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Research Article

Effect of Iron Enrichment on Textural Properties of Rice Based Ashwagandha (*Withania Somnifera*) Fortified Extruded Snacks

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Abstract

The aim of this research work is to study the Effect of Iron Enrichment on Textural Properties of Rice Based Ashwagandha *(Withania somnifera)* Fortified Extruded Snacks. Extrusion cooking technology was used to prepare extrudate from Rice Flour (RF), Blanched and dried spinach powder (BDSP) - Ashwagandha Powder (AP) blends in a Brabender single screw extruder. Processing parameters of feed including moisture content of feed (MCF) (9 – 21%), Blend Ratio (BR) (80:15:5 to 80:3:17). Operational parameters of extruder like Barrel Temperature (BT) (120 to 200^{0}C), Die Head Temperature (DHT) (130 – 210^{0}C) and Screw Speed (SS) (60 – 100 rpm) were used for textural properties of extrudates. The value of hardness and crispness of extrudates ranged from 1.5 to 7.5 kg and no of peaks 9 to 22 respectively. The highest value of crispness and lowest value of hardness was obtained at 15% feed moisture, blend ratio of rice (80%): Ashwagandha powder (3%): Spinach powder (17%), 160^0 C barrel temperature, 170^0 C die head temperature and 80 rpm screw. Texture is one of the key quality attributes used in the processed food industry to assess product quality and acceptability.

Keywords: Extrusion Technology, rice flour (RF), blanched and dried spinach powder (BDSP), ashwagandha powder (AP), Response Surface Methodology, Textural Properties

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Introduction

Texture is one of the key quality attributes used in the fresh and processed food industry to assess product quality and acceptability. The textural properties of a food are that group of physical characteristics that arise from the structural elements of the food are sensed primarily by the feeling of touch are related to the deformation, disintegration and flow of the food under a force and are measured objectively by functions of mass, time and distance.

Extrusion cooking is a high-temperature, short-time process in which moistened, expansive, starchy and/or pertinacious food materials are plasticized and cooked in a tube by a combination of moisture, pressure, temperature and mechanical shear, resulting in molecular transformation and chemical reactions [2] [7].

Cereal grains are generally used as major raw material for development of extruded snack foods due to their good expansion characteristics because of high starch content. Rice is a popular, nonallergic, gluten free source of carbohydrate, vitamins, and minerals with little fat. Rice contains approximately 7.3% protein, 2.2% fat, 64.3% available carbohydrate, 0.8% fiber and 1.4% ash content [6]. Ashwagandha contains many useful medicinal ingredients, including withanolides (steroidal lactones), alkaloids, choline, fatty acids, amino acids, and a variety of sugars. Spinach is a valuable fresh-market vegetable due to its high levels of vitamins, folic acid, potassium, antioxidants and Iron enrichment.

In order to incorporate healthy nutrients available in BDSP, AP and RF to prepare extrudate snacks. In particular, we aimed at studying the textural characteristics of extruded RF, AP - BDSP snack foods and optimizing the extrusion process using response surface methodology with a Central Composite Rotatable Design [10].

Materials and Methods

The experiment was conducted in the food science and extrusion lab of department of Post Harvest Process and Food Engineering college of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur (M.P). Rice Flour (RF), Blanched and Dried Spinach Powder (BDSP), Ashwagandha Powder (AP), were procured from the Local Market of Jabalpur (M.P)

In the present study, a laboratory single screw extruder model D47055 DUISBURG, make Brabender, Germany was used for extrusion of different blends of RF, BDSP and AP. The extruder consists of grooved barrel with heating elements and cooling jackets. The constructional features of the extruder incorporate motor and gear unit, coupling, loading unit, extruder barrel with screw and control cabinet. A temperature controller controls the temperatures of all the zones; the maximum temperature which can be achieved is 450^0C. The feeding zone of the extruder is water-cooled and compression and metering zones are air-cooled. A round die head assembly is fixed at the end of the barrel. In the present study a round die of 5 mm diameter was used. The feed screw with feeding device is mounted above the feed opening. Transducers and sensors are available for measuring melt pressure and melt temperature within the extruder and on the die head assembly. The L/D ratio of the screw used in Brabender food extruder is 20:1 and the compression ratio of the screw was 2:1.

Response surface methodology is a combination of mathematical and statistical techniques and is used for the development of an adequate functional relationship between a response of interest and a number of associated dependent variables. RSM uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations graphically represented as response surfaces in 3-D plots [10]. CCRD of RSM was used to reduce the number of experimental runs without affecting the accuracy of results and determines interactive effect of variables on the response [12]. In this study CCRD with half replicate of five independent variables with five levels of each has been chosen (**Table 1**).

The CCRD can be fitted into a sequential program starting with an exploratory 2k factorial to which a linear response surface is fitted [13]. Based on the information available in the literature and preliminary trial five independent variables namely; DHT (^{0}C), BT (^{0}C), MCF, BR (RF: AP: BDSR) and SS (rpm) were selected for production of ready to eat snack food. The experimental plan consisted of 32 treatment combinations of each independent variable chosen. The data obtained from the experiment outlined were processed using the software Design Expert (ver. 9.0.0). The adequacy of model was tested using F ratio and coefficient of determination (R^2). The model was considered when the calculated F ratio was more than that of table value [14]. The effect of variables at linear, quadratic and interactive level on the response was described using significance at 1, 5 and 10% level of confidence.

Table 1 Details of levels of process and operational parameters

S. No	**Variable Parameters**	**Code**	**Code levels**				
			-2	**-1**	**0**	**+1**	**+2**
1	Moisture content of feed (w.b.) (%)	MC_f	9	12	15	18	21
2	Blend Ratio	B_R	80:15:5	80:12:8	80:9:11	80:6:14	80:3:17
3	Die head temperature	T_{die}	130	150	170	190	210
4	Barrel Temperature (Zone III ^{0}C)	T_{brl}	120	140	160	180	200
5	Screw Speed	S_s	60	70	80	90	100

The conditioned samples were then feed to the extruder under set operational conditions. The product after coming out of the extruder discharge end through round die, expanded due to sudden release of pressure. The extrudates were collected and packed in laminated polythene bags and properly labeled for further analysis.

Texture Analyzer (**Figure 1**) (Make Stable Micro System, UK, and model: TA-XT2i) available at the Department of Post Harvest Process and Food Engineering, JNKVV, Jabalpur. Texture Analyzer is a highly scientific device, was used for determination of mechanical properties of extrudates with the help of different kind of probes. The peak force as an indication of hardness was measured by using 3 mm cylindrical probe (**Figure 2**). Crispness is measured by counting the number of peaks formed on textural profile analysis curve when subjected to Uniaxial compressive loading by a needle probe **Figure 3**. In order to test the hardness or crispness of extruded product a piece of extrudates is taken and put over the test platform of texture analyzer. The texture Analyzer is pre-set as per the following settings pre-test speed of 5.0 mm/s, test speed of 2.0 mm/s, post test speed of 10.0mm/s, moving distance of 5.0 mm, trigger force of 25 g and load cell of 50 ± 1kg. Three measurements performed on each sample.

The textural properties of extrudates including hardness and crispness were performed using a TA – XT – plus Textural Analyzer (Stable Micro – System UK) after extrusion. A cylindrical probe was used for hardness test and needle probe for crispness test. This texture analyzer was commanded through the computer software. A 50 mm long extruded product was put over the platform to test the hardness and crispness. The extruded pieces compressed using a SMS P/5 cylindrical probe for hardness test and punctured with a needle probe for crispness test to 50% of its original thickness at a test speed of 2 mm/s, pretest speed 5 mm/s and post test speed 10 mm/s. The hardness and crispness data were then recorded automatically and graph was plotted between force and time (**Figures 4** and **5**) Determination were made in triplicate.

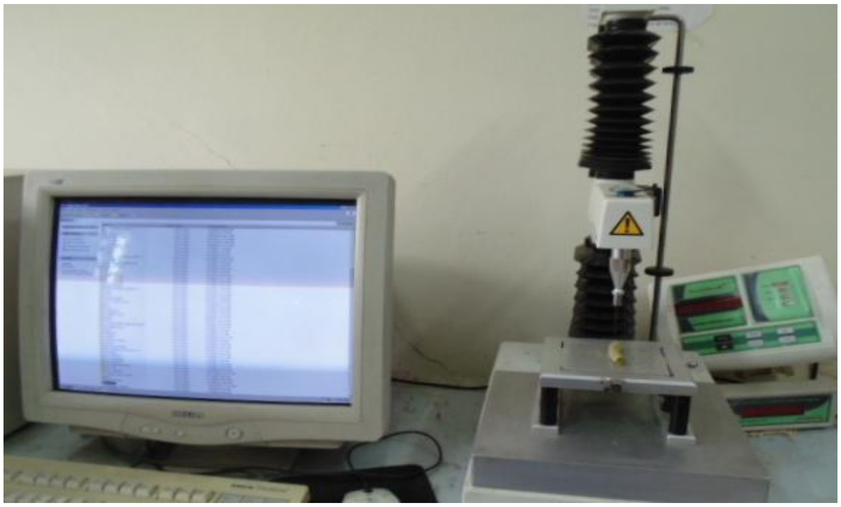

Figure 1 Set up of texture analyser

Figure 2 Cylindrical probe

Figure 3 Needle probe

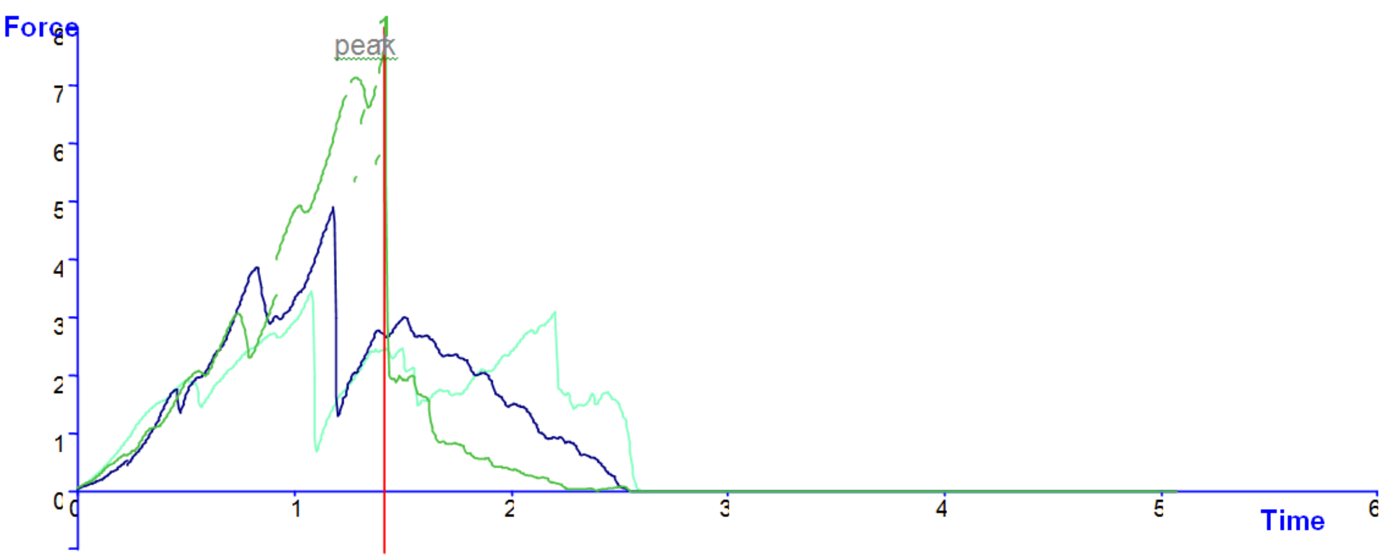

Figure 4 Force determination curve of minimum hard extrudate of Rice, Ashwagandha and Spinach

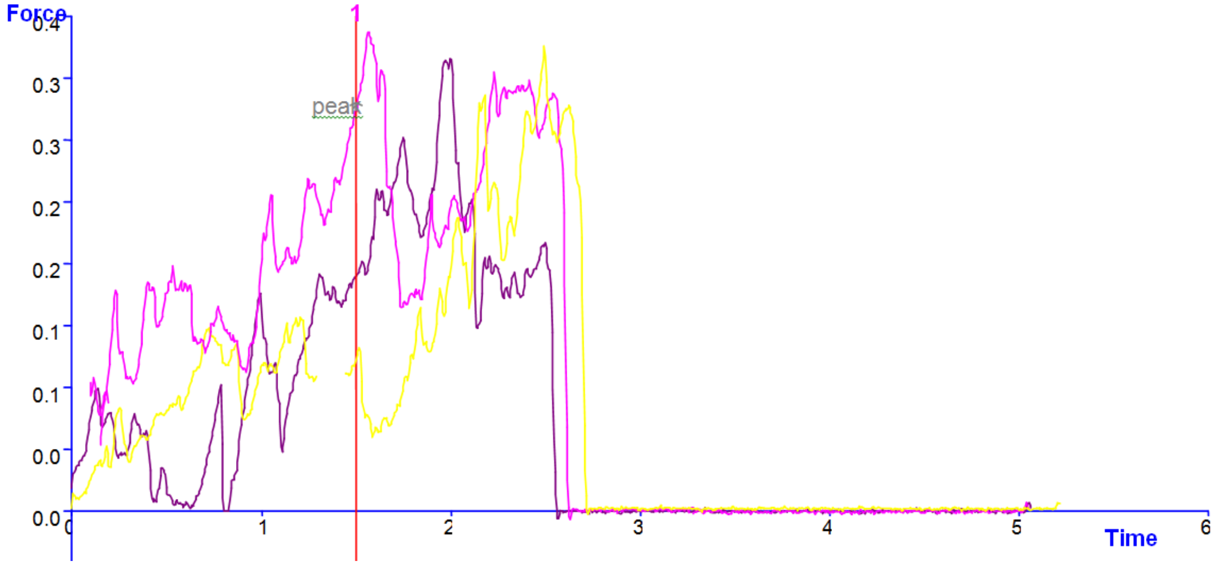

Figure 5 Textural profile of highly crispy extrudate of Rice, Ashwagandha and Spinach

Results and Discussion

Hardness is the force required to cut through a food material using the front teeth or the maximum peak force during the first compression cycle (first bite)

During the hardness test the peak force for all extruded snacks ranged from 1.3 kg to 7.5 kg Figure 4. Shows the textural profile of minimum hard extruded of rice, ashwagandha and spinach. The multiple regression model for predicting the hardness showed regression coefficient (R^2) 0.923 and non - significant F – value of 0.778. The significant quadratic model was established at probability P- value of 0.0085. The response surface 3 – D graph for hardness (**Figures 6** and **7**) shows the interactive effect of feed moisture, blend ratio, screw speed, barrel temperature and die head temperature. In this experiment, hardness for all the extruded samples ranged from 0.604 to 8.446. The lowest value of hardness was obtained at 15% feed moisture, blend ratio of rice (80%): aswagandha powder (3%): spinach powder (17%), 160^0 C barrel temperature, 170^0 C die head temperature and 80 rpm screw The multiple regression equation representing the effect of processing parameter of hardness in coded value is given by following second order method.

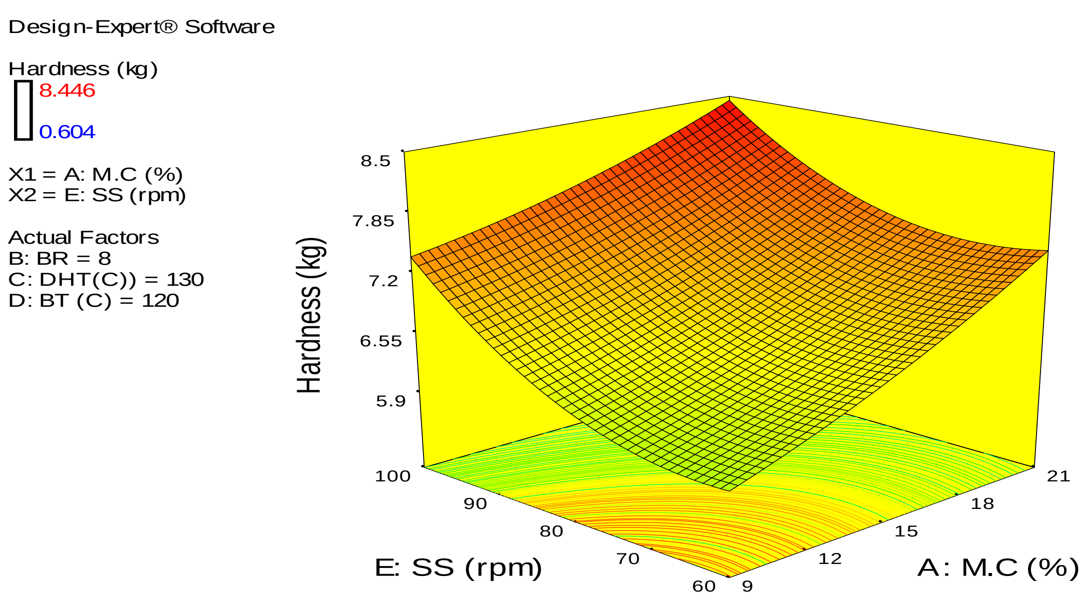

Figure 6 Effect of moisture content and screw speed on hardness of extrudate

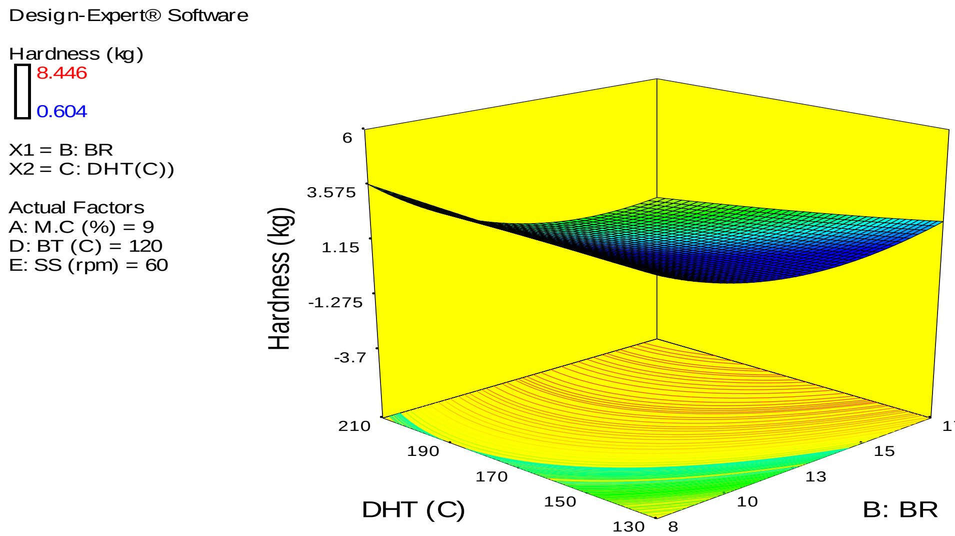

Figure 7 Effect of blend ratio and die head temperature on hardness of extrudate

$$Hardness = 20.5112 + 0.38855xM.C + 0.11858\ x\ BR - 0.36631xDHT + 0.24203xBT - 0.12278xSS + 1.11806E - 003xM.CxBR + 5.31250E - 005xM.CxDHT - 2.5614E - 003\ M.C\ x\ BT - 9.89583E - 004xM.CxSS - 4.7538E - 003xBR\ x\ DHT - 6.40625E - 004\ xBR\ x\ BT + 6.43750E - 004\ \ x\ BR\ x\ SS + 2.14844\ E - 003x\ DHT\ x\ BT + 1.14469\ E - 003\ x\ DHT\ x\ SS - 1.29094E - 003\ x\ BT\ x\ SS + 3.00434E - 003\ x\ MC^2 + 3.92763E - 003\ xBR^{\ 2} + 4.1240E004\ x\ BT^2 + 1.05789E - 00\ x\ SS^{2)} \quad (1)$$

The negative effect of first order term of blend ratio and interaction term (equation 1) indicate the decrease in hardness with increase of these variables while positive coefficient of the first order terms of MCF, BT, DHT & SS quadratic terms and interaction terms resulted in increase in hardness of the extrudate.

Figure 6 shows the minimum value of hardness was observed at 9% feed moisture and maximum at 21% reported that increase in feed moisture results in lower degree of starch gelatinization for different products. When screw speed increases the hardness of snacks also increases because of less retention time. Ashwagandha and spinach is rich in fiber content and fiber raise hardness of outer layer of extrudate.

Figure 7 shows the minimum value of hardness was appeared at 9% spinach powder in blend. Since spinach is rich in fiber content and fiber raise hardness of outer layer of extrudate and as the die head temperature increases the hardness of snacks also increases, die head temperature has the positive effect on hardness the tendency to increase hardness at high die head temperature may be due to the high melt temperature that has change in the chemistry of melt.

Crispness is related with rapid drop of force during mastication process, attribute that is based on fracture propagation in brittle materials [27]. When force is applied to brittle snacks, rupture of the cellular structure occurs, generating a typical sound that contributes to the crispness sensation [1, 26]. Materials considered to be crisp usually generate irregular force–deformation curves. In this experiment, crispness for all the extruded samples ranged from 9 to 22. The highest value of crispness was obtained at 15% feed moisture, blend ratio of rice (80%): ashwagandha powder (3%): spinach powder (17%), 160^0 C barrel temperature, 170^0 C die head temperature and 80 rpm screw speed. Figure 5 shows the textural profile of highly crispy extrudate of rice, ashwagandha powder and spinach powder. Second order polynomial model was good descriptor for these process parameters. The multiple regression models for predicting the crispness showed regression coefficient (R^2) 0.85 and a non-significant F-value of 0.69 as lack of fit. The model was significant having P-value of 0.0121. The response surface 3D graphs for crispness (**Figures 8** and **9**) show the interactive effect of moisture of feed, blend ratio, screw speed, barrel temperature and die head temperature. The multiple regression equation representing the effect of processing parameters on crispness in coded values is given by following second-order model:

$$Crispness\ (Nos) = -85.61814 + 5.97960\ x\ M.C - 6.32487\ x\ BR + 0.10505\ x\ DHT + 0.55833\ x\ BT + 0.97292\ x\ SS + 0.020833\ x\ M.C\ x\ BR - 1.04167E - 003\ xM.CxDHT - 9.37500E - 003xM.CxBT - 0.031250\ x\ M.C\ x\ SS - 1.01467\ E - 003\ BTx\ DHT + 7.29167E - 003\ x\ BR\ x\ BT + 0.035417\ x\ BR\ x\ SS - 1.56250E - 1.04167E - 003\ x\ BR\ x\ DHT + 7.2916E - 003x\ DHT\ x\ SS - 2.18750E - 003\ x\ BT\ x\ SS - 0.070964\ x\ M.C^{2} + 0.10441\ x\ BR^{2} - 5.10864E - 004\ x\ BT^{2} - 5.13672E - 003\ x\ SS^{2} \quad (2)$$

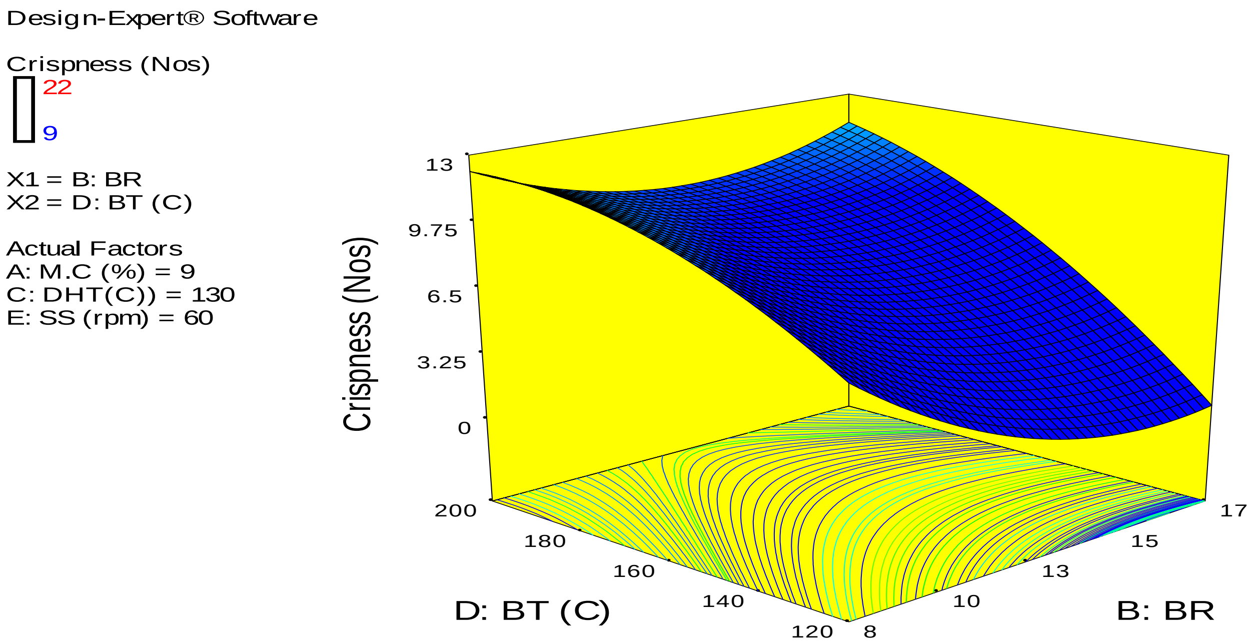

Figure 8 Effect of blend ratio and barrel temperature on crispness of extrudate

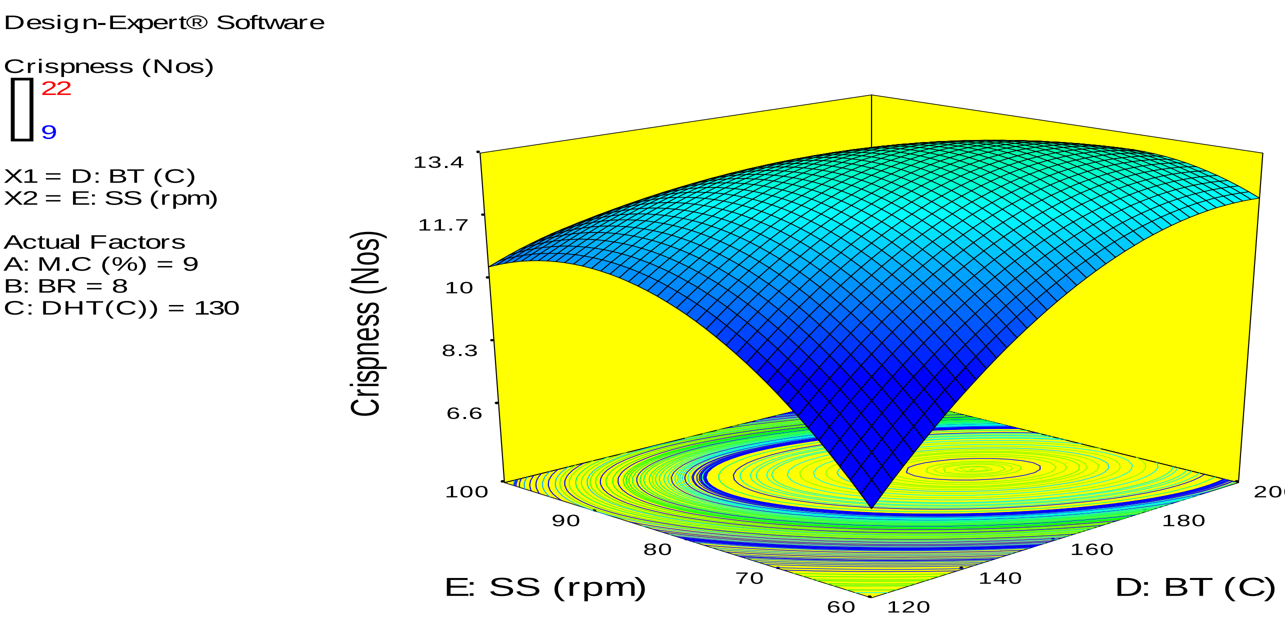

Figure 9 Effect of screw speed and barrel temperature on crispness of extrudate

The negative coefficients of the first order terms of BR, interaction terms and quadratic terms (Equation 2) indicated that crispness decreases with increase of these variables while positive coefficients of the first order terms of MCF, BT, DHT and SS, quadratic terms and interaction terms resulted in increase in crispness of the extrudate with increase in these variables.

Figure 8 Shows that the concentration of spinach in blend ratio increases the crispness of extruded snacks decreases because of high fiber content in spinach and it intervenes with air bubble formation and increase in cell wall thickness. As the barrel temperature increases the crispness of extruded snacks also increases.

Figure 9 shows Effect of screw speed and barrel temperature on crispness was found positive reported that soluble starch increased [21]. Increasing screw speed and barrel temperature improved the expansion of extrudate ultimately high screw speed and barrel temperature resulted in the high crispness.

Conclusion

The highest value of crispness and lowest value of hardness was obtained at 15% feed moisture, blend ratio of rice (80%): aswagandha powder (3%): spinach powder (17%), 160^0 C barrel temperature, 170^0 C die head temperature and 80 rpm screw. It was confirmed in this study that higher fiber content present in spinach and ashwagandha decreases the crispness and increases hardness of extruded.

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