Assessment of Textural Properties of Brown Rice based Ready to Eat Extrudate Snacks Blended with Water Chestnut and Safed Musli Powder

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Abstract

Objective: The main objective of this finding was to assess the textural properties of brown rice based ready to eat extrudate snacks blended with water chestnut and safed musli powder. Method/Statistical Analysis: Extrusion cooking technology was used for the production of extruded snacks. In this research work, the effects of feed parameters i.e. feed moisture (10-18 %), blend ratio of brown rice:water chestnut flour: safed musli powder (80:18:2–80:10:10) and machine parameters of single screw extruder i.e. screw speed (120-200 rpm), barrel temperature (120-200°C) and die head temperature (160-240°C) on the textural properties of extrudates (i.e. hardness and crispiness) were analyzed using response surface methodology. Finding: Optimum parameters for highly acceptable products with 13% moisture content of feed and 3% concentration of safed musli powder that were extruded at the screw speeds (180 rpm), barrel temperature (188°C) and die head temperature (170°C) presented the lower hardness (2.6 Kg) and higher crispiness (22). Application: Textural properties of ready to eat extrudate snacks are perceived by the final consumer as criteria of quality.

1. Introduction

Texture is the combination of those properties which are associated with the response of the structure of food to applied forces and the physiological senses involved being vision, kinesthetic and hearing. Several investigators admit that crispness and hardness are related to the structural properties of a food1-4. Textural quality attributes of food may be evaluated by sensory (subjective) evaluation or instrumental (objective) measurement. As compare to sensory evaluation, the instrumental analysis of texture in food is faster and relatively less expensive indications on product characteristics. In this study hardness and crispness were evaluated through instrument Texture Analyzer (TA-XT-Plus).

Textural properties of extrudate foods mainly influenced by the composition of feed ingredients i.e. cereals, starches, type of protein and fiber5,6. In present investigation, feed ingredients were brown rice, water chestnut flour and safed musli powder. Brown rice" contains 8.50% protein, 2.80% fat, 1.77% ash, 1.23% fiber and 77.31% carbohydrate at 9.61% moisture; whereas water chestnut" flour composed of 7.30% moisture, 1.85% fat, 10.80% protein, 71.55% carbohydrate, 6.35% fiber and 8.50% ash. Safed musli (Chloro-Phytum Borivilianum) has medicinal value with nutritional elements of protein (5-10 %), carbohydrate (35-45 %), fiber (25-35 %), saponins (2-15 %) and alkaloids (15-25 %).

During extrusion cooking, grain flour is mixed and cooked under high temperature and pressure in barrel section. The resulting plasticized mass is come out through a narrow hole i.e. die of different shapes. The puffed extruded snacks are cut into various sizes as per the consumer preference6. In order to make products that will be acceptable in a very competitive market, extrusion of snack foods demands the control of many parameters
that will directly or indirectly influence the consumer acceptability. There are number of quality parameters of extrudate snacks that directly and indirectly affect the consumer acceptability. These quality parameters are influenced by moisture content of feed, composition of raw ingredients and their proportion, extrusion temperature and screw speed. Hence, control of these parameters is essential in order to make an acceptable extrudate snacks. The critical parameters which partly affect the texture of the final product are moisture, retention time, thermal energy input and mechanical energy input. The control of screw speed, feed rate, barrel temperature and barrel pressure, together with the above mentioned critical parameters determine the crispness, hardness and various other characteristics that influence the success of the product.

Thus, the aim of this research was to assess the influence of feed moisture, blend of brown rice, water chestnut and safed musli powder, screw speed and temperature on textural properties (hardness and crispness) of extrudate snacks and optimize these variables for highly acceptable product.

2. Materials and Methods

2.1 Materials

Brown rice, Water chestnut and safed musli (supplied by local market) were used as raw material for preparation of ready to eat extrudate snacks. These ingredients were converted into flour using a hammer mill.

2.2 Sample Preparation

Initial moisture of ingredients (brown rice flour, water chestnut flour and safed musli powder) was estimated through standard AOAC, 2002 method. All ingredients were passed through 100 mm IS sieve, weighed and mixed in different proportion according to blend ratio as shown in Table 1. The moisture content of all formulations (250 gm of sample size), was adjusted by calculating the amount of water required to be added. Samples were stored in laminated plastic bags for 24 h before extruding to equilibrate the moisture.

2.3 Production of Extrudates

The conditioned samples were supplied to feed hopper (forced feeder) at 20 rev/min feeder speed, into a single-screw extruder (laboratory model Brabender D47055 DUISBURG) of three heating zones. An extrusion screw having compression ratio: 2:1 and length-to-diameter ratio of 20:1 at different speeds with die of 5 mm circular shape was used. The temperature of feeding zone and compression zone was maintained constant at 40°C and 60°C respectively, whereas the mixing/cooking zone temperature (barrel temperature zone III) and die head temperature varied as shown in Table 1. The extruded products were cooled at room temperature and packed in sealed aluminum bags stored under moisture free conditions until the observations were taken.

2.4 Statistics Design

The influence of five independent variables i.e. Feed Moisture (MCF), Blend Ratio (BR), Screw Speed (SS), Barrel Temperature zone III (BT), Die Head Temperature (DHT) on hardness and crispness were analyzed by using central composite rotatable design. All independent variables were controlled at five different levels discussed in Table 1. A second-order polynomial equation was then used to fit the measured, dependent variable (hardness and crispness) as a function of independent extrusion variables. Response Surface Methodology (RSM) which explores the relationship between several explanatory

### Table 1. Coded levels for the independent variables

| Independent variables                                      | Levels                        |
|------------------------------------------------------------|-------------------------------|
| Feed moisture,(% wb)                                       | -2  | -1  | 0    | +1  | +2  |
| Blend Ratio (Brown Rice flour:Water chestnut: Safed musli powder) | 80:18:2 | 80:16:4 | 80:14:6 | 80:12:8 | 80:10:10 |
| Barrel temperature zone-III (°C)                           | 120 | 140 | 160  | 180 | 200 |
| Die Head Temperature (°C)                                  | 160 | 180 | 200  | 220 | 240 |
| Screw speed (rpm)                                          | 120 | 140 | 160  | 180 | 200 |
variables and one or more response variables was applied to the experimental data using the trial package, Design expert version 10 (Stat-ease Inc., USA). The process was optimized for maximum values of crispness and minimum value of hardness of extrudate snacks conducting statistical analysis.

2.5 Textural Properties Analysis

The textural properties of extrudates including hardness and crispness were performed using a TA-XT-Plus Texture Analyzer (Stable Micro-Systems, UK) after extrusion. A cylindrical probe is used for hardness test and needle probe for crispness test[10]. This texture analyzer was commanded through the computer software Exponent Lite. A 30 mm long extrudate product was put over the platform to test the hardness and crispness. The extrudate piece 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, pre test 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 (Figure 1 and Figure 2). Determinations were made in triplicate.

![Figure 1](image1.png)

**Figure 1.** Force deformation curve of minimum hard extrudate of brown rice, water chest nut and safed musli powder.

![Figure 2](image2.png)

**Figure 2.** Textural profile of highly crispy extrudate of brown rice, water chest nut and safed musli powder.

3. Results and Discussion

3.1 Hardness of Extrudate Snacks

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 experiment the hardness for all the extruded snacks ranged from 2.6 Kg to 9.69 Kg. Figure 1 shows the textural profile of minimum hard extrudate of brown rice, water chestnut and safed musli powder. The multiple regression models for predicting the hardness showed regression coefficient (R²) 0.88 and a non-significant F-value of 0.68 as lack of fit. The significant quadratic model was established at probability P-value of 0.0095. The response surface 3D graphs for hardness (Figures 3 to 5) 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 hardness in coded values is given by following second-order model:

\[
\text{Hardness} = -54.99 - 0.28 \times \text{MCF} + 5.10 \times \text{BR} + 0.34 \times \text{BT} + 0.10 \times \text{DHT} + 0.15 \times \text{SS} + 0.08 \times \text{MCF} \times \text{BR} - 0.01 \times \text{MCF} \times \text{BT} - 0.01 \times \text{BR} \times \text{BT} - 0.02 \times \text{BR} \times \text{DHT} + 0.10 \times \text{MCF}^2
\] (1)
The negative coefficients of the first order terms of MCF and interaction terms (Equation 1) indicated the decrease in hardness with increase of these variables while positive coefficients of the first order terms of BR, BT, DHT and SS, quadratic terms and interaction terms resulted in increase in hardness of the extrudate.

There was a positive correlation of hardness with blend ratio as shown in Figure 6. The minimum value of hardness was appeared at 2% concentration of safed musli powder in blend. Since safed musli is rich in fiber content and fiber raises the hardness of outer layer of extrudate[11]. Feed moisture set up the curvilinear relation with hardness. Hardness was found in decreasing order up to middle value of feed moisture afterwards it started to increase on increasing the feed moisture. Minimum hardness was observed at 14% feed moisture and maximum at 18%, [12,13] also reported that increasing feed moisture resulted in a significant increase in hardness. Increasing feed moisture results in lower degree of starch gelatinization for different products[14,15].

Figure 3 depicted the combine effect of die head temperature and barrel temperature on the hardness. Barrel temperature shows the negative effect whereas die head temperature has the positive effect on hardness. The tendency to increase hardness at higher die head temperature may be due to the higher melt temperature that has caused changes in the chemistry of the melt[17].

3.2 Crispness of Extrudate Snacks

Crispness is related with rapid drop of force during mastication process, attribute that is based on fracture propagation in brittle materials[18]. When force is applied to brittle snacks, rupture of the cellular structure occurs,
generating a typical sound that contributes to the crispness sensation\textsuperscript{19}. Materials considered to be crisp usually generate irregular force–deformation curves.

In this experiment, crispness for all the extruded samples ranged from 4 to 22. The highest value of crispness was obtained at 14% feed moisture, blend ratio of brown rice (80%): water chestnut (18%): safed musli powder (2%), 160°C barrel temperature, 200°C die head temperature and 160 rpm screw speed. Figure 2 shows the textural profile of highly crispy extrudate of brown rice, water chestnut and safed musli powder. Second order polynomial model was good descriptor for these process parameters. The multiple regression models for predicting the crispness showed regression coefficient ($R^2$) 0.87 and a non-significant F-value of 0.79 as lack of fit. The model was significant having P-value of 0.0108. The response surface 3D graphs for crispness (Figure 6 to Figure 8) 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:

\[
\text{Crispness: } -258.33 + 14.93 \times \text{MCF} - 1.06 \times \text{BR} - 0.16 \times \text{BT} + 1.08 \times \text{DHT} + 0.89 \times \text{SS} + 0.14 \times \text{MCF} \times \text{BR} - 0.023 \times \text{MCF} \times \text{DHT} - 0.04 \times \text{MCF} \times \text{SS} - 0.03 \times \text{BR} \times \text{BT} - 0.20 \times \text{MCF}^2 + 0.23 \times \text{BR}^2
\]  

(2)

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.

Concentration of safed musli powder had negative effect on crispness of extrudate (Figure 6). Safed musli is a root crop, having higher percentage of fiber and it intervenes with air bubble formation and increases air cell wall thickness\textsuperscript{20,21}. It can be seen that extrudate snacks having higher feed moisture had the lower crispness. It might be due to the reduced expansion caused by the increase in moisture content\textsuperscript{22}.

Increasing screw speed improved the expansion of extrudate\textsuperscript{23}, ultimately higher screw speed resulted in the higher crispness (Figure 7).

Effect of barrel temperature on crispness was found positive (Figure 8).\textsuperscript{34} reported that soluble starch increased with increasing extrusion temperature and decreasing feed moisture. At high temperatures, the feed moisture flashes off as steam and causes bubble growth resulting a higher crispy texture of extrudates.
4. Conclusion

The optimum extrusion conditions that resulted in extrudate snacks with the best textural quality (minimum hardness and higher crispiness) were: 13% feed moisture with the higher range of screw speed (180 rpm), die head temperature (170°C), barrel temperature (188°C) and 3% concentration of safed musli powder. The replacement of increasing amounts of safed musli powder from 2% to 10% with water chestnut flour affects the textural properties (hardness and crispness) in a negative way. It was confirmed in this study that higher fiber content present in safed musli decreases the crispness and increases the hardness of extrudate. Screw speed showed the positive effect for crispness and negative for hardness. An optimum range of temperature is required for starch gelatinization. Higher range of temperature was preferred in the range of 170°C barrel temperature and 188°C die head temperature for crispiness and negative for hardness. An optimum range of temperature is required for starch gelatinization. An optimum range of temperature is required for starch gelatinization.

5. Reference

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