ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(22), 10.17485/ijst/2016/v9i22/88437, June 2016*

Effect of Single Screw Extrusion Parameters on Textural Properties of Rice based Expanded Snacks Enriched with Okara

Varsha Kanojia*, Mohan Singh, B. M. Khandelwal and Mohammad Azam

Post Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur - 482004, Madhya Pradesh, India; varsha.cae023@gmail.com, mohansingh65@redifmail.com, bmk3@redifmail.com, mazam226@gmail.com

Abstract

Objective: The objective of present research work is to investigate the effect of single screw extrusion parameters on textural properties of rice based expanded snacks enriched with okara. **Method/Analysis**: The expanded snacks were prepared through extrusion cooking of broken rice (*Oriza Sataiva L*) with Okara (a by-product of soy milk)by using a Brabender single-screw extruder. The effects of machine parameters (i.e. barrel temperature (120-160°C), die head temperature (160-200°C), screw speed (50-90 rpm)) and feed parameters (i.e. blend ratio of broken rice and okara (70:30-90:10) and moisture content of feed (14-22 percent w.b.) were analyzed using Response Surface Methodology (RSM) with central composite rotatable design. Multiple regression equations and various response surface plots were generated to show the impact of each independent parameter on the quality of extruded snacks. **Findings**: The extruded snacks textural characteristics (hardness and crispness) were determined by texture analyser. The product textural characteristics were found to be most dependent on feed moisture content, blend ratio, barrel temperature and die head temperature. The presence of okara in blend ratio contributed to decrease the crispness and to increase in hardness of extrudate. **Applications**: This research effort to encourage the utilization of by-products of rice mill and soy milk units for the production of new value added expanded snacks. Textural properties (Hardness, Crispness etc.) of expanded snacks have prime importance in the acceptability of extruded product among the consumers.

Keywords: Broken Rice, Extrusion Cooking, Okara, Response Surface Methodology, Textural Properties

1. Introduction

Extrusion cooking is a flexible, inexpensive and very efficient technique in field of food processing. Extruders are used for the formation of simple to more complex extruded snacks involving significant changes in extruded feed material, ultimately they reduce the operational costs and make the extrusion process more versatile and energy efficient[1]. During extrusion process, the feed ingredients are subjected to several chemical and physical changes i.e. gelatinization of starch, denaturation of protein, and degradation of vitaminsetc[2]. The quality of final extruded product is greatly affected by a small change in feed parameters and machine parameters[3]. The type of extruder, screw configuration, moisture content of feed, temperature in different barrel sections and die head section, screw speed of extruder and feed rate are some important variables which considerably contribute to alter the quality of extruded product. Extrusion is a promising process that allows the utilization and co-processing of various food by-products. The addition of food processing by-products in feed material during extrusion cooking is a

**Author for correspondence*

good manner to enrich the extruded snacks with several nutrients and has potential to utilize the by-products for the production of a new commercial extruded product. This research efforts and optimizes the extrusion process which will bring progress in by product utilization for development of a new value added extruded product. In this context research study was undertaken for developing economical and proteinous new extruded food product using blended flour of broken rice (a by-product of rice milling) as base material and okara (a by-product of soya milk industry) as fortifying material for enrichment of protein in the product. Rice broken (*Oryza Sativa L.*), the by-product of rice milling industry has lower market price. Rice flour prepared out of rice broken can be used as an important ingredient for many ready to eat breakfast cereals and snacks. Consequently, rice based expanded snacks production enhances the price of broken rice and prepares a value added product for the market. Rice flour has high puffing quality, low cost, attractive white colour, hypoallergenicity and ease of digestion[4]. Hence it is a better adopted ingredient in the extrusion industry. Okara is the by-product of Soymilk and tofu manufacturing industry and its utilization due to high water content posses a severe problem. Soybean grain contains 9.28% moisture, 42.72% protein, 18.80% fat, 4.90% crude fiber, 16.27% starch, 4.8% ash and rest are the other elements[5]. In soymilk production, 1 Kg soybean (moisture content 8-12% wb)is added into 10 Kg of water and about 1 Kg to 1.1 Kg of fresh solid residue i.e. Okara (moisture content 75-80% wb) is produced. During this process 70% of bean solids and 80% of soy proteins (i.e. about 27% on dry basis) are extracted in form of Okara. Okara has potential to be a low cost protein source for human nutrition[6]. In present study, extrusion technology was applied to develop a soya based expanded snacks that could utilize and maximize the health benefits of okara for consumers. Based on these facts, in this experiment, the effects of operational parameters on the textural properties (i.e. hardness and crispness) of expanded snacks were studied.

2. Material and Method

2.1 Material

Rice broken was procured from local market and Okara was supplied by Mahalaxmi Associates (a soya paneer manufacturing company) Suhagi, Jabalpur. A hammer mill was used to grind the rice broken into flour. The flour was allowed to pass through 100 mesh IS sieve. The underflow flour, collected in pan was used for production of extrudate product.

2.2 Methodology

2.2.1 Determination of Moisture Content Feed Flour

Moisture content of feedflour was determined using the standard AOAC method, 2002.

2.2.2 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 10% extra moisture in the blend was kept to compensate the moisture loss due to evaporation and other losses. The mixture of rice flour and dried okara having different level of moisture content was stored in laminated plastic bags for 24 h in order to equilibrate (tempering of the samples) the moisture.

2.2.3 Extrusion Cooking

In present study, the Brabender single screw extruder (laboratory model Brabender D47055 DUISBURG) was used for extrusion cooking of broken Rice and Okara blends with 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 production of expanded snacks, the extruder was operated at different level of barrel temperature, die head temperature and screw speed with different combinations of moisture content and blend ratio of feed. Extrudates were allowed to cool down at room temperature and collected in aluminum laminated bags. These bags are sealed until the observation of hardness and crispness.

2.2.4 Experimental Design

A central composite rotatable design was used to observe the impact of Moisture Content of feed (MC), Blend Ratio

Table 1. Levels of feed parameters and machine parameters

Independent variables	Levels				
	-2	-1	0	+1	+2
Moisture content of feed,(%wb)	14	16	18	20	22
Blend ratio (Rice: Okara)	70:30	75:25	80:20	85:15	90:10
Barrel temperature zone-III (oC)	120	130	140	150	160
Die Head Temperature (oC)	160	170	180	190	200
Screw speed (rpm)	50	60	70	80	90

(BR), Barrel Temperature (BT), Die Head Temperature (DHT) and Screw Speed (SS) on hardness and crispness of extrudate. Five level of each parameter were taken 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) was used to generate the 3-D plots for hardness and crispness of extrudates.

2.2.5 Product Characteristics

Two textural parameters i.e. Hardness and Crispness were determined using Texture Analyzer (Model; TAXT2i). In order to test the hardness and crispness of expanded snacks, a piece of extrudate was placed on the test platform. After setting the Texture Analyzer, the test was started. The probes used were 3 mm cylindrical probe for hardness test, test and needle probe for crispness test.

3. Results and Discussion

3.1 Hardness of Expanded Snacks

Hardness of the extrudates is the peak corresponding to first major rupture in the TPA curve when the extrudate breaks (peak breaking force or collapse). It was seen that hardness of extrudates varied from 1032.6 g to 20695 g. The data obtained from the experiments was analyzed using CCRD and mathematical model was generated with independent variables. The relationship developed by independent variables is given in equation (1).

Hardness=*3.30752E+005-19717.51452×MC+6919.93162×BR 5287.15549×BT-1982.19506×DT+4296.47696×SS+ 87.96481×MC×BR+61.81884×MC×BT+41.4375*

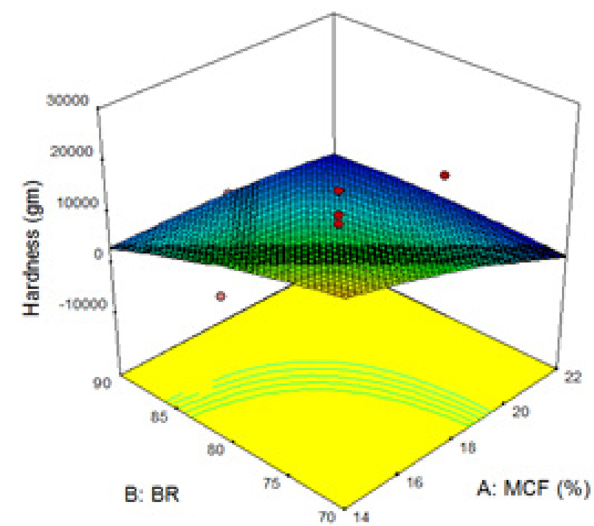

Figure 1. Impact ofBR and MC on hardness of extrudate.

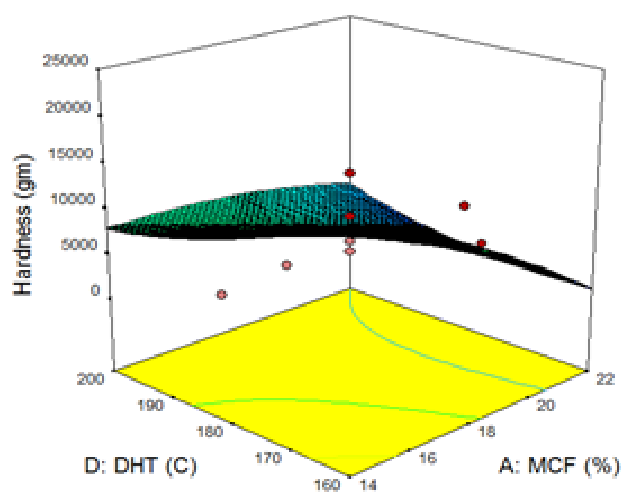

Figure 2. Impact of DHT and MC on hardness of extrudate.

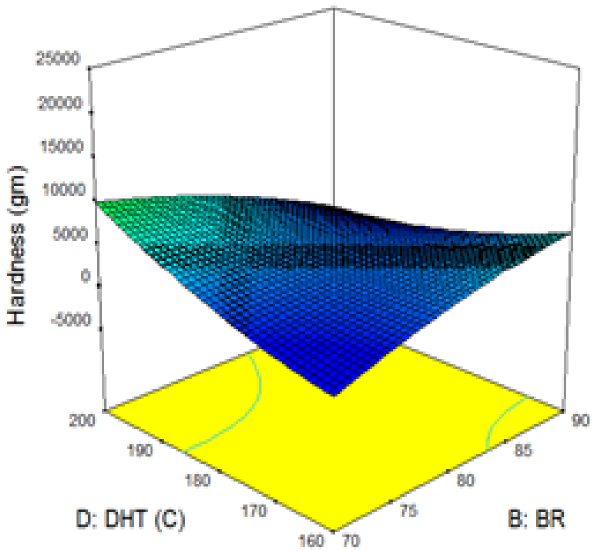

Figure 3. Impact of DHT and BR on hardness of extrudate.

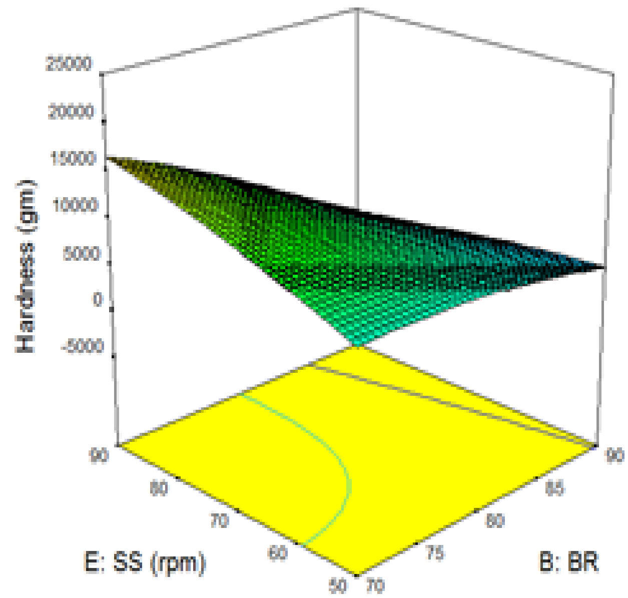

Figure 5. Impact of SS and BR on hardness of extrudate.

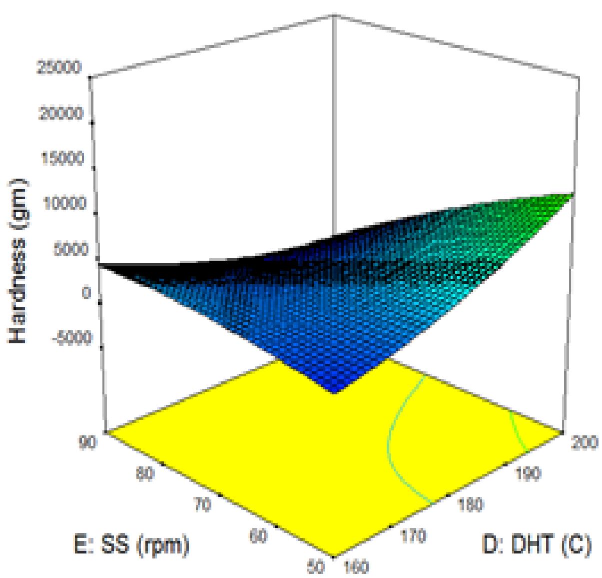

Figure 4. Impact of SS and DHT on hardness of extrudate.

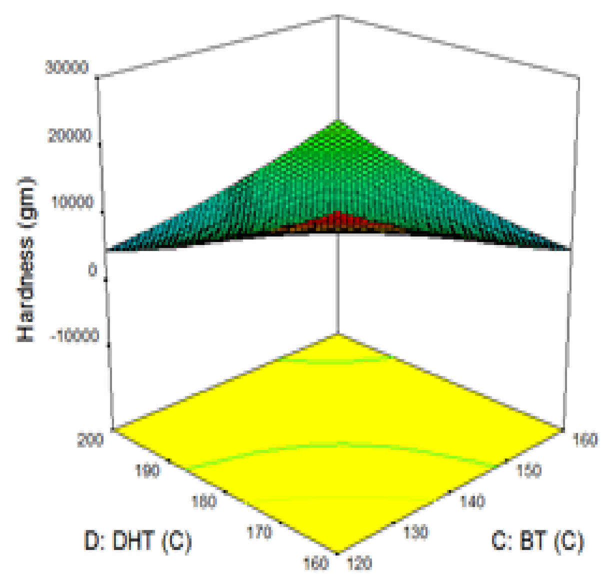

Figure 6. Impact of DHT and BT on hardness of extrudate.

$$9\times MC\times DT-48.16009\times MC\times SS+4.57546\times BR\times BT-21.03554\times BR\times DT16.10696\times BR\times SS+16.64927\times BT\times DT+0.19698\times BT\times SS-10.83577\times DT\times SS-36.48349\times MC^2-27.09136\times BR^2+2.73316\times BT^2+3.55478\times DT^2-1.65876\times SS^2 \quad (1)$$

A positive association between the different variables under study was endorsed by good value of $\mathbf{R^2}$ i.e. **0.6167**. The second order model was adequate in describing the hardness of extrudates. Figures 1 to 6 show the interactive response of pair of two different independent variables taken together on hardness of extrudates. It is seen by figure 1 that increment in moisture content, decreased the hardness of extrudates. This is because when the moisture content of mixture blends is high enough, it enhances rapid gelatinization of the extrudates. Better puffing and lower hardness was observed at high moisture content. It was also observed by Shi C[7]. The effect of blend ratio on hardness of extrudates was noted that on increasing the broken rice percent in blend ratio, the hardness of expanded snacks decreased shown in Figure 1, 3 & 5. On the other hands, increment in Okara content increased the hardness of extrudates. When excess amount of protein is added to a cereal starch, it may alter the nature of protein transformation, resulting less expansion and the product becomes harder. Only gelatinized starch granules can participate in the formation of a thin cellular structure[8]. According to Figure 4 & 5, effect of screw speed on hardness of extrudate was not significant. This was also confirmed byDing[9]. Figure 2, 3 and 6 show the negative effect of temperature on the hardness of extrudate snacks. On increasing the temperature, the hardness decreased because the increment in temperature p enhances the bubble formation and reduces in melt viscosity[10]. Minimum hardness is desirable for the extrudate-product and hardness of extrudate was minimum (1032.6 g) at 18% moisture content of feed, blend ratio 90:10, barrel temperature 140^{0}C, die head temperature180^{0}C, screw speed 70 rpm.

3.2 Crispness of Expanded Snacks

Crispness is the quality of snacks which is related to the low density cellular structure i.e. brittleness and creates a high-pitched noise when fractured[11]. Crispness was varied from 2 to 7 and higher crispness is desirable. CCRD was used for the analysis of experimental data with Second order polynomial model. The relationship developed with the independent variables is given in equation (2).

$$\textbf{Crispness}=150.55578+6.2650\times MC-3.64280\times BR-0.21561\times BT-0.30393\times DT-0.74120\times SS-0.025187\times MC\times BR-0.014\times MC\times BT-0.025031\times MC\times DT+0.012531\times MC\times SS+3.33750E-003\times BR\times BT+0.014188\times BR\times DT-2.48750E-003\times BR\times SS-8.43750E-004\times BT\times DT+4.99375E-003\times BT\times SS-2.08125E-003\times DT\times SS+0.054006\times MC^2+8.64091E-$$

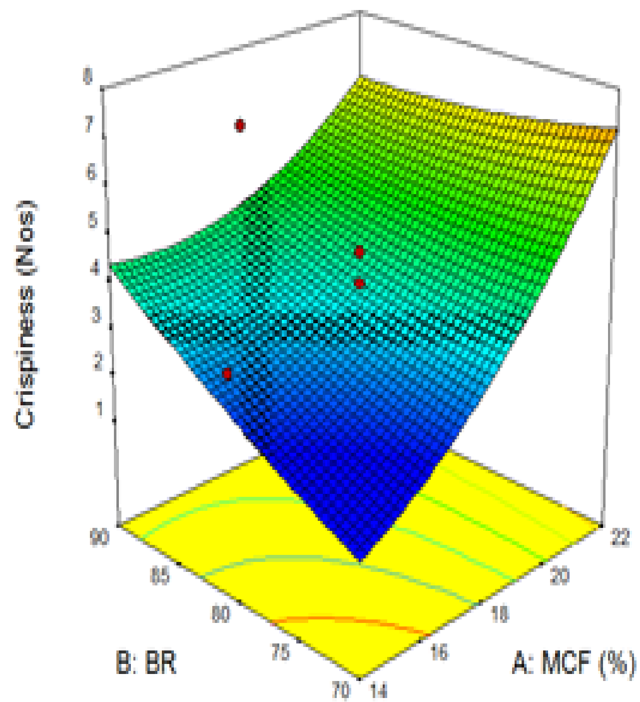

Figure 7. Impact of BR and MC of crispness on extrudate.

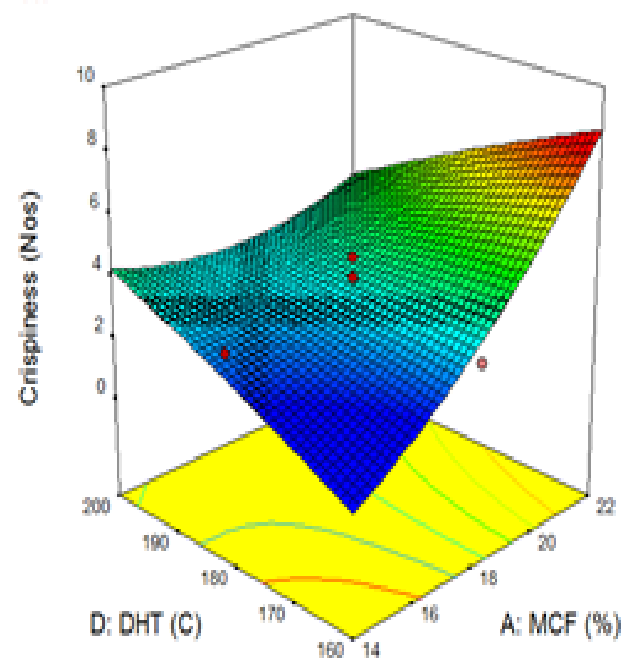

Figure 8. Impact of DHT and MC on crispness of extrudate.

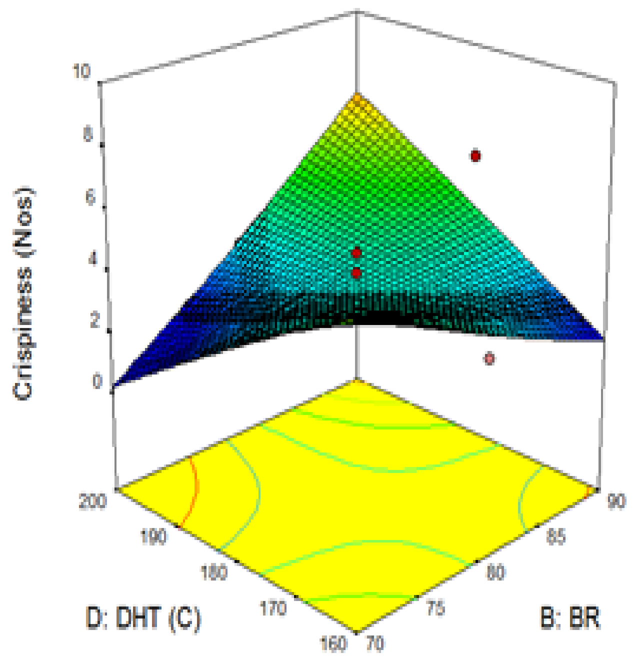

Figure 9. Impact of DHT and BR on crispness of extrudate.

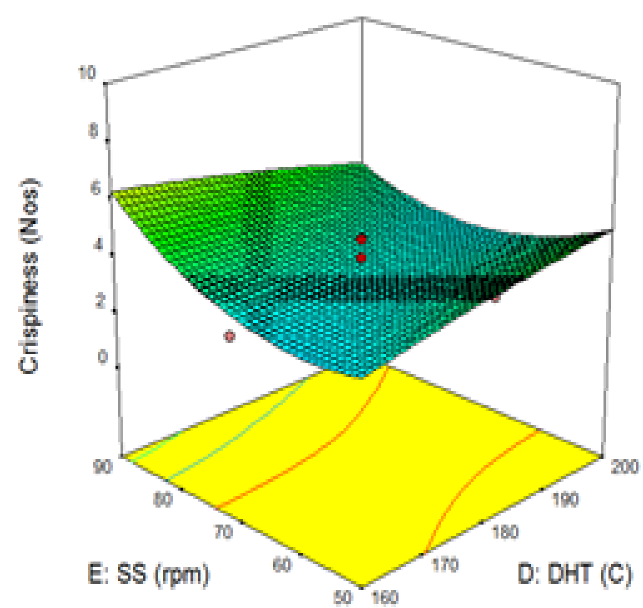

Figure 10. Impact of SS and DHT on crispness of extrudate.

$$003BR^2+7.27273E\text{-}005BT^2-3.39779E\text{-}004\times DT^2+2.98523E\text{-}003\times SS^2 \quad (2)$$

A strong association between the different variables under study was endorsed by very high value of $\mathbf{R^2}$

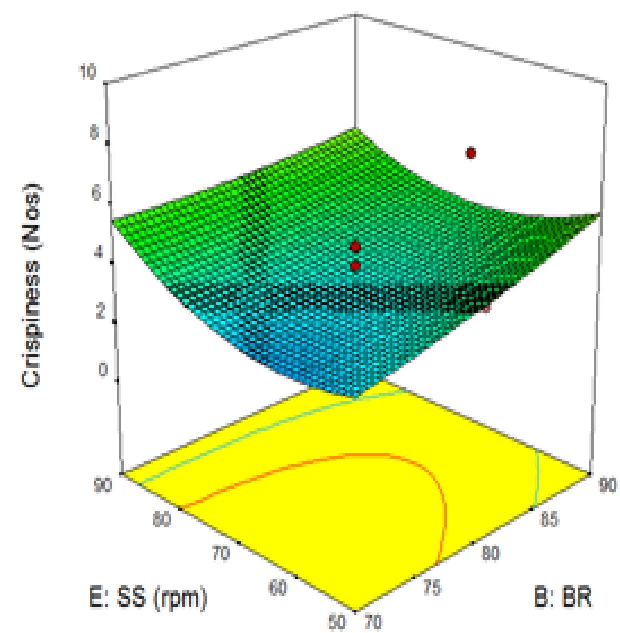

Figure 11. Impact of SS and BR on crispness of extrudate.

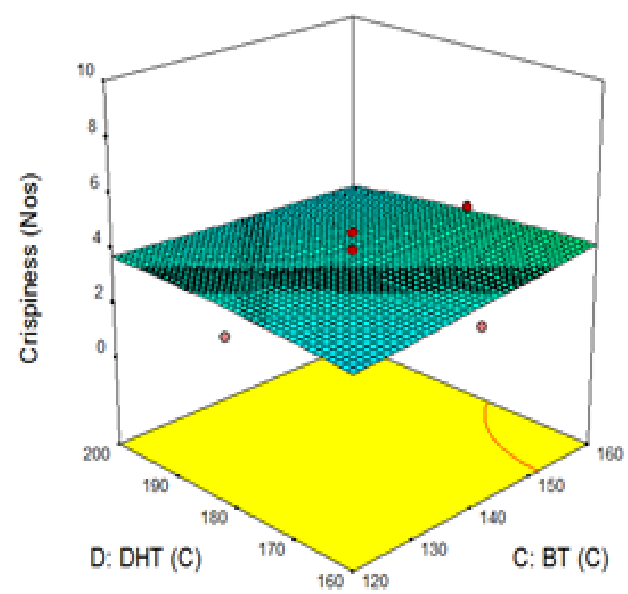

Figure 12. Impact of DHT and BT on crispness of extrudate.

i.e.**0.84**. Figure 7 to 12 show the interactive response of pair of two different independent variables taken together on crispness of extrudates. For a batter product quality the crispness of extrudates material should be maximum. Crispness of extrudate was maximum (7) at 18% moisture content of feed, blend ratio 90:10, barrel temperature 140^{0}C, die head temperature 180^{0}C, screw speed 70 rpm. The effect of moisture content of feed on crispness of extrudate was that increment in moisture content of feed also increased the crispness of extrudate as shown in Figure 7. Effect of blend ratio on crispness of extrudates was observed that on decreasing the broken rice content (i.e. at high Okara content), the crispness of extrudates is reduced (Shown in Figure 7, 9 and 11). It was also noted by Chinnaswamy[12] that expanded volume of extrudates, decreases with increase in protein and increases with increase in starch content in raw feed material. Incorporation of protein contributes to reduce starch conversion and to compress the bubble growth resulting a dense structure of extrudate, ultimately it reduces crispness of extrudate. Effect of temperature on crispness was found positive i.e. on increasing the barrel temperature and die head temperature, the crispness of extrudates was also increased as shown in Figure 8, 10 & 12. This was confirmed by Ding[13] that the increment in temperature enhances the growth of bubbles, resulting porous extrudate structure with thin cells[14]. Thus the crispness of extrudate increases with increase in temperature. Similar finding was reported by[7]in Okara-maize snack food that when the temperature is progressively increased it results into greater porosity in the extrudates due to formation of large number of large-sized air pockets.

4. Conclusion

The textural properties (i.e. hardness and crispness) of broken Rice-Okara based expanded snacks prepared through a single-screw extruder were affected by various feed parameters (blend ratio of broken rice and okara, moisture content of feed) and machine parameters (barrel temperature, die head temperature and screw speed). These parameters had some significant impact on extrudate quality as discussed in results. The extrudate textural properties were greatly dependent on blend ratio, moisture content of feed and temperature of extruder. The effect of screw speed was not significant. Moisture content of feed material had positive effect on extrudate hardness and had negative effect on crispness of extrudate. Temperature of extruder (i.e. barrel temperature and die head temperature) had positive effect on crispness and negative effect in hardness. Effect of okara content on textural properties was negative. High okara content was not acceptable for good textural properties of extrudates. The best textural properties of Broken Rice-Okara based extrudate product was observed at 18% moisture content, 90:10 (Broken Rice: Okara) blend ratio, screw speed 70 rpm, barrel temperature 140^{0}C and Die head temperature 180^{0}C.

5. References

1. Ficarella A, Milanese M, Laconia D. Numerical simulation of cereal extrusion and influence of design and process on the final quality. Tecnica-Molitoria (Italy). 2003 Jan; 54(1):9–24.
2. Ilo S, Berghofer E. Kinetics of colour changes during extrusion cooking of maize grits. Journal of Food Engineering. 1999; 39(1):73–80.
3. Desrumaux A, Bouvier JM, Burri J. Effect of free fatty acids addition on corn grits extrusion cooking. Cereal Chemistry. 1999; 76(5):699–704.
4. Kadan RS, Bryant RJ, Pepperman AB. Functional properties of extruded rice flours. Journal of Food Science. 2003; 68(5):1669–72.
5. Thilagavathi T, Kanchana S, Banumathi P, Hemalatha G, Vanniarajan C, Sundar M, Ilamaran M. Physico-chemical and Functional Characteristics of Selected Millets and Pulses. Indian Journal of Science and Technology. 2015 Apr; 8(S7):147–55.
6. Chan WM, Ma CY. Modification of proteins from soymilk residue (okara) by trypsin. Journal of Food Sciences. 1999; 64(5):781–86.
7. Shi C, Wang L-, Adhikari B, Li L-L. Optimization of twin screw extrusion process of produce Okara-Maize snack foods using response surface methodology. International Journal of Food Engineering. 2011; 7(2):1–24.
8. Gomez MH, Aguilera JM. A physicochemical model for extrusion of corn starch. Journal of Food Science. 1984; 49(1):40–3.
9. Ding QB, Ainsworth P, Tucker G, Marson H. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. Journal of Food Engineering. 2004; 66(3):283–89.
10. Fletcher SI, Richmond P, Smith AC. An experimental study of twin-screw extrusion cooking of maize grits. Journal of

Food Engineering. 1985; 4(4):291–12.

11. Meste ML, Champion D, Roudaut G, Blond G, Simatos D. Glass transition and food technology: A critical appraisal. Journal of Food Sciences. 2002; 67(7):2444–58.
12. Chinnaswamy R, Hanna MA. Expansion, colour and shear strength properties of corn starches Extrusion cooked with urea and salts. Starch/Starke. 1988; 40(5):186–90.
13. Ding QB, Ainsworth P, Tucker G, Marson H. The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. Journal of Food Engineering. 2006; 73(2):142–48.
14. Azam M, Singh M, Verma DK. Textural Properties of Kodo (Paspalum scrobiculatum L.) based Soy Fortified Ready to Eat Extruded Snacks using Response Surface Methodology. Indian Journal of Sciences and Technology. 2016; 9(4):1–6.