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Textural Properties of Kodo (*Paspalum scrobiculatum L.*) based Soy Fortified Ready to Eat Extruded Snacks using Response Surface Methodology

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Abstract

Background/Objective: The aim of this research work is studied the textural characteristics of extruded Kodo millet-defatted soy-water chestnut flours and optimizing the extrusion process using response surface methodology. **Methods/ Statistical Analysis:** Response Surface Methodology (RSM) with Central Composite Rotatable Design (CCRD) was used to investigate the textural properties of extruded Kodo Millet Flour (KMF)-Defatted Soy Flour (DSF)-Water Chestnut Flour (WCF) blends in a Brabender single screw extruder. Texture Analyzer System (make from Stable Micro System, UK, model: TA-XT2i) is a highly scientific device was used for determination of mechanical properties of extrudates with the help of cylindrical and needle probes. **Findings:** Processing parameters of feed including moisture content of feed (MC_F), Blend Ratio (BR), operational parameters of extruder like Barrel Temperature (BT), Die Head Temperature (DHT) and Screw Speed (SS) were optimized for textural properties of extrudates. The value of hardness and crispness of extrudates ranged from 4.63 to 23.02 N and 8.3 to 18.9 respectively and it had a mean value of 11.68 N and 14.58 respectively. The optimum values obtained for MC_F, BR, DHT, BT and SS are 10.0%, 20% DSF, 220^{0}C, 180^{0}C and 100 rpm, respectively. The corresponding optimum values of crispness and hardness were 17.43 and 5.54 N respectively. **Application:** Texture is one of the key quality attributes used in the processed food industry to assess product quality and acceptability.

Keywords: Extrusion Technology, Kodo Millet, Response Surface Methodology, Textural Properties

1. 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[1]. Since millets are of relatively low cost, widely available source of food, their contribution to energy intake is highest among the typical Indian vegetarian meal[2].

Millets are important ecological food security crops and they are more nutritious, non-glutinous, non-acid forming and easy to digest[3]. India is a top producer of millets with an annual production of 334500 t (43.85%)[4] and Kodo (*Paspalum scrobiculatum*) is one among the six other minor millets. Nutrient composition of Kodo per 100 g edible portion with 12 % moisture content is: protein 9.8 g, fat 3.6 g, ash 3.3 g, fiber 5.2 g, carbohydrate 66.6 g, energy 353 kcal, Ca 35 mg, Fe 1.7 mg, thiamine 0.15 mg, riboflavin 0.09 mg and niacin 2.0 mg[5]. Soy protein is widely used in food applications due to its functionality and health benefits[6,7]. American Soybean Association (ASA) recommended standard for defatted soy flour

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is protein 50%, moisture 9%, fat 1.5%, crude fiber 3.5% and ash 7%[8]. The nutrient composition of the raw water chestnut fruit per 100 g edible portion is: energy 117 kcal, moisture 66.4 g, protein 4.1 g, fat 0.4 g, total carbohydrate 27.8 g, fibre 0.8 g, ash 1.3 g, Ca 54 mg, P 114 mg, Fe 1.2 mg, Na 21 mg, K 452 mg, β-carotene traces, thiamine 0.13 mg, riboflavin 0.06 mg, niacin 2.0 mg and ascorbic acid 7 mg[9].

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

2. Materials and Methods

2.1 Selection of Raw Materials

The KMF, DSF and WCF were taken as raw materials for the present study. The kodo millet was procured from Tamia (block), Chhindwara (MP). DSF was procured from Ruchi Soya Industries Ltd., Indore (MP). WCF was procured from the local market of Jabalpur, manufactured by Dhanhar Exim Pvt. Ltd., Surat (Gujarat).

2.2 Extrusion Process

In the present study, a laboratory single screw extruder model D47055 DUISBURG, make Brabender, Germany was used for extrusion of different blends of KMF, DSF and WCF. 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 by each zone is 450^{0}C. 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 3 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.

2.3 Experimental Design

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[11]. 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 programme 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), MC_P, BR (KMF:DSF:WCF) 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

Independent Variables	Levels				
	−2	−1	0	+1	+2
Moisture Content (% wb)	8	10	12	14	16
Blend Ratio (KMF:DSF:WCF)	70:5:25	70:10:20	70:15:15	70:20:10	70:25:5
Die Head Temperature(^{0}C)	160	180	200	220	240
Barrel Temperature (^{0}C)	120	140	160	180	200
Screw Speed (rpm)	80	100	120	140	160

2.4 Preparation of Extrudates

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 labelled for further analysis.

2.5 Determination of Textural Properties

Texture Analyzer System (Figure 1.) (make from Stable Micro System, UK, 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[15] 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)[16]. 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 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. Ten measurements performed on each sample.

Figure 1. Texture analyzer.

Figure 2. Cylindrical probe.

Figure 3 Needle probe.

3. Results and Discussion

3.1 Hardness of Extrudates

The multiple regression equation representing the effect of processing parameters on hardness in coded values is given by following second-order model:

$$\text{Hardness} = 11.08 + 1.18 \times MC_F - 2.17 \times BR + 0.91 \times BT - 0.37 \times DHT + 1.87 \times SS + 0.053 \times MC_F \times BR + 0.90 \times MC_F \times BT - 0.20 \times MC_F \times DHT - 1.33 \times MC_F \times SS - 0.54 \times BR \times BT - 1.07 \times BR \times DHT - 1.26 \times BR \times SS - 0.64 \times BT \times DHT - 0.043 \times BT \times SS - 0.54 \times DHT \times SS - 0.084 \times MC_F^2 + 1.02 \times BR^2 - 0.24 \times BT^2 + 0.037 \times DHT^2 + 0.079 \times SS^2$$

The value of hardness of extrudates ranged from 4.63 to 23.02 N and it had a mean value of 11.68 N. It is observed (Figure 4.) that hardness increases with increase in moisture content of feed as an indicative of creation of less porous structure of extrudates leading to increased hardness with increase in DHT, which may be mainly due to the strengthening of fiber content present in outer layers of extrudates at higher temperature[17]. The hardness of extrudates increases with the increase in percent of WCF, it contains high amount of sugar which retard the expansion of extrudates (Figure 5.)[18], with increase in screw speeds the hardness of extrudates increases because the increase in screw speed creates a better homogeneous

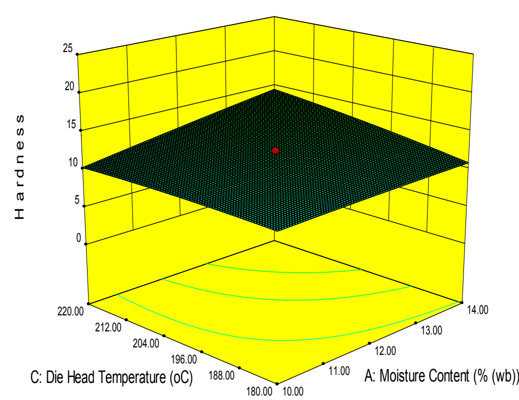

Figure 4. Effect of DHT and MC_F on hardness of extrudates.

mass by better mixing of melt inside the barrel, which creates a uniform structure of extrudates and places fibers uniformly on the upper layers of extrudates and imparting a hard upper coat to the extrudates. Barrel temperature has not significant effect of extrudates (Figure 6).

The coefficient of determination R^2 had a value of 0.619 for the model with F-value of 0.90. This implies that the model terms had a significance level of probability less than 0.601.

3.2 Crispness of Extrudates

The multiple regression equation representing the effect of processing parameters on crispness in coded values is given by following second-order model:

Crispness = $16.08 - 0.48 \times MC_F + 0.37 \times BR + 0.38 \times BT + 0.12 \times DHT - 0.66 \times SS - 0.50 \times MC_F \times BR - 0.1 \times MC_F \times BT - 0.77 \times MC_F \times DHT + 0.46 \times MC_F \times SS - 0.17 \times BR \times BT + 0.35 \times BR \times DHT - 1.81 \times BR \times SS + 0.65 \times BT \times DHT - 0.11 \times BT \times SS + 1.26 \times DHT \times SS - 0.80 \times MC_F^2 - 1.01 \times BR^2 - 0.39 \times BT^2 + 0.45 \times DHT^2 - 0.24 \times SS^2$

The crispness of extrudates ranged from 8.3 to 18.9 with a mean value of 14.58. Crispness of any product is a measure of its quality and freshness. It is observed (Figure 7.) that crispness increases with decrease in MC_F as an indicative of creation of more porous structure of extrudates leading to increased crispness.

It is evident (Figure 8.) that with increase in BT and DHT the crispness of extrudates increases this mainly because high extrusion temperature is mainly responsible for less moisture and formation of more porous structure of extrudates. Similar finding was reported by[19].

It is seen from Figure 9, the crispness of extrudates increases, with decrease in percent of DSF, it contain

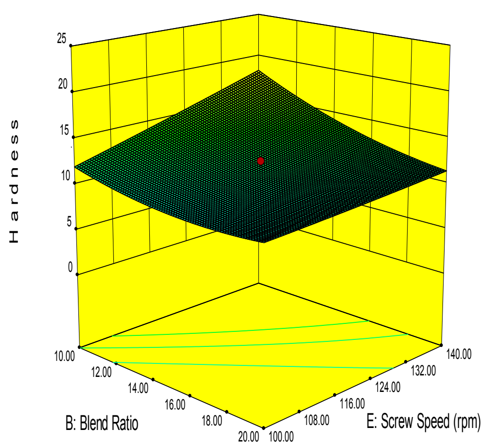

Figure 5. Effect of SS and BR on hardness of extrudates.

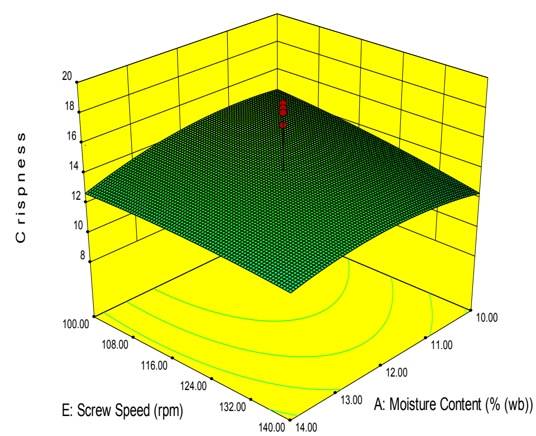

Figure 7. Effect of SS and MC_F on crispness of extrudates.

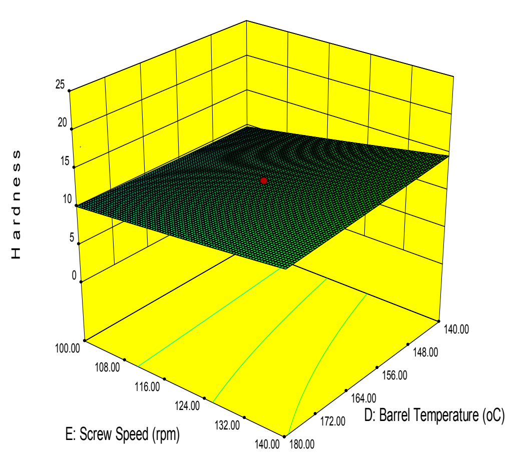

Figure 6. Effect of SS and BT on hardness of extrudates.

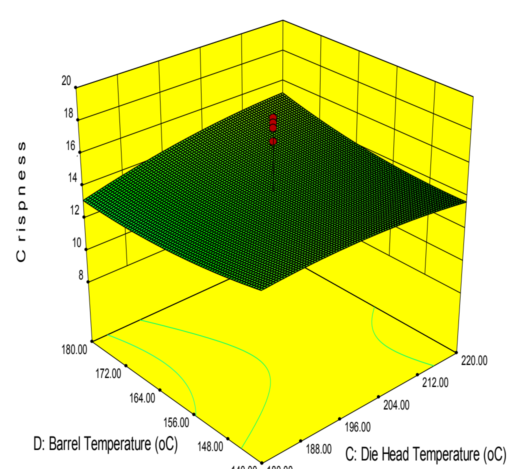

Figure 8. Effect of BT and DHT on crispness of extrudates.

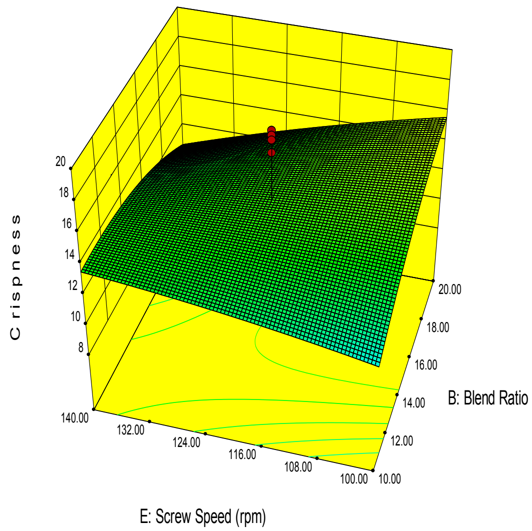

Figure 9. Effect of SS and BR on crispness of extrudates

higher amount of fiber than WCF. Therefore with decreases in DSF the amount of fiber content decreases and increases the crispness of extrudates.

The coefficient of determination R^2 had a value of 0.822 for the model with F-value of 1.10. This implies that the model terms had a significance level of probability less than 0.452.

3.3 Optimization of Process Parameters

Based upon the results obtained from the experiment which was designed according to CCRD and the analysis of results by using RSM through software Design Expert (ver. 9.0.0) and interdependence of different process parameters namely; MC_F, BR, SS, BT and DHT and their effect on textural parameters under study and as assessed by various response surface graph generated for hardness and crispness of extrudates. Desired goals were assigned for all the parameters for obtaining the numerical optimization values for the responses. All the processing parameters were kept in range. Crispness was maximized, while hardness was minimized. The optimum values obtained for MC_F, BR, DHT, BT and SS are 10.0%, 20% DSF, 220^{0}C, 180^{0}C and 100 rpm, respectively. The corresponding optimum values of crispness and hardness were 17.43 and 5.54 N respectively.

4. Conclusions

Designed experiments were conducted following RSM with a CCRD. The main advantage of RSM is that it requires less number of experimental runs to provide sufficient information for statistically acceptable results. In this study, the effect of processing parameters: MC_F (8–16% w.b.), BR (5–25% DSF), DHT (160–240^{0}C), BT (120–200^{0}C) and SS (80–160 rpm) were optimized against the responses crispness and hardness of extrudates. The corresponding optimum values of crispness (maximum) and hardness (minimum) were 17.43 and 5.54 N respectively.

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