# OPTIMIZATION OF FIBRE AND PROTEIN RICH EXTRUDED SOYBEAN-RICE BASED READY TO EAT SNACKS


## ABSTRACT

Ready to eat, nutritious and low-cost snack was developed by composite flour containing defatted soya, rice, salt, radish leaves and pea pods powder. The best possible combination of process parameter was obtained with response surface methodology (RSM) using Box Behnken design. The different process variables viz., screw speed, die temperature, feed moisture and composition of base and supplement materials were optimized to obtain good quality soybean-rice based snack food. The designed experimental runs were conducted to obtain the optimal conditions as 360.42 rpm speed of screw (SS), 152.29 °C die temperature (DT), 13.17% feed moisture (FM), 35 % vegetable waste-soy powder (VW-SP) proportion and 65% of base flour. The results revealed that the addition of vegetable waste (radish leaves and pea pods powder) and soy powder had the most significant impact on all process variables followed by the feed moisture content. The blend proportion under optimum extrusion conditions had improved the nutritional quality of snack food with 1.55g/ 100g of fiber and 20.61g/100g of protein content and overall acceptability of 78.41%.



Keywords: Vegetable waste powder, Response surface methodology, Nutrional rich




**Novelty Impact Statement**

India is the 2nd major producer of fruits and vegetables and next rank to China in the world. India contributes 8% of world fruit production and 15% of world vegetable production. In accordance with fruit and vegetable production, wastes are also created in huge amount during different stages of harvesting, processing, marketing, transportation etc. At present up to 1/3rd of fruit and vegetable in the form of peels, skins and leaves can be discarded during preparation and processing therefore creating waste. These wastes are dumped which create health and environmental issues. Fruit and vegetable by-products are characterized by a high dietary fibre content resulting with large water binding capacity and fairly low enzyme digestible organic matter. Recycling of fruit and vegetable waste is an essential way of utilizing it in a number of inventive ways developing new products. Researchers are discovering new inventive ways to find alternative ways to use these wastes as potential value-added ingredients in feed. This research work gives a potential utilization of vegetable waste (Radish leaves and pea pods) in development of value-added products.

## Introduction

The consumption pattern for inexpensive ready-to-eat snacks is increasing in developing countries. Different sources of protein i.e. mungbean, chickpea and groundnut and fiber from fruit and vegetable by-products (Grigelmo-Miguel and Martín-Belloso 1999) i.e.,apple pomace (Hwang et al 1998), onion pomace (Ng ~~A~~ et al 1999), blueberry (Khanal et al 2009), citrus pomace (Navneet et al 2010), sweet orange (Syed et al 2011), peach pomace (Sarkar and Gour 2014), sweet lemon pomace ~~(~~(Kirandeep et al 2015), carrot pomace and cauliflower trimming ~~(Alam et al 2016)~~ and have been used to replace base material i.e. rice and improve nutritional

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quality of rice based snacks. (Alam et al 2016). Nowa-day's peoples are also using soybean (*Glycine max*) as a source of plant protein to improve the diet. The defatted soybean flour was used to improve the protein content of the extruded snacks, i.e. by-products of the oil processing industry.

Fruit and vegetables are an important source of our daily nutrition as they are rich in vitamins, minerals and other nutrients. In addition to nutrition, fruits and vegetables are considered as cash crop by growers. The growing of fruits and vegetables were limited in many countries, to certain season and local localities. But India with 20 agro climatic regions has an advantage of favourable environmental condition to produce most of the fruit and vegetables. India is the 2nd major producer of fruits and vegetables next to China. –India contributes 8% of world fruit production and 15% of world vegetable production. In accordance with fruit and vegetable production, wastes are also created in huge amount during different stages of harvesting, processing, marketing, transportation etc. At present up to 1/3rd of fruit and vegetable in the form of peels, skins and leaves can be discarded during preparation and processing therefore creating waste. These wastes are dumped which create health and environmental issues. Fruit and vegetable by-products are characterized by a high dietary fibre content resulting with large water binding capacity and fairly low enzyme digestible organic matter (Serena and Kundsen, 2007). Recycling of fruit and vegetable waste is an essential way of utilizing it in a number of inventive ways developing new products. Researchers are discovering new inventive ways to find alternative ways to use these wastes as potential value added ingredients in feed.

Radish (*Raphanus sativus L.)* is an edible root vegetable belonging to the family of Brassicaceae.- The radish leaves comprises 30-40% of the whole crop and the ratio of leaf to radish varies as per the maturity level. The leaves of radish are rich in protein having digestibility coefficient of 73.5% and biological value of 76.6. It also contains twenty-two amino acids and the essential oil extracted from leaves is of the tune of 0.002% containing 2-hexane -1 al (leaf aldehyde) 3- hexane -1 ol (leaf alcohol). Additionally meagre amount of isovaleraldehyde, n – and isobutyraldehyde, and some lavone compounds also found in leaves (Suleiman and Maryam, 2005). The radish leaves rich in iron, ascorbic acid and calcium has a great potential for its utilization in processed food. Moreover, phytin in rice helps in calcification when consumed along with radish leaves high in calcium (Singh and Singh 2013). Pea (*Pisum sativum L.)* is another important crop with a high waste index, the tiny spherical seed that belongs to the family of Ffabaceae, also known as the legume family.

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Fresh pea contains protein (25%), amino acids (12%), carbohydrates (16%), vitamin A and C, Calcium, phosphorous and small quantity of iron. Pea contains only 30-40% seed and 60-70% portion as pods which go as wastage (Ref). Pea pods content and nutritional values are unexploded but it consumed as raw in some places and they contain a waxy layer known as parchment layer, which is not consumable and irritates consumer. This content of pea pods makes them healthy and nutritious alternatives to be utilized in current food chain. By using this waste produced from various processing industries, the intake of dietary fiber that is easily recommended is met by creative ways of introducing attractive items.

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Extrusion cooking is considered as high temperature and short time i.e. HTST process in which the wet ingredients are exposed for a particular residence time in the extruder for obtaining the specified temperature and pressure. This technique has wider adoptability for production of snacks, pet foods, modified starch, nuts, baby foods, pasta etc. (Toft, 1979). Extrusion cooking is becoming popular due to its versatile application, low operational cost, good quality products and effluents free process (Abbott 1987, Camire et al 1990). Therefore, it is possible to use radish leaves and pea pods profitably to produce value added items using extrusion cooking.

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The objective of this wok was to study the effect of screw speed, die temperature and composition of different ingredients on the nutritional quality of ready to eat fiber rich extruded snacks and to optimize the levels of composition of different ingredients, speed of screw, feed moisture.

## 2 Material and methods

### 2.1 Materials

Broken rice, degreased soybean flour and salt were obtained from the local Ludhiana, Punjab market. In Ludhiana, Punjab, radish leaves and pea pods were collected from local vegetable markets. For extrusion research, a laboratory scale co-rotating intermeshing twin screw extruder (Model BC2; Clextral, Firminy Cedex, France) available at the Department of Food Science and Technology, Punjab Agricultural University, Ludhiana was used. The analytical grade was used for all chemicals and reagents used in the analysis.

### 2.2 Methods

#### 2.2.1 Experimental design for preparation of composite flour

Ready to eat extruded snack was prepared by varying the extruder temperature (130-170 °C), speed of screw (300-500 rpm), feed moisture (12-20%), base material i.e. rice flour (65-85%) and supplement material vegetable waste powder (35-15%). The product was optimized through Box Behnken design with 27 trails using response surface methodology. The response evaluated were bulk density (BD), expansion ratio (ER), Hardness (H-N), specific mechanical energy (SME), water solubility index (WSI), water absorption index (WAI-g/g), protein content (PC) ,colour change (CC), crude fiber (CF) content and overall acceptability (OA).

2.2.2 Preparation of raw material and its characterization

The rice flour is prepared by using a grinder to make broken rice. Radish leaves were pre-treated with hot water and placed uniformly on a 65 °C tray dryer until a moisture content of 2.08 per cent was reached (d.b.). Although untreated pea pods were placed uniformly at 75 °C to a moisture content of 2.98 percent on a tray dryer (d.b.). The vegetable waste was ground to get powder. Vegetable waste powder was stored in laminated sealed aluminium pouches till further use. All the ingredients i.e. rice flour, defatted soybean flour, salt and vegetable waste powder were mixed as presented in Table 1. Radish leaves and pea pods powder are mixed in a 50:50 ratio in a food processor with a mixing attachment for the preparation of vegetable waste powder. In the same food processor with mixture attachment, rice flour (65-85g/100g), degreased soy flour (7.5-17.5g/100g) and vegetable waste powder (7.5-17.5g/100g) were mixed in the same proportion. Samples were placed in laminated sealed aluminium pouches at room temperature for further use after preparation of the mixture. Developed extruded were shown in Fig.1.

2.2.3 Characterization of extruded snacks

2.2.3.1 Protein and fibre content analysis

The protein and fiber content of developed extrudates was determined by standard procedures outlined by Association of Official Analytical Chemists (HorwitzAOAC, 2000).

2.2.3.2 Determination of properties of developed extrudates snacks

Bulk density (BD): A 500 ml measuring cylinder was used to determine the density of extruded snacks by rapeseed displacement method. The volume of 10 g randomized samples was measured for each sample. The ratio of sample weight and replaced volume in the cylinder was calculated as density (Patil et al 2007).

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$$\text{Bulk Density (g/cm}^3\text{)} = \frac{\text{Weight of extrudates (g)}}{\text{Volume displaced by extrudates (cm3)}}$$

2.2.2.1 Expansion ratio (ER): The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate (Fan et al 1996). (Fan et al 1996). The diameter of extrudate was calculated as the mean of 10 random measurements made with a Vernier caliper. The expansion ratio of extruded products was measured as:

$$\text{Expansion ratio} = \frac{\text{Extrudate Diameter}}{\text{Die diameter}}$$

2.2.2.2 Water absorption index (WAI) and Water solubility index (WSI): Water Absorption Index (WAI) and water solubility index (WSI) was determined according to method developed for cereals (Stojceska *et al*., 2008). A sample of 2.0 g ± 0.005 g was put in a tare centrifuge tube and added 20 ml of distilled water. The sample was centrifuged at 4000 rpm for 15 min after holding for 15 min (with periodic shaking every 5 min). A tared aluminium pan was decanted into the supernatant and weight gain in the gel was noted. Water absorption index (WAI) was measured as the increase in weight of sediment obtained after decanting the supernatant as:

$$\text{WAI (g/g)} = \frac{\text{Weight of wet sediment (g)}}{\text{Weight of dried sample (g)}}$$

At 105 ° C until constant weight, the supernatant evaporated to dryness. The index of water solubility (WSI) was measured as:

$$\text{WSI (\%)} = \frac{\text{Weight of dried supernatant (g)}}{\text{Weight of dried extrudate (g)}} \times 100$$

2.2.2.3 Texture attributes: Textural attributes of extrudates were determined by texture profile analysis (TPA) using Texture Analyzer, model TA-XT2i (Stable Micro-Systems, Surrey, England) equipped with a compression plate P75. The tests were conducted at pre–test speed of 1.0 mm/sec, test speed of 5 mm/sec, post test speed of 5 mm/s at strain of 75% and trigger force of 0.4903 N using load cell of 50kg. The highest first peak value was recorded as this value indicated the first rupture of snack at one point and this value of force was taken as a measurement for hardness (Stojceska et al., 2008).

2.2.2.4 Color attributes: The Color Reader CR-10 (Konica Minolta Sensing Inc.) was used for measuring the color of extruded samples. For determination of color, the sample was ground to powder with the help of Grinder (Make: Sujata 750 W). The powder was completely filled in Petridis in such a way that that no light could pass through sample during the measuring process. The ‘L’, ‘a’ and ‘b’ values were recorded at D 65/10°.

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The color change, hue angle and chroma were measured by the equation given by Gnanasekharan et al (1992).

Color change = √ (L-L0) 2 + (a-a0) 2 + (b-b0) 2

Hue angle = Tan-1(b/a)

Chroma = √ (a2 + b2)

Where; L0, a0 and b0 represent the respective readings of developed raw sample before extrusion.

2.2.2.5 Sensory evaluation: Organoleptic quality of developed product was conducted on a 9-point hedonic scale (9-liked extremely to 1-disliked extremely) according to the method described by Amerine et al (1965). Semi-trained panels of ten judges were selected for the evaluation. The samples were evaluated in terms of appearance, colour, taste, aroma and overall acceptability. Overall acceptability was evaluated as an average of appearance, colour, taste and aroma and is expressed in percentage. The average score of all the 10 panellists were computed for different characteristics.

2.2.2.6 Specific mechanical energy (SME): Specific mechanical energy SME (Wh/kg) was calculated from rated screw speed, motor power rating (8.5kW), actual screw speed, % motor torque and mass flow rate (kg/h) using the following formula (Pansawat *et al* 2008):

$$\text{SME (Wh/kg)} = \frac{\text{Actual screw speed (rpm)} \times \text{\% motor torque} \times \text{motor power rating} \times 1000}{\text{Rated screw speed (rpm)} \times \text{Massflow rate } (\frac{\text{kg}}{\text{h}}) \times 100}$$

### 2.2.3 Statistical analysis

All analysis has been performed in the duplicates and using the RSM to fir the quadratic polynomial equation generated by design expert software, the data obtained in the experiment was analyzed. Multiple regressions were used to compare the response variable with the independent variables to fit the coefficient of the polynomial response model. Variance analysis (ANOVA) is used to measure the fitted model's consistency.

### 2.2.4 Extrusion process parameters optimization

The Box-Behnken design is used for optimization of extrusion process and aimed at finding the levels of independent variables i.e. SS (300-500rpm), DT (130-170 °C) and radish leaves and pea pods powder (7.5-17.5 g/ 100g) in base material (rice flour 65-85g /100g) which would give minimum BD, CC, H and SME maximum ER, PC, FC, WAI, WSI, OA.

## 3 Results and discussion

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3.2 Functional properties of vegetable waste, rice and defatted soy flour

The result of the composite flours functional properties are shown in Table 02. The variables were VW-SP, SS, DT and FM, while the responses were bulk density, water solubility index, water absorption index, expansion ratio, hardness, protein content, crude fiber, specific mechanical energy, colour change and overall acceptability.

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### 3.2.1 Bulk density (BD)

The Eextrudates ranged in bulk density from 0.18 to 0.68 g/cm$^3$, which is high. It is also observed that higher values of bulk density are desirable in developed product. BD is desirable higher for reduction of paste thickness and ease of dispensability The ANOVA outcome for BD's response surface model (RSM) showed that the components of the liner mixture as well as $D^2$ are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was achieved. The $R^2$ value changed is 0.8090. The BD of the extrudates has been shown to increase with the increase in the moisture content of the feed. Increased feed moisture content during extrusion may decrease the elasticity of the dough by plasticizing the melt, resulting in decreased SME and thus decreased gelatinization, decreased expansion and increased extrudate density (Mercier and Feillet 1975; Barrett and Peleg 1992; Pan et al., 1998). However, an increasing trend in BD of the extrudates was noticed with the increase in VW-SP in feed while a decreasing trend in BD of the extruded was notice with increase in die temperature and screw speed. The decrease in bulk density might be due to starch gelatinization at higher temperatures. Similar trend were observed for barley-tomato pomace blended snacks during extrusion processing (Altan et al., 2008). The final equation showing the effect on the bulk density of the variables is shown in eq.

$$\textbf{BD} = 0.34 + 0.040 * A - 0.054 * B - 0.022 * C + 0.10 * D + 0.089 * D^2$$

### 3.2.2 Water solubility index (WSI)

WSI values of the extrudates varied from 6.50% to 21.29%. The WSI determines the amount of polysaccharides released from granule after addition of excess water (Sriburi and Hill 2000). As an indication of degradation of molecular components, it is used (Kirby et al 1988). The ANOVA outcome for WSI's Response Surface Model (RSM) showed that the components of the liner mixture as well as CD and $D^2$ are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was obtained. The adjusted $R^2$ value is 0.7618. The WSI values of the extrudates showed decreasing trend with increase feed moisture content. In the extrusion process, greater feed

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Comment [JLRC8]: It is not in the References moisture content will decrease protein denaturation, which subsequently reduces WSI values. Similar results for wheat flour and cassava flour extrudates have been documented by Badrie and Mellowes (1991) and Hernandez-Diaz et al (2007). WSI values increased with the increase in screw speed, VW-SP proportion and die temperature. The temperature rise could increase the degree of gelatinization of the starch, which could increase the amount of soluble starch, resulting in an increase in WSI. The positive relation between WSI and temperature in extruded products was also achieved by Ding et al (2005). The final equation showing the effects on the WSI of the variables is shown in eq.

$$\textbf{WSI} = 14.32 + 0.43 * A + 1.0 * B + 1.51 * C - 2.29 * D - 2.42 * C * D - 2.8 * D^2$$

### 3.2.3 Water absorption Index

WAI values of the extrudates ranged from 3.9 to 5.862 g/g. Water absorption measures the amount of water absorbed by starch that can be used as an index of gelatinization (Anderson et al 1969). It tests the water retained by the starch in excess water after swelling, which corresponds to the weight of the produced gel. It will ensure cohesiveness of goods. For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as $A^2$ are essential terms of the model ($p \leq 0.05$). -A non-significant lack of fit was achieved. The adjusted $R^2$ value is 0.7594. WAI values of the extrudates also increased whereas a decreasing trend in the WAI values of the extrudates was observed with increase in feed moisture content, VW-SP proportion and die temperature. A decrease in WAI with increasing die temperature was probably due to decomposition or degradation of starch (Pelembe et al 2002). -The decrease in WAI with increase in feed moisture can be easily explained by the fact that with the subsequent increase in moisture, tendency to absorb water decreases. The final equation showing the effects on the WSI of the variables is shown in eq.

$$\text{WAI} = 5.23 - 0.42 * A + 0.015 * B - 0.1 * C - 0.2 * D + 0.4 * A2$$

### 3.2.4 Expansion ratio (ER)

The values of expansion ratio of the extrudates ranged from 1.17 to 2.36 irrespective of the extrusion process variables. Expansion ratio indicates extent of puffing of extruded products. For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as $B^2$ are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was achieved. The $R^2$ value changed is 0.8786. The ER showed increasing trend with increase in screw speed whereas a decline in expansion ratio of extrudates was observed with increase in die temperature, VW-SP proportion and feed moisture content. The increase in ER with increase in screw speed may be attributed to the structural breakdown. Similar trends were reported by Mercier ~~and Feillet~~ (1975); Guha et al (1997). The final equation that shows the impact of variables on ER is shown in eq.

$$ER = 1.66 - 0.1 * A + 0.16 * B - 0.05 * C - 0.33 * D + 0.2 * B^2$$

3.2.5 Hardness (H)

The hardness of extruded materials varied between 101.05 and 189.37 N. Hardness is the peak force required for a probe or parallel blade to penetrate the extrudates. The higher the peak force required which means the more force required to break the sample, the higher is the hardness of the sample (Li et al 2005). For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as $C^2$ are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was achieved. The adjusted $R^2$ value is 0.8769. The hardness of the extrudates increased with increase in the feed moisture content and screw speed. It may be due to the fact that water acts as a plasticizer to rescue its viscosity and mechanical energy dissipation in the extruder to the starch-based material and hence the substance becomes dense and the growth of bubbles is compressed. Hardness of extrudates showed decreasing trend with increase in VW-SP proportion and temperature. It is expected that increasing temperature would decrease the melt viscosity, which favours the bubble growth and produce low density products with small and thin cells, thus increasing the crispness of the extrudates. Similar trend was also reported for barley flour tomato pomace blended extrudates (Altan *et al* 2008). The final equation showing effect of variables on H is shown in eq.

$$\mathbf{H} = 118.57 - 2.56 * A + 2.02 * B - 19.50 * C + 6.09 * D + 33.12 * C^2$$

3.2.6 Protein content (PC)

The protein content of the extrudates varied from 17.51 % to 20.80% with an average of 19.16%. For the response surface model (RSM) of WSI, the study of variance (ANOVA) outcome showed that the components of the liner mixture are important ($p \leq 0.05$) model terms. A non-significant lack of fit was achieved. The $R^2$ value

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changed is 0.9658. The Protein content of extrudates increasing trend with increase in VW-SP proportion while decreasing trend with increasing screw speed, feed moisture content and die temperature. The increase in protein content with increase in VW-SP proportion is because of the increase in the proportion defatted soya flour with decreasing rice flour proportion in the extrudates. The protein content decreased with increase die temperature may be due to protein denaturation during extrusion. According to Valentina *et al* (2014) lowering of proteins seems to be result of a combination of shearing, heat and pressure during extrusion. It has been suggested that low protein digestibility must result from changes in the proteins themselves during cooking (Duodu~~o~~ *et al* 2002). The final equation documenting the effect of variables on the PC is shown in eq.

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**PC** = 18.83 + 1.35 * A - 0.07 * B - 0.32 * C - 0.12 * D

3.2.7 Crude Fiber (CF)

The value of crude fibre for extrudates varied between 0.31 and 2.07%. For the response surface model (RSM) of WSI, the study of variance (ANOVA) outcome showed that the components of the liner mixture are relevant ($p \leq 0.05$) model terms. A non-significant lack of fit was achieved. The adjusted $R^2$ value is 0.7568. The crude fibre showed decrease trend with die temperature and feed moisture while increasing trend with increase in VW-SP proportion and screw speed. The increase in crude fibre of extrudates with increase in VW-SP proportion may be due to the fact that as the VW-SP proportion increases proportion of rice flour decreases which is main source of fibre in our snacks. Screw speed showed positive correlation with crude fibre of the extrudates. According to Stojceska et al (2008) extrusion cooking significantly decreased the level of fibres due to conversion of insoluble to soluble fibres. The final equation that shows the impact of variables on CF is shown in eq.

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**CF** = 1.34 + 0.44 * A + 0.0054 * B - 0.06 * C -0.007 * D

3.2.8 Specific mechanical energy (SME)

The SME of extruded products ranged from 143.1 Wh/kg to 210 Wh/kg. In starch conversion, the amount of mechanical energy supplied to the extruded material plays an important role. Higher SME usually results in a higher degree of gelatinization of starch and expansion of extrudates. Increased SMEs are therefore necessary for product expansion (Meng et al 2010). For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as BC and $D^2$ are essential terms of the model ($p \leq 0.05$). A non-

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significant lack of fit was achieved. The adjusted $R^2$ value is 0.8719. The hardness of the extrudates increased with increase in the feed moisture content and screw speed. It may be due to the fact that water acts as a plasticizer to rescue its viscosity and mechanical energy dissipation in the extruder to the starch-based material and hence the substance becomes dense and the growth of bubbles is compressed. Hardness of extrudates showed decreasing trend with increase in VW-SP proportion and temperature. It is expected that increasing temperature would decrease the melt viscosity, which favours the bubble growth and produce low density products with small and thin cells, thus increasing the crispness of the extrudates. Similar trend was also reported for barley flour tomato pomace blended extrudates (Altan et al 2008). The final equation that shows the impact of variables on CF is shown in eq.

$$\textbf{SME} = 180.33 - 2.33 * A + 3.15 * B - 13 * C - 24.20 * D + 17 * B * C - 12 * D^2$$

### 3.2.9 Colour change (CC)

The colour change of extrudates varied from 3.68 to 16.41. Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extrudate products.). For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as CD and $D^2$ are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was achieved. The adjusted $R^2$ value is 0.8871. The colour change showed increasing trend with increase in VW-SP proportion and feed moisture while decreasing trend with increase screw speed and die temperature According to Martinez-Flores et al (19998) the lightness reduction in extruded samples was probably due to the intensification of the maillard reaction, which occurred between reducing sugars and proteins, causing the products to change from light brown colours to dark colours. The final equation showing effect of variables on CC is shown in eq.

$$\textbf{CC} = 7.06 + 3.73 * A - 0.13 * B - 0.5 * C + 1.63 * D - 2.73 * C * D + 2.01 * D^2$$

### 3.2.10 Overall acceptability (OA)

OA of the extrudates ranged from 55.56% to 94.44%. Using a 9 point hedonic scale, overall acceptability for sensory attributes (appearance, texture, taste and aroma) was measured by 15 judges. For the response surface model (RSM) of WSI, the analysis of variance (ANOVA) outcome showed that the components of the liner mixture as well as B2 are essential terms of the model ($p \leq 0.05$). A non-significant lack of fit was achieved. The adjusted $R^2$ value is 0.9145. –The oOverall acceptability of the

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extrudates decreased with increase in VW-SP proportion and moisture content. It may be due to the fact that with increase in moisture content hardness also increases. OA increased with increase die temperature and screw speed. OA increased with increase in temperature because at a higher temperature, starch gelatinization is more which give better product quality. Increased OA with increased screw speed means that at higher screw speed, the substance is more homogenized and well gelatinized, which gives extruded products the favorable property. The final equation that shows the impact of variables on OA is shown in eq.

$$\mathbf{OA} = 73.15 - 3.43 * A + 4.4 * B + 1.20 * C - 10.5 * D + 4.20 * B^2$$

3.3 Process Optimization for ready to eat extruded product

Numerical optimization, which finds a point that maximizes the desirability function and equal importance was given to all the process parameters predicted values of BD (0.37), WSI (14.10), WAI (5.114), ER (1.78), H (110.68), PC (20.61), CF (1.55), SME (193.41), CC (10.43) and OA (78.40), was used for graphical optimization, i.e. numerical optimization plot (fig 2), to optimize extrusion process conditions. Best extrusion conditions by RSM were 152°C DT, 360 rpm SS, 13.17% FM, 35% VW-SP with desirability value of 0.60.

The technique of graphical multi-response optimization was introduced to assess the optimal working conditions for extruded product production using design expert software (Statease, DE 8.0.6.1). For lower BD, H, SME and higher ER, the process parameters were optimized while other parameters were kept 'in range'. These constraints resulted in optimum conditions in the "feasible zone" (shaded area in the superimposed contour plots). Superimposed contour plots with a general superimposed region of all extrusion process responses are shown in Fig 3. Screw speed is the range of optimized process variables that generate goods with identical properties: 320-375 rpm, FM: 13.5-13.8 percent, DT: 151-152 °C. The range of optimized process variables which will yield product with similar properties is screw speed: 320-375 rpm, FM: 13.5-13.8%, DT: 151-152°c and VW-SP: 32-35%

4 Conclusion

It is clear that vegetable waste powder could be used in ready-to-eat snacks. The developed snack has a relatively higher content of protein (20.61 g/100 g) and fibre (1.55 g/100 g), which would help to meet the recommended daily intake in children and adults of the functional components. To develop a good quality acceptable snack, optimum extrusion conditions of 152.29 °C DT, 360.42 rpm SS and 35 percent vegetable waste-soy powder (VW-SP) proportion and 65 percent of base flour blend with a desirability value of 78.41 percent could be used.

## COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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Table 1 Ingredient formulation for extruded snack

| | 85:7.5:7.5 | 75:12.5:12.5 | 65:17.5:17.5 |
|---|---|---|---|
| Broken rice flour (g) | 425 | 375 | 325 |
| Vegetable waste (g) | 37.5 | 62.5 | 87.5 |
| Defatted-soy flour (g) | 37.5 | 62.5 | 87.5 |
| Total (g) | 500 | 500 | 500 |

**Table 2 Experimental data of vegetable waste incorporated soy-cereal based product for response surface analysis**

| Process Parameters | | | | Product quality responses | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CP: VW-SP (%)** | **SS (rpm)** | **DT ($^0$C)** | **FM (%)** | **BD (g/cm$^3$)** | **ER** | **SME (Wh/Kg)** | **WAI (g/g)** | **WSI (%)** | **H (N)** | **CC** | **OA (%)** | **PC (g/100g)** | **CF (g/100g)** |
| 75:25(0) | 300(-1) | 130 (-1) | 16(0) | 0.24 | 1.90 | 205.0 | 5.233 | 12.44 | 186.72 | 7.34 | 77.78 | 19.18 | 1.073 |
| 85:15(-1) | 300(-1) | 150(0) | 16(0) | 0.36 | 1.96 | 207.8 | 5.799 | 10.49 | 153.78 | 3.68 | 77.78 | 17.55 | 0.630 |
| 75:25(0) | 400(0) | 150(0) | 16(0) | 0.35 | 1.80 | 180.0 | 5.225 | 14.32 | 118.57 | 7.06 | 70.37 | 18.83 | 1.069 |
| 75:25(0) | 500(1) | 150(0) | 20(1) | 0.44 | 1.67 | 149.0 | 4.906 | 09.24 | 150.81 | 9.73 | 71.30 | 18.64 | 1.071 |
| 65:35(1) | 400(0) | 170(1) | 16(0) | 0.43 | 1.57 | 176.0 | 4.996 | 12.23 | 132.70 | 13.30 | 67.15 | 19.65 | 1.470 |
| 75:25(0) | 400(0) | 170(1) | 20(1) | 0.47 | 1.45 | 143.3 | 4.365 | 08.85 | 134.75 | 08.12 | 59.74 | 18.2 | 1.015 |
| 75:25(0) | 500(1) | 150(0) | 12(-1) | 0.37 | 2.16 | 195.0 | 5.233 | 11.69 | 101.05 | 07.90 | 83.74 | 18.69 | 1.070 |
| 75:25(0) | 400(0) | 130(-1) | 20(1) | 0.58 | 1.51 | 146.0 | 3.900 | 08.20 | 189.37 | 16.41 | 56.96 | 18.89 | 1.072 |
| 85:15(-1) | 400(0) | 150(0) | 20(1) | 0.51 | 1.35 | 152.0 | 5.612 | 07.60 | 112.23 | 05.19 | 68.07 | 17.66 | 0.671 |
| 75:25(0) | 500(1) | 170(1) | 16(0) | 0.25 | 2.11 | 189.8 | 4.392 | 13.80 | 134.78 | 07.62 | 84.74 | 18.36 | 0.980 |
| 75:25(0) | 300(-1) | 150(0) | 12(-1) | 0.38 | 2.00 | 194.3 | 4.926 | 10.19 | 113.59 | 07.37 | 84.74 | 18.86 | 1.063 |
| 75:25(0) | 400(0) | 150(0) | 16(0) | 0.30 | 1.37 | 176.0 | 4.625 | 15.00 | 112.69 | 06.46 | 75.93 | 18.23 | 0.87 |
| 65:35(1) | 400(0) | 150(0) | 12(-1) | 0.31 | 1.89 | 193.8 | 5.016 | 13.14 | 113.29 | 10.10 | 85.67 | 20.78 | 1.490 |
| 75:25(0) | 400(0) | 170(1) | 12(-1) | 0.26 | 2.13 | 192.8 | 4.596 | 21.29 | 133.15 | 10.12 | 81.04 | 18.49 | 1.040 |
| 85:15(-1) | 400(0) | 150(0) | 12(-1) | 0.23 | 2.36 | 200.8 | 5.862 | 11.33 | 109.85 | 03.81 | 94.44 | 17.73 | 0.668 |
| 75:25(0) | 300(- | 150(0) | 20(1) | 0.68 | 1.1 | 145.0 | 4.56 | 06.5 | 107.98 | 14.7 | 55.5 | 18.67 | 1.060 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1) | | | | 7 | | 6 | 0 | | 4 | 6 | | |
| 75:25(0) | 400(0) | 130(-1) | 12(-1) | 0.39 | 2.02 | 198.6 | 4.800 | 10.95 | 165.96 | 07.49 | 70.37 | 18.93 | 1.080 |
| 85:15(-1) | 400(0) | 130(-1) | 16(0) | 0.37 | 1.85 | 210.0 | 5.762 | 10.55 | 163.81 | 03.68 | 73.62 | 17.75 | 0.680 |
| 75:25(0) | 300(-1) | 170(1) | 16(0) | 0.36 | 1.40 | 145.0 | 4.401 | 13.19 | 113.81 | 06.06 | 69.93 | 18.58 | 0.948 |
| 75:25(0) | 500(1) | 130(-1) | 16(0) | 0.33 | 2.03 | 182.0 | 5.125 | 11.04 | 168.70 | 9.30 | 79.63 | 19.02 | 1.110 |
| 85:15(-1) | 400(0) | 170(1) | 16(0) | 0.32 | 1.71 | 143.1 | 5.790 | 14.10 | 155.13 | 03.90 | 80.11 | 17.51 | 0.310 |
| 65:35(1) | 400(0) | 150(0) | 20(1) | 0.51 | 1.47 | 149.6 | 4.816 | 10.69 | 114.88 | 12.17 | 62.52 | 19.98 | 1.441 |
| 75:25(0) | 400(0) | 150(0) | 16(0) | 0.37 | 1.80 | 185.0 | 5.825 | 13.64 | 124.44 | 7.66 | 73.15 | 19.43 | 2.07 |
| 65:35(1) | 300(-1) | 150(0) | 16(0) | 0.48 | 1.82 | 180.2 | 5.016 | 12.33 | 122.70 | 12.55 | 69.93 | 20.62 | 1.463 |
| 85:15(-1) | 500(1) | 150(0) | 16(0) | 0.18 | 2.25 | 208.2 | 5.688 | 16.28 | 125.40 | 04.52 | 85.67 | 17.69 | 0.580 |
| 65:35(1) | 400(0) | 130(-1) | 16(0) | 0.44 | 1.63 | 203.2 | 4.908 | 12.13 | 163.78 | 10.39 | 69.93 | 20.8 | 1.510 |
| 65:35(1) | 500(1) | 150(0) | 16(0) | 0.28 | 1.90 | 191.1 | 4.772 | 14.94 | 142.12 | 11.05 | 83.33 | 20.21 | 1.485 |

Note: DT= Die Temperature, CP=Cereal Proportion, VW-SP= Vegetable waste-soya powder mixture, FM= Feed Moisture, SS= Screw Speed, BD= Bulk Density, ER= Expansion Ratio, SME= Specific Mechanical Energy, WAI= Water Absorption Index, WSI= Water Solubility Index, H= Hardness, CC= Color Change, OA= Overall Acceptability PC = Protein content, CF = Crude fibre.

Table 3 **Optimum values of process parameters and responses for vegetable waste incorporated soy-cereal based product using RSM**

| | Target | Experimental Range | | Optimum value | Desirability |
|---|---|---|---|---|---|
| | | Min | Max | | |
| Screw speed (rpm) | Range | 330 | 500 | 360.42 | |
| Die Temperature (°C) | Range | 130 | 170 | 152.29 | |
| Feed Moisture (%) | Range | 12 | 20 | 13.17 | |
| VW-SP Proportion (%) | Range | 15 | 35 | 35 | |
| Responses | | | | | |
| BD (g/cm3) | Minimize | 0.18 | 0.68 | 0.37 | 0.60 |
| ER | Maximize | 1.17 | 2.36 | 1.78 | |
| H(N) | minimize | 101.05 | 189.37 | 110.66 | |
| WAI(g/g) | Maximize | 3.9 | 5.862 | 5.11 | |
| WSI (%) | Maximize | 6.5 | 21.29 | 14.10 | |
| SME(Wh/kg) | Minimize | 143.1 | 210 | 193.41 | |
| CC | Minimize | 3.68 | 16.41 | 10.43 | |
| PC (%) | Maximize | 17.51 | 20.8 | 20.61 | |
| CF (%) | Maximize | 0.31 | 2.07 | 1.55 | |
| OA (%) | Maximize | 55.56 | 94.44 | 78.41 | |


Fig. 1 Extrudates developed from composite powder of rice flour-defatted soy flour-vegetable waste powder

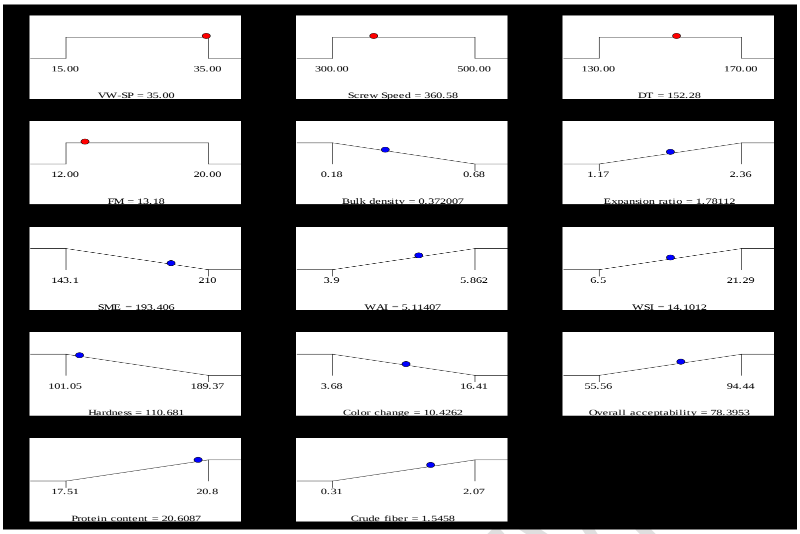


Fig 2 Point predication of process parameters and response using numerical optimization for extrusion process parameters.

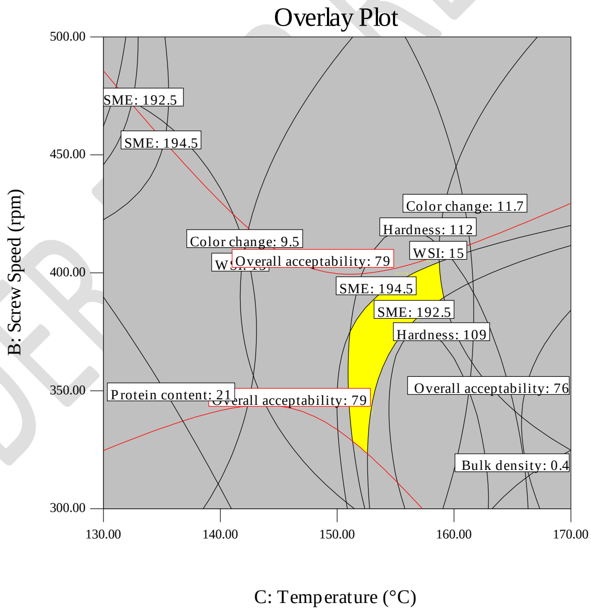


Fig 3 Overlay contours of different responses for optimization of extrusion process parameters for extruded snack