operational parameters i.e. moisture content of feed, blend ratio of broken rice and okara, screw speed, barrel temperature and die head temperature on the physical properties of extrudate were studied using response surface methodology.

Materials and Methods

Materials

Rice broken was procured by the local market and Okara was supplied by Mahalaxmi Associates (a soya paneer manufacturing company) Suhagi, Jabalpur. The broken rice was ground into flour by a hammer mill. The ground flour was then passed through 100 mesh I.S. sieve. The flour collected in the pan was used for further research work.

Methodology

Moisture determination of the raw materials

Moisture content of raw materials was determined using the standard air oven.

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method according to AOAC, 2002

Moisture Management of Blends

Moisture content of blends is an important parameter, and it was managed separately of each 32 blends of samples, obtained from Central composite rotatable design using 5×5 matrix. To achieve the desire level (14, 16, 18, 20 & 22 % wb) of moisture content in different blend ratio the moisture was added or removed by drying. The mixture was left for tempering to equilibrate the moisture [12].

Extrusion cooking

The Brabender single screw laboratory model extruder (model Brabender D47055 DUISBURG) was used for preparation of extrudate snacks of broken rice and okara. Extruder was operated at some constant parameters such as feed screw speed of 20 rpm, length-to-diameter ratio of 20:1, compression ratio of 2:1, diameter of die of 5 mm.

During extrusion, the barrel temperature, die head temperature and screw speed were the variable machine parameters [Table-1]. Extrudates were cooled to room temperature and sealed in polyethylene bags until observations were taken.

Statistical design

A central composite rotatable design was used to show the effects of interactions of moisture content (MC), blend ratio (BR), barrel temperature (BT), Die Head Temperature (DHT) and screw speed (SS) on extrudates. Each parameter was taken in five levels as shown in [Table-1].

The results were analyzed using 45 days trial pack of software *Design expert @ 9.0.3.* The Response surface methodology (RSM) in Central Composite Rotatable Design (CCRD) was used. The observed data were analyzed and response surfaces were generated for bulk density, sectional expansion index and specific length of extrudates.

Product quality analysis

Sectional expansion index is a measure of degree of puffing, an important property from the quality point of view of extrudate to yield a soft, porous and crispy extrudate. Expansion was determined using the method of [13]. The ratio of diameter of extrudate to the diameter of die was used to express the sectional expansion of extrudate.

The bulk density of the dried extrudates was calculated by determining the volume of the extrudates by filling a container of known volume, and the sample weight [14]. The reported values are the mean of three replicates.

Specific length was measured as the method described by [15]. It is the ratio of length of specimen to the mass of specimen.

Results and Discussion

Bulk Density (BD) of extrudates

Bulk density is the mass per unit bulk volume is calculated including the volume of void spaces. Bulk density was varied from 0.08 to 0.45 g/cm^3. Minimum bulk density (0.08 g/cm^3) was found at moisture content 20%, blend ratio 85:15 (rice broken: Okara), barrel temperature 130^{0}C, die head temperature 170^{0}C and screw speed at 80 rpm. Multiple-regression analysis of the bulk density (BD) versus feed moisture content (MC), blend ratio (BR), barrel temperature (BT), die head temperature (DHT) and screw speed (SS) yielded following polynomial model [Eq-1]:

$$\mathbf{BD} = 12.58 - 0.70 \times MC + 0.02 \times BR - 4.6E-003BT - 0.07 \times DT + 0.03 \times SS + 2.16E-003 \times MC \times BR + 1.7E-003 \times MC \times BT + 1.9E-003 \times MC \times DT + 3.8-004 \times MC \times SS - 3.25E-004 \times BR \times BT + 5.5E-004 \times BR \times DT + 5E-005 \times BR \times SS + 2.25E-004 \times BT \times DT - 7.5E-005 \times BT \times SS + 1.25E-005 \times DT \times SS - 2.84E-003 \times MC^2 + 4.5E-004 \times BR^2 - 1.3E-004 \times BT^2 + 1.5E-004 \times DT^2 - 2.4E-004 \times SS^2 \quad \text{[Eq-1]}$$

Value of R^2 was 72.74%, which shows that model was adequate in describing the bulk density of extrudates. [Fig-1, 2, 3 and 4] show the interactive response of pair of two different independent variables taken together on bulk density of extrudates. Response surface plot for bulk density, as a function of blend ratio (Rice: okara) and moisture content of feed is given by [Fig-1]. It shows that on increasing the rice broken percentage in blend, the bulk density decreases. In other words, increment in Okara content in blend, results higher bulk density of extrudate because okara contains high protein and high fiber. This was also observed by [16]. Effect of moisture content was observed positive i.e. on increasing the moisture content; the bulk density was also increased. This may be due to the reason that increased feed moisture content during extrusion would change the amylopectin molecular structure of the material reducing the melt elasticity thus decreasing the expansion but increasing the density of extrudate [17]. [Fig-2] and [Fig-3] show the effect of temperature (barrel temperature and die head temperature) on bulk density of extrudate. On increasing the die head temperature and barrel temperature, the bulk density was decreased. The reduction of rice okara extrudate density caused by increased barrel temperature and die head temperature was also found by [18, 19]. The variation in bulk density with respect to screw speed was almost linear as shown in [Fig-4]. It was also reported that screw speed had no significant effect on the bulk density of rice extrudates including rice bran, rice flour, amaranth extrudate, and oat-corn puff [14, 18, and 20].

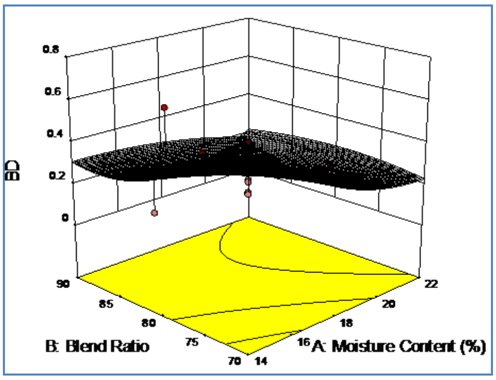

Fig-1 Effect of blend ratio and moisture content on BD of extrudate

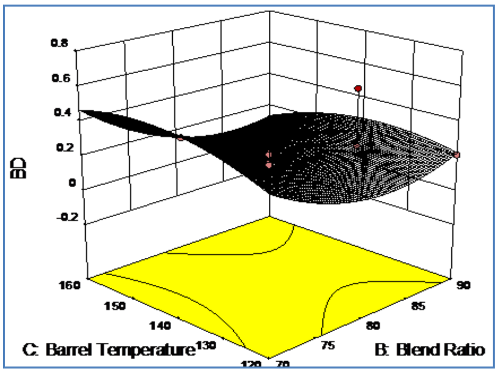

Fig-2 Effect of barrel temperature and blend ratio on BD of extrudate

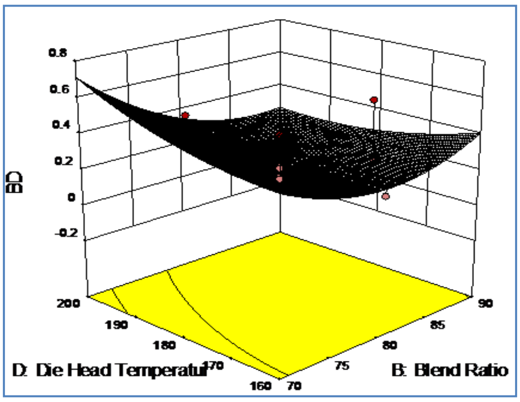

Fig-3 Effect of die head temperature and blend ratio on BD of extrudate

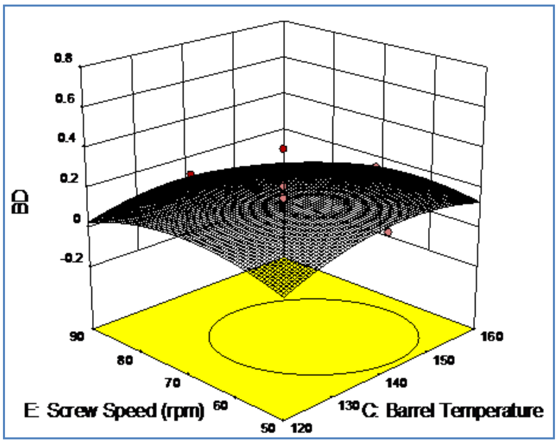

Fig-4 Effect of screw speed and barrel temperature on BD of extrudate

Sectional Expansion Index (SEI).

It is a measure of degree of puffing of extrudate; an important property from the quality point of view of extrudate to yield a soft, porous and crispy extrudate. The maximum sectional expansion index (4.95) was found at blend ratio of 85:15 (rice broken:okara), 16% moisture content, barrel temperature 150 ^{0}C, die head temperature 170^{0}C, screw speed 60 rpm and minimum value (1.04) of sectional expansion index was observed at blend ratio of 75:25 (rice broken:okara), 20% moisture content, barrel temperature 130 ^{0}C, die head temperature 190^{0}C, screw speed 60 rpm. The data obtained from the experiments was analyzed by using multiple regressions and second order polynomial model was fitted to the experimental data of independent variables. The relationship of sectional expansion index developed with the independent variables i.e. moisture content (MC) and blend ratio (BR) of feed, screw speed (SS), barrel temperature (BT) and die head temperature (DHT) is given in [Eq-2].

$$\mathbf{SEI} = 35.29 + 2.6 \times MC - 0.048 \times BR - 0.65 \times BT - 0.14 \times DT - 0.08 \times SS + 0.024 \times MC \times BR - 3.19E - 0.003 \times MC \times BT - 9.19E - 0.003 \times MC \times DT - 0.024 \times MC \times SS + 1.18E - 0.003 \times BR \times BT - 6.25E - 0.004 \times BR \times DT - 1.58E - 0.003 \times BR \times SS + 1.21E - 0.003 \times BT \times DT + 3.13E - 0.004 \times BT \times SS + 1.19E - 0.003 \times DT \times SS - 0.01 \times MC^2 - 1.32E - 003 \times BR^2 + 1.29E - 003BT^2 + 1.57E - 004 \times DT^2 + 1.97E - 003 \times SS^2 \quad \ldots\ldots \text{[Eq-2]}$$

A strong association between the different variables under study was endorsed by good value of R^2 i.e. 81.53%. The second order model was adequate in describing the sectional expansion index of extrudates. The response surface graphs for the Sectional Expansion Index as a dependent variable against combinations in pair of two different independent variables of the model [Eq-2] are represented in [Fig-5, 6], and [Fig-7]. For a better product quality, Sectional Expansion Index should be higher. [Fig-5] shows the effect of moisture content and blend ratio on SEI. It shows that on increasing the broken rice content from 70% to 90% in blend, there was a sharp increase in SEI. In other manner, the incorporation of okara in blend ranges from 10% to 30% contributes to decrease in SEI. [21] studied extrusion of rice flour with 10, 15, and 20% of soybean peels (crude fiber ranging from 14.54 to 20.1) and obtained expansion index values between 4.37 and 4.90. The presence of fiber can break the walls of the bubbles in the product preventing its maximum expansion [22]. Effect of moisture content on SEI was negative i.e. on increasing the moisture content of feed, there was a sharp decrease in SEI. This was also observed by [17]. [Fig-7] shows the effect of barrel temperature and die head temperature on sectional expansion index of extrudate. It was observed that on increasing the both barrel temperature and die head temperature, the SEI increased. An increase in the barrel temperature will decrease the melt viscosity, which was confirmed by the report of [23] that extrudate viscosity decreased with increased temperature. The reduced viscosity effect would favour the bubble growth during extrusion. Moreover, the degree of superheating of water in the extruder would increase at higher temperatures, also leading to greater expansion.

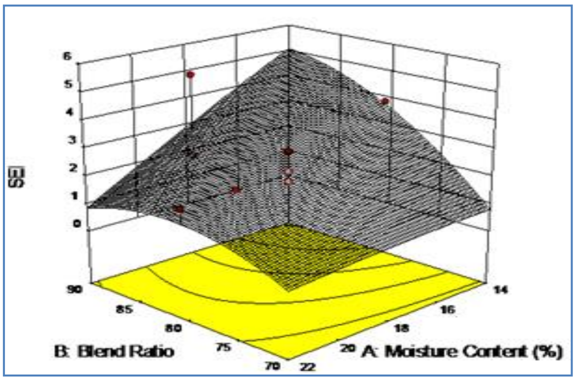

Fig-5 Effect of blend ratio and moisture content of feed on SEI of extrudate

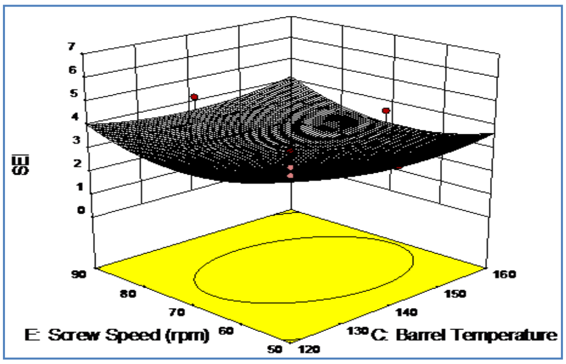

Fig-6 Effect of barrel temperature and screw speed on SEI of extrudate

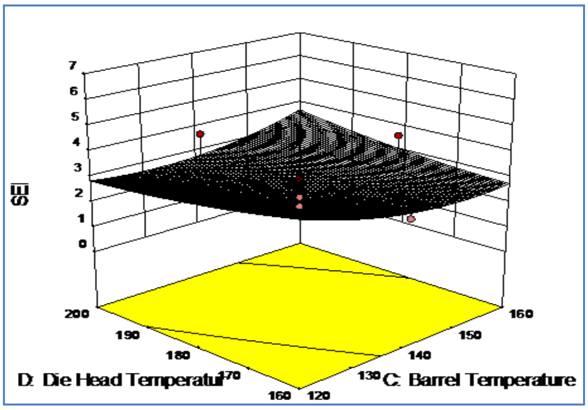

Fig-7 Effect of barrel temperature and die head temperature on SEI of extrudate

Specific Length (SL) of Extrudate

Specific length of broken rice and okara based extruded snacks varied from 3.37 to 9.95 mm/g. The maximum specific length (9.95) was found at blend ratio of 80:20 (rice broken:okara), 18% moisture content, barrel temperature 160 ^{0}C, die head temperature 180^{0}C, screw speed 70 rpm and minimum value (3.37) of specific length was observed at blend ratio of 85:15 (rice broken:okara), 16% moisture content, barrel temperature 130 ^{0}C, die head temperature 170^{0}C, screw speed 60 rpm. The data obtained from the experiments was analyzed by using multiple regressions and second order polynomial model was fitted to the experimental data with coded value of independent variables. The relationship developed with the coded values of independent variables is given in [Eq-3].

$$\mathbf{SL} = 156.1 + 5.26 \times MC - 1.27 \times BR - 2.05 \times BT + 0.53 \times DT - 1.64 \times SS - 4.38E - 004 \times MC \times BR - 1.72E - 003 \times MC \times BT - 0.02 \times MC \times DT - 2.19E - 004 \times MC \times SS + 8.99E - 003 \times BR \times BT + 9.38E - 003 \times BR \times DT + 0.02 \times BR \times SS + 2.99E - 003 \times BT \times DT + 2.64E - 003 \times BT \times SS - 3.13E - 005 \times DT \times SS - 7.21E - 003 \times MC^2 - 8.50E - 003 \times BR^2 + 2.46E - 003 \times BT^2 - 1.59E - 003 \times DT^2 - 7.65E - 004 \times SS^2 \quad \ldots\ldots \text{[Eq-3]}$$

A strong association between the different variables under study was endorsed by good value of R^2 i.e. 63.96%. The second order model was adequate in describing the specific length of extrudates. The response surface graphs for the specific length as a dependent variable against combinations in pair of two different independent variables of the model 3 are represented in [Fig-8, 9] and [Fig-10]. [Fig-8] shows the effect of moisture content and blend ratio on specific length of extrudate. It was observed that on increasing the moisture content, the SL also increases. This was also observed by [24]. Effect of blend ratio on SL of extrudate was that on increasing the rice broken content in blend, the SL increased. On the other hands, on increasing the Okara content in blend, SL decreased. It may be because of the material become hard due to high protein denaturation and poor gelatinization of starch [25]. [Fig-9] represents the effect of die head temperature and barrel temperature on SL of extrudate. Effect of temperature on SL was positive i.e. on increasing the temperature, the SL also increased. This was also observed by [26] that at high temperatures, the pressure of saturated vapor was higher than that of melt towards the die exit, and this would favor the start of bubble growth inside the die in the direction of flow and thus higher Specific length. Effect of screw speed on SL was also positive as shown in [Fig-10].

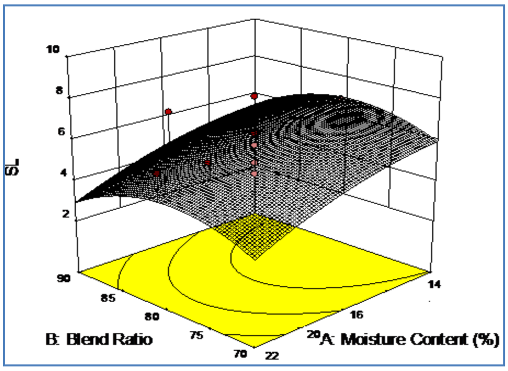

Fig-8 Effect of blend ratio and moisture content on SL of extrudate

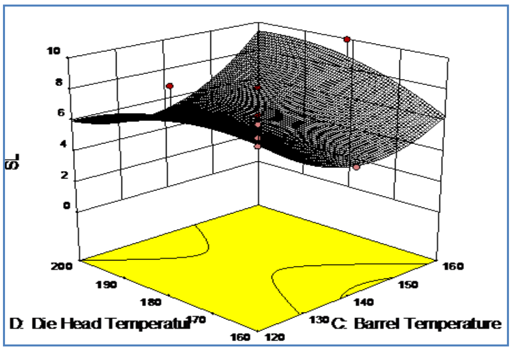

Fig-9 Effect of Die head temperature and barrel temperature on SL of extrudate

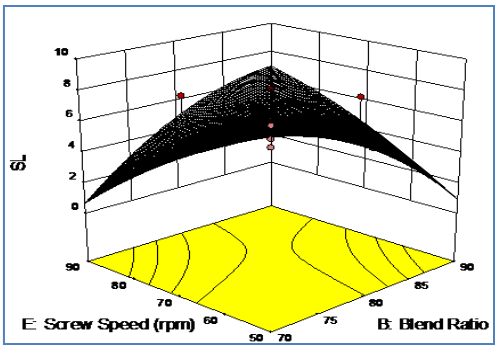

Fig-10 Effect of screw speed and blend ratio on SL of extrudate

Conclusions

The physical properties (bulk density, sectional expansion index and specific length) of broken rice and okara based extrudates produced on a single-screw extruder were dependent on several process variables. Feed moisture content, screw speed and barrel temperature all had some significant effect on various extrudate properties. The product properties were found to be most dependent on feed moisture, blend ratio and barrel temperature. During the extrusion process, the dough viscosity, elastic swell effect and bubble growth effect contribute to the structure change of the extrusion mix. The degree of starch gelatinization and extrudate expansion was found to be reduced as the feed moisture increased. The water acts as a plasticizer to the starch-based material reducing its viscosity and the mechanical energy dissipation in the extruder thus the product becomes dense and bubble growth is compressed. The reduced starch gelatinization and limited bubble growth would result in a dense and therefore harder product, as we observed in this work. It is expected that increasing temperature would decrease melt viscosity, which favours bubble growth and produce low density less firm products. The presence of okara content in blend ratio contributed to decrease the sectional expansion index, specific length and to increase in bulk density. The optimum operating parameters for the production of extrudate was found at 90% broken rice, 10% okara content contain, screw speed 76 rpm, barrel temperature 159⁰C, Die head temperature 160⁰C and 18% moisture content.

Conflict of Interest: None declared

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