Study on the effect of machine operative parameters on physical characteristics of rice/maize based fruit/vegetable pulp fortified extrudates

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Abstract: Rice / Maize based extruded products were formulated in addition to fruit (guava, banana) and vegetable (tomato, pumpkin) pulp to enhance the nutritive value and flavour to fulfil the requirements of children from three to five years old. The Response Surface Methodology was used with machine parameters as independent variables (die temperature, screw speed and feed rate) while physical parameters such as expansion ratio, density and textural characteristics were analysed for model validation. The extrusion of cereals by adding 10% of pulp of fruit and vegetable was an added advantage on nutrition and structure. The final product was agreeable in terms of physical structure by slightly compromising in expansion and texture. The banana added extrudates of rice and maize had maximum expansion and lower in toughness.

Keywords: Extrusion process, fruit and vegetable fortified extrudates, response surface method; snack food, optimization

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1 Introduction

Extrusion cooking is a well known method that has gained popularity due to its technological advantages over the traditional processing techniques and is widely utilized in the production of snack foods that are cholesterol free, low in fat and rich in phyto factors (Robin, 2001; Riaz, 2000). Extrusion cooking combines several unit operations such as mixing, kneading, cooking, shearing, shaping, drying, and expanding (Harper, 1978, 1981 and 1991). The stated unit operations take place in the barrel of extruder and provide different physical and chemical functionality to food materials (Kokini and Karve, 1992). This is a process of high temperature in a short time that brings several changes in the feed material such as physical expansion, change in density, texture etc. in addition to chemical changes such as gelatinization of starch, denaturation of protein, modification of lipid, inactivation of enzymes etc. Cooking of starch granules at higher temperature, pressure and shear causes changes in starch morphological and molecular structure depending on several factors including moisture content, cooking temperature, and mechanical/thermal energy input (Faubion et al., 1982, Tadmor and Klein, 1970).

Several studies have shown that extrusion processing variables such as extruder type, screw configuration, screw speed, extrusion temperature and feed rate greatly influences the overall properties of extruded products (Chiu et al., 2012; Nurtama and Lin, 2009; Leonel et al., 2009). Extruded products are generally prepared with cereals that are rich in starch which is an important constituent during the process and influences the properties of end product. In extrusion cooking the mass of raw material transformed into a melt stream and subjected to a number of unit operations to mix and transform the native ingredients into new functional form. Therefore, extrusion cooking is a feasible technique to manufacture expanded products and has been the object of studies to enhance the nutritional and functional properties

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of extrudates for the development of various products (Robin, 2001).

Consumers are these days more concerned with the quality of product and are demanding a healthy product that can fulfil all the nutritional needs and that is also cost effective. To meet the challenge of consumers great effort is required to either produce a new product with desirable functional characteristics or to modify the composition of existing products. Since, extruded products are well known among consumers of all the age group, it can be enriched with required nutrition to meet the growing demand of health conscious consumer. Fruits and vegetables are known to fulfil most of the required vitamins and minerals. These are highly consumed and are a part of our regular diet. Since children are found to be very selective about their food and most of them are not having a proper balanced diet required for their growth and development. A product that is different from the usual food and that is capable to provide needed nutrition in the form children are attracted will help to fulfil their requirement.

In the present study, a functional food product for children of age from three to five years old is developed that can meet their nutritional requirements as per Recommended Dietary Allowance (RDA). An extruded product with added benefits of fruits and vegetables pulp, was formed that helped in enhancing both the nutritional quantity and flavour. Fruits such as banana and guava while vegetables such as pumpkin and tomato were pulped and the pulp were mixed at certain level (10%) to rice and maize flours along with other constituents to prepare snack food for children. Further, the effect of the extruder parameters such as die temperature, screw speed and feed rate on the quality of final product was assessed. Since market is flooded with a variety of extruded product hence there is need for a product that is different from the one available in market. Hence, a product with additional benefits of fruits and vegetables was prepared.

2 Material composition

2.1 Nutritional requirement

Protein, fat, calcium, and energy requirement for children of age up to three years, as per the Recommended Dietary Allowance (RDA) were considered for formulation of functional foods. The nutritional requirement of the said age group has been depicted in Table 1 and these facts were considered for recipe preparation and optimization. On the basis of these nutritional facts feed ingredients were selected.

Table 1 Nutritional requirement (RDA) of children of 3-5 years age (Gopalan et al, 2007)

Protein/g	Fat/g	Calcium/mg	Energy/kcal
57	32	600	1900

2.2 Feed ingredients

Nutritional properties and cost of the feed ingredients have been presented in Table 2. Experiments were planned to blend fruits and vegetable pulp with rice or maize, wheat, bengal gram and milk powder. Two fruits (banana and guava) and two vegetables (tomato and pumpkin) were considered for the purpose. Some important nutritional properties of selected fruits and vegetables are mentioned in Table 3.

Table 2 Important nutritional facts of feed ingredients (Gopalan et al., 2007)

Material	MC /%	Protein /g $(100g)^{-1}$	Fat /g $(100g)^{-1}$	Calcium /mg $(100\ g)^{-1}$	Energy /kcal
Rice	13.7	6.8	0.5	10.0	345.0
Maize	14.9	11.1	3.6	10.0	342.0
Wheat	12.2	12.1	1.7	48.0	341.0
Bengal Gram	9.9	20.8	-	56.0	372.0
Milk powder	3.5	20.5	19	1370.0	462.0

Table 3 Important nutritional facts of selected Fruits and Vegetables (Gopalan et al., 2007)

	Tomato	Pumpkin	Banana	Guava
Water/g	93.1	95	75.1	84.7
Protein/g	0.7	0.7	1.2	0.8
Fat/g	0.3	0.2	0.3	0.5
Carbohydrate/g	3.1	2.2	23.2	5
Energy/kcal	17	13	95	26
Total sugars	3.1	1.7	20.9	4.9
Starch/g	Tr	0.3	2.3	0.1
Dietary fibre	1	1	1.1	3.7
Ca/mg	7	29	6	13
Fe/mg	0.5	0.4	0.3	0.4

2.3 Feed material ingredients and feed preparation

The optimized formulations were obtained with the help of MATLAB. While preparing the functional food the cost of product has to be optimized (minimized) with respect to meet various nutritional requirements. Thus linear objective functions were best optimized with linear programming technique of MATLAB using function "linprog". The basic ingredients were maize, rice, bengal gram, milk powder, guava, banana, tomato and pumpkin. The respective unit per Kg cost (in Indian rupees) were 40, 50, 80, 250, 30, 30, 25 and 40. The recipe, ingredients, and their proportion in feed have been shown in Table 4, which are optimized by the given method in MATLAB.

Table 4 Feed ingredients and their proportion in feed

Ingredient	Rice/Maize	Barley	Bengal gram	F&V Pulp	Milk Powder
% in feed	60	15	10	10	5

Feed material was prepared by blending the above mentioned material in 0.5 kg. Rice, maize, wheat and bengal gram were procured from local market and coarsely ground. The ground material was sieved (14 mesh size, ASTM standard). "Nestle dairy whitener" was used for milk powder blending in feed mixture. The selected fruits and vegetables were procured from local market on need basis and blended to feed mixture in pulp form with the help of a blender.

3 Methodology

3.1 Optimization technique for selection of raw ingredients

Initial trials were conducted to ascertain apposite level of starch forming material for adequate expansion of extrudates. Different level of maize and rice in combination with wheat, Bengal gram, sesame, and milk powder were formed. Some formulations were formed to get final products through extrusion for the children from three to five years old. Protein, fat, calcium and energy requirement for the age group were considered to formulate the raw material mix for final extrusion. Wheat, Bengal gram, maize, rice, and milk powder were taken to formulate the products on the basis of their nutritional values for the above mentioned parameters. The nutritional properties of the raw material (protein, fat, calcium and calorific value), costs of the ingredients, and required nutritional properties as mentioned for the children of three years old were used to optimize their proportion in the raw material for extrusion with the help of linear programming.

3.2 Fruit and vegetable pulp preparation

Fruit or vegetable pulp was prepared as per the flow of process given in Figure 1.

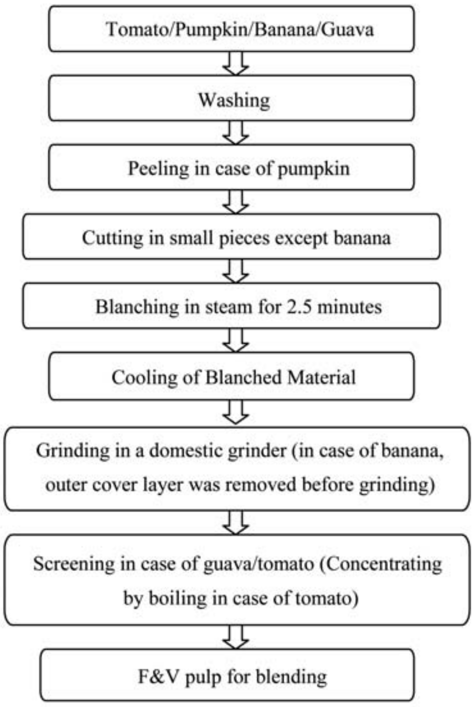


Figure 1 Flow diagram for processing of fruit/vegetable pulp

3.3 Extruder and machine parameters

A co-rotating twin screw extruder (BTPL, Kolkata, India) was used for extrusion cooking. The extruder was powered with a three phase motor of 10 hp, 10.4 A and 1,445 r min^{-1}. The screw was of three starter type with 58 mm pitch. The barrel length and diameter were 345 mm and 108.6 mm, respectively with a length and diameter ratio of 11.7. There was a clearance of 1.5 mm between barrel length and screw length. The extruder had self-wiping system for easy cleaning of the machine. The feed rates obtained for feed screw speed of 20. 25 and 30 r min^{-1} were 10.5, 14.5 and 18.5 kg h^{-1} respectively.

The following machine parameters were selected for forming extrudates for decided composition of feed material as shown in Table 5. For reducing the number of experiments and getting appropriate results, a response surface methodology suggested by Box –Behnken (Box and Behnken, 1960) was used.

Table 5 Machine parameters

Machine Parameter	Level 1	Level 2	Level 3
Temperature /℃	130	145	160
Screw Speed /r min^{-1}	225	250	275
Feed Rate /r min^{-1}	20	25	30

3.4 Evaluation of dependent physical parameters

Extrudates of 100 mm length were extruded and expansion ratio was calculated with respect to the die diameter of 3 mm (Expansion Ratio = Diameter of extrudate / Diameter of die). The diameter of extrudate was evaluated by using vernier calliper. For density measurement, weight of extrudate was determined with weighing balance while volume was calculated by length and diameter. Toughness of samples was measured using texture analyser TA-Hdi (Stable Micro System, England) with 50 kg load cell and a cylindrical probe of 75 mm diameter was used for compression study. For each parameter procedure was repeated for 10 samples each and then average was taken for result analysis.

4 Results and discussion

4.1 Response on physical properties of rice based extrudates

4.1.1 Response model equation for expansion ratio, density and toughness

The response model equation for three variables in quadratic form has been simplified by eliminating the interactive response relations. The following model equation was used.

$$Y = B_0 + B_1 \cdot T + B_2 \cdot T^2 + B_3 \cdot S_r + B_4 \cdot S_r^2 + B_5 \cdot F_r + B_6 \cdot F_r^2 \quad (1)$$

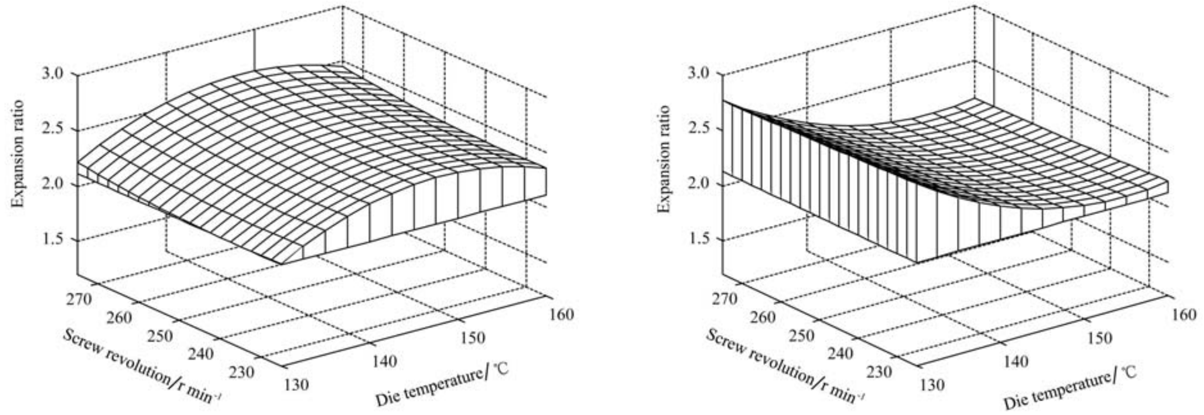
where, Y is response; T, is die temperature; S_r, screw revolution (rpm) and F_r, feed screw revolution (r min^{-1}).

The coefficients of the surface response model in polynomial (quadratic) form for response on expansion, density and texture and their correlation coefficients were determined by using linear programming in the MatLab software and presented in the Table 6.

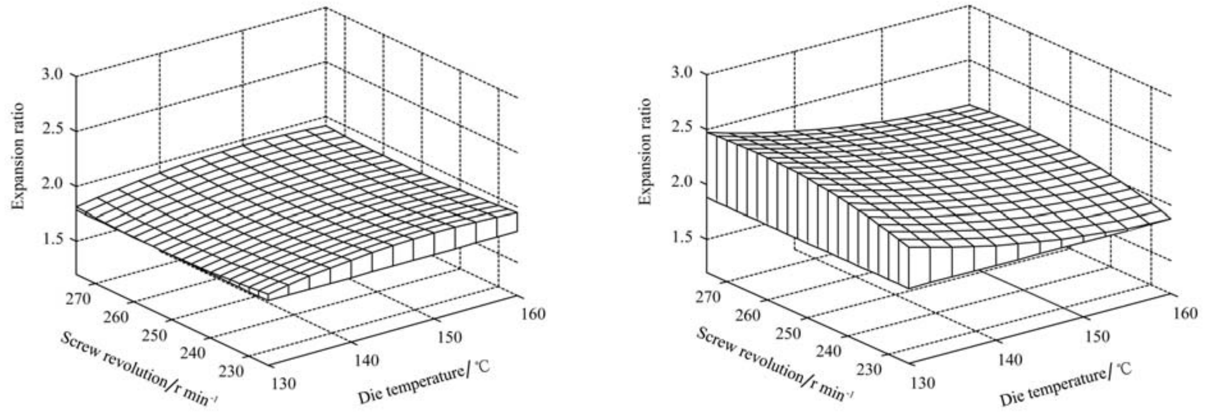
Table 6 Coefficients of model equation in polynomial (quadratic) form for response on expansion, density and texture for rice based extrudates

Fruits/ vegetable pulp additive	Property	Model coefficient							Correlation coefficient	
		B_0	B_1	B_2	B_3	B_4	B_5	B_6	e_s	r^2
Guava	Expansion	-22.5118	0.3735	-0.0013	-0.0343	0.0001	0.1039	-0.0018	0.5830	0.7763
	Density(e^3)	5.4070	-0.1002	0.0003	0.0254	-0.0001	-0.0355	0.0006	0.3153	0.6097
	Toughness(e^3)	-1.2782	0.0093	-0.0000	0.0093	-0.0000	-0.0317	0.0008	140.6467	0.7132
Banana	Expansion	26.5783	-0.3270	0.0011	-0.0076	0.0000	0.1682	-0.0035	0.7322	0.8121
	Density(e^3)	10.5388	-0.0465	0.0002	-0.0562	0.0001	0.0088	-0.0003	0.2741	0.6722
	Toughness(e^3)	-3.8585	0.0904	-0.0003	-0.0171	0.0000	-0.0228	0.0004	121.2665	0.8054
Tomato	Expansion	-0.2811	0.0945	-0.0003	-0.0354	0.0001	-0.0364	0.0008	0.3103	0.6144
	Density(e^3)	5.2132	-0.0801	0.0003	0.0053	-0.0000	0.0489	-0.0010	0.1874	0.6113
	Toughness(e^3)	-8.1265	0.0506	-0.0002	0.0357	-0.0001	0.0177	-0.0003	151.6431	0.6578
Pumpkin	Expansion	6.3140	-0.1155	0.0004	0.0850	-0.0002	-0.4548	0.0086	0.8737	0.7050
	Density(e^3)	-3.1223	0.0858	-0.0003	-0.0361	0.0001	0.1472	-0.0029	0.2908	0.7116
	Toughness(e^3)	-2.1781	0.0699	-0.0002	-0.0172	0.0000	-0.0542	0.0012	178.7061	0.6770

The surface response graphs on these results are presented in the Figure 2, Figure 3 and Figure 4. The response surface curves of expansion ratio, density and texture are shown for rice based guava, banana, tomato and pumpkin pulp added extrudates for the screw revolution ranged from 225 to 275 r min^{-1} and die temperature ranged from 130 to 160℃, since the model equations are developed for these ranges. Though the feed screw speed ranged from 20 to 30 r min^{-1} and the model equations were developed considering this range of feed screw speeds, however the surface response curves were plotted only for 25 r min^{-1} of feed screw speed to interpret the results due to linear relation of this parameter.

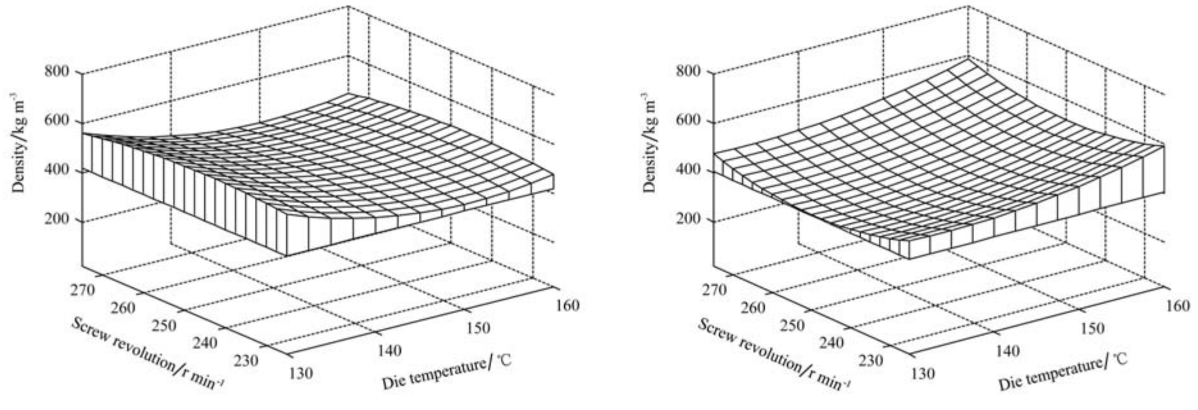


a. Guava b. Banana

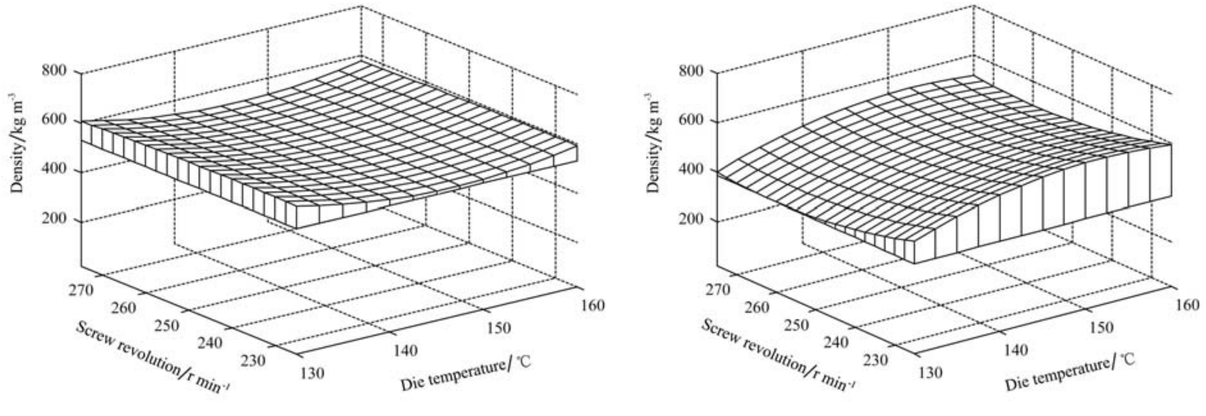


c. Tomato d. Pumpkin

Figure 2 Response on expansion of rice based extrudates as effect of screw revolution and temperature of die;,

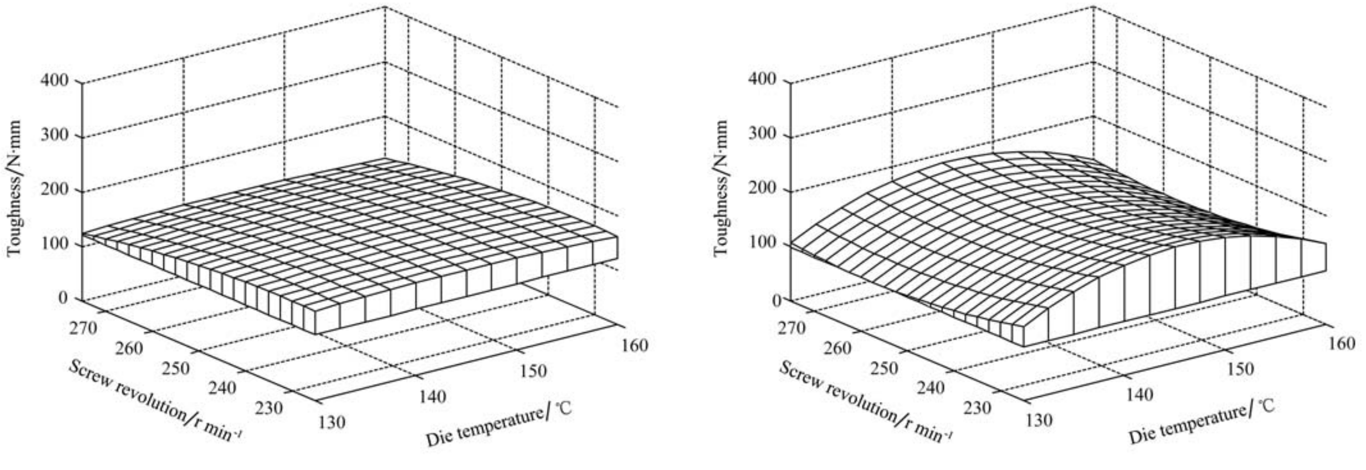


a. Guava b. Banana



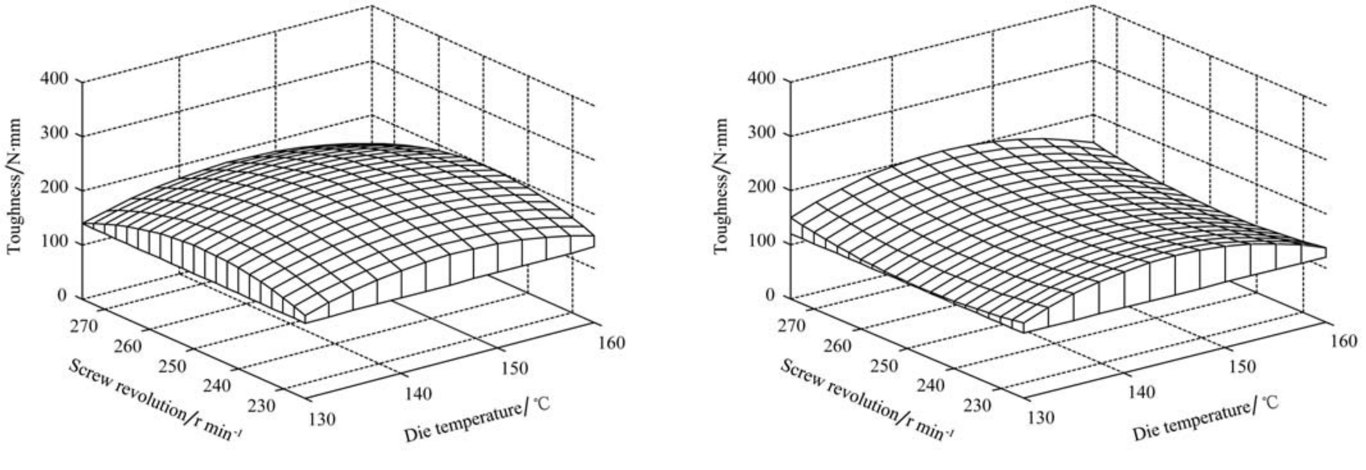
c. Tomato d. Pumpkin

Figure 3 Response on density of rice based extrudates as effect of screw revolution and temperature of die



a. Guava

b. Banana



c. Tomato

d. Pumpkin

Figure 4 Response on texture of rice based extrudates as effect of screw revolution and temperature of die

4.1.2 Expansion ratio of rice based extrudates

The expansion ratio of extrudates varied from 1.687 to 2.835% (Figure 2) for all the four combination of rice with fruits and vegetables pulp based extrudates. The observed r^2 values for the extrudates made of guava, banana, tomato and pumpkin were 0.7763, 0.8121, 0.6144 and 0.7050 respectively. Both screw revolution and die temperature had an influence on the expansion ratio of final extrudates. A significant increase in expansion ratio was observed with an increase in die temperature and screw revolution but for banana and pumpkin a decreasing trend was seen with higher die temperature. At the highest screw revolution (270 rpm) maximum rise in expansion was for banana i.e. 2.875% while minimal affect was seen in tomato based extrudates.

Die temperature influences the expansion ratio due to the formation of air bubbles as there is a higher degree of superheating of water in the extruder (Ding et al., 2006). The extruded products mainly expand due to the water evaporation that creates air bubbles in it. This air bubbles are formed because there is a pressure drop at the end of die that leads to starch plasticization. The sudden drop in temperature from high die temperature to ambient temperature affects the degree of starch plasticization thus properties of final extruded products are greatly influenced (Brummer et al., 2002). The higher the die temperature greater will be temperature drop as product leaves the die and interact with lower atmospheric temperature and thus will expand more. However, for banana and pumpkin the water absorption index was higher compared to other two pulps, it increased the plasticization of melt reducing the dough elasticity resulting in reduced expansion. Both pumpkin and banana produced sticky dough with higher viscosity compared to other two pulps thus it hindered in expansion.

Whereas, in case of guava ER increased with rise in temperature and for tomato it was nearly constant since tomato derivatives lubricates the melt and drops the torque, thus expansion is decreased. Shoar et al. (2010) also reported similar results with tomato lycopene enriched extruded snacks.

High screw speed resulted in less retention time of dough in the extruder while there will be an increase in pressure with increased screw speed that will result in high temperature in the extruder. Thus, higher temperature melt viscosity will decrease resulting in more expanded product. An increase in barrel temperature increased the degree of superheating of water thus decreasing viscosity and more bubble formation (Fletcher et al., 1985). Hence, banana and pumpkin that have higher water absorption index when subjected to higher shear in the barrel with increased temperature will decrease its viscosity. Also the excess water present will get superheated producing more air bubbles and thus reported higher expansion ratio as screw revolution increase.

4.1.3 Density of rice based extrudates

Density of extrudates influences its structure and is related to other properties as well. The results obtained for the products revealed that the density of products were inversely proportional to the expansion (Figure 3). The highest density was reported for tomato based extrudates i.e. near 600 kg m^{-3} followed by guava, banana and pumpkin respectively. The correlation coefficient was found above 0.6 for the different blends while pumpkin based extrudate had the maximum correlation i.e. 0.71. Both die temperature and screw revolution had a positive impact on the density of extrudates that led to denser product with higher temperature and screw revolution. Therefore, this can be seen from the results that the product that expanded more had lower density and vice versa.

With an increase in die temperature the density had a constant increase for banana and pumpkin based extrudate while for guava and tomato it slightly decreased at 140℃ then again increased at 150℃. Generally, screw revolution did not much affected the density since not much variation was there and at the highest temperature the dough mix was subjected i.e. 160℃ the density was nearly the same for all i.e. around 500 kg m^{-3}. The steady increase in density could be due to the increased amount of fibre to the blend that alters the extent of starch gelatinization and thus rheological properties of melted material in the extruder (Yağcı and Gōğűs et al., 2008). No polysaccharide material binds to the water tightly and inhibits the water loss at die thus probably the density increases (Camire and King, 1991).

As the screw revolution increased maximum increase in density was seen for tomato based blend as the product did not get sufficient expansion thus the density increased to 6 kg m^{-3}. Tomato has a high amount of free water present with very traceable amount of starch (responsible for expansion of extruded products). Also, in the pulp added to the flour mix has soluble sugars and fibres that absorb moisture which further that influenced the density. Hsieh et al. (1989) has also suggested that presence of insoluble fibre reduces the elasticity and plasticity of dough. With increase in screw revolution banana and pumpkin showed greater expansion due to more air bubble formation thus that directly altered the density which was found to be lower than other two blends.

4.1.4 Toughness of rice based extrudates

Toughness of the product was defined as the force required compressing the product that changed from 100 N·mm to 178 N·mm (Figure 4). The r^2 values were significantly higher for fruit pulp based products compared to vegetable pulp based products, respectively. The dramatic change in force indicates that products were influenced by the operating conditions as well as with variation in the inlet mixture composition. There was an increase in toughness of product at higher die temperature while it had not much effect on guava pulp based product. Similar pattern of increase was observed as the screw revolution increased. Toughness of extruded products is highly dependent on its expansion ratio and density.

It is evident from the Figure 4 that with higher die temperature product obtained was harder. Several physical and chemical changes occur as the dough moves in extruder and finally when leaves through die. Banana based extrudates were the most crispy among all the four pulp based extrudates. Since guava has the highest fibre content among all the pulps, fibre on interaction with other constituents reduces the cell size which decreases overall expansion resulting in less porous and harder product. Increase in toughness with increase in die temperature may be due to increased dextrinization that produces weak cell structure (Mendonca et al., 2000; Yağcı and Gōğűs, 2008). Further weak structure decreases the porosity affecting the texture of final product.

Similarly screw revolution also influenced the texture and produced harder product at increased screw revolution. The shear force increases inside the barrel with higher screw speed thus raising the cooking temperature. This is a known fact that starch structure gets distorted at high temperature leading to a harder product. It is evident from results that banana pulp based extrudate that had maximum expansion less density had crisp product compared to tomato based extrudate that had minimum expansion, high density and harder produc

4.2 Response on physical properties of maize based extrudates

4.2.1 Response equation for expansion ratio, density and texture (toughness) maize based extrudates

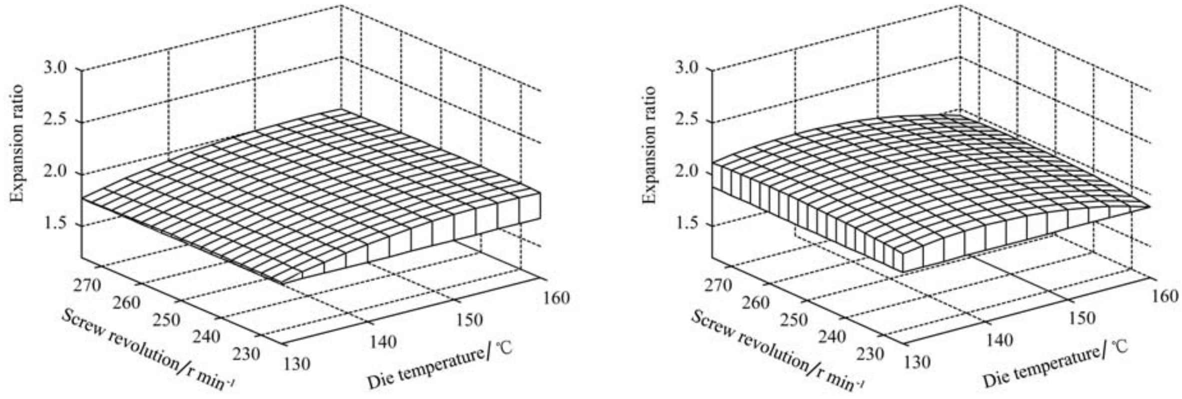
The model coefficients of Equation (1) for response on expansion ratio, density and texture of maize based extrudates were evaluated similarly as rice based extrudates and are presented in Table 7. The surface response graphs on these results are presented in the Figure 5, Figure 6 and Figure 7 similarly as in rice based extrudates.

4.2.2 Expansion ratio of maize based extrudates

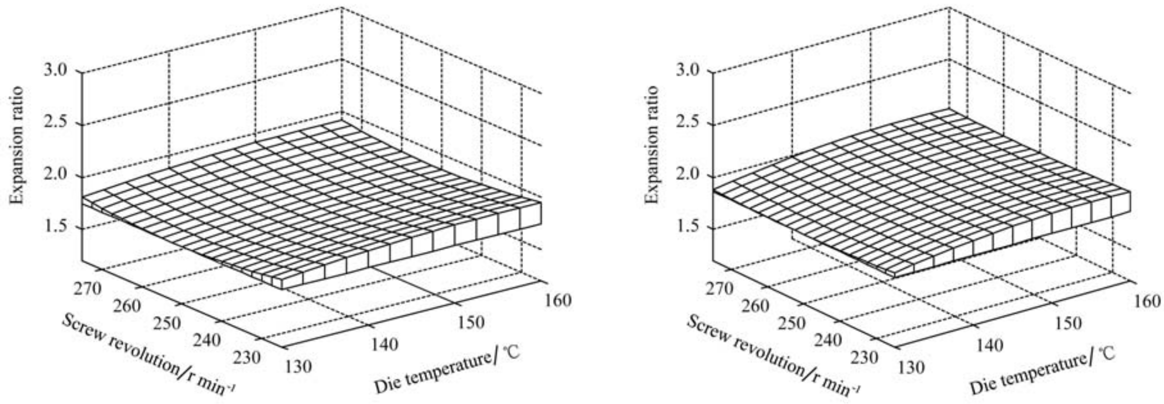
Figure 5 depicts the results for fruit/vegetable pulp incorporated, maize based extruded products. Although in addition to fruits and vegetable pulp a similar trend was observed for both maize and rice flour, the extrudates expansion ratio was found to be lower than rice based extrudates. The highest expansion ratio was for banana based extrudates with respect to screw revolution followed by pumpkin, guava and tomato respectively. Die temperature had a less impact on expansion ratio since only a slight increase was seen for all the samples. Maize with banana had the maximum r^2 i.e. 0.8551. Less expansion compared to rice based product can be attributed to different chemical composition of maize. Since maize has higher protein and lower carbohydrates content, its interaction with added pulp decreased the expansion. Higher proteins prevent bubble formation, and it produces viscous dough as maize has lower solubility in water. Thus, the final product had lower expansion compared to rice based products.

Table 7 Coefficients of model equation polynomial (quadratic) form for response on expansion, density and texture for maize based exrudates

Fruits/ vegetable pulp additive	Property	Model coefficient							Correlation coefficient	
		B_0	B_1	B_2	B_3	B_4	B_5	B_6	e_s	r^2
Guava	Expansion	-9.3210	0.1183	-0.0004	0.0111	-0.0000	0.0713	-0.0015	0.2962	0.7913
	Density(e^3)	-13.8748	0.0351	-0.0001	0.0786	-0.0002	0.1377	-0.0025	0.2209	0.8392
	Toughness(e^3)	-1.9861	0.0167	-0.0001	0.0156	-0.0000	-0.0517	0.0010	110.5366	0.8118
Banana	Expansion	-14.8511	0.1747	-0.0006	0.0338	-0.0001	0.0386	-0.0008	0.2477	0.8551
	Density(e^3)	-13.7191	0.0273	-0.0001	0.0741	-0.0001	0.2247	-0.0045	0.1025	0.9606
	Toughness(e^3)	4.2067	-0.0276	0.0001	-0.0125	0.0000	-0.0445	0.0008	119.5889	0.6149
Tomato	Expansion	7.8016	0.0469	-0.0001	-0.0656	0.0001	-0.1113	0.0023	0.2457	0.7460
	Density(e^3)	-12.0534	-0.0290	0.0001	0.1069	-0.0002	0.1137	-0.0024	0.2423	0.8205
	Toughness(e^3)	-1.6363	0.0102	-0.0000	0.0059	-0.0000	0.0136	-0.0003	258.2669	0.7466
Pumpkin	Expansion	22.7481	-0.1328	0.0004	-0.1046	0.0002	0.2074	-0.0042	0.3412	0.6145
	Density(e^3)	-0.4911	-0.0703	0.0003	0.0459	-0.0001	0.0006	0.0000	0.3672	0.6359
	Toughness(e^3)	-9.6024	0.0396	-0.0001	0.0593	-0.0001	-0.0653	0.0016	254.2391	0.7504

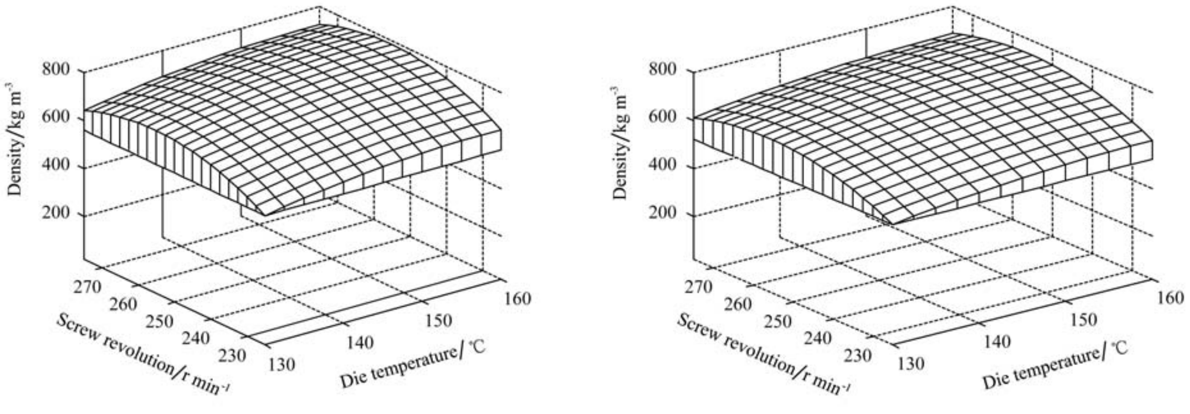


a. Guava b. Banana

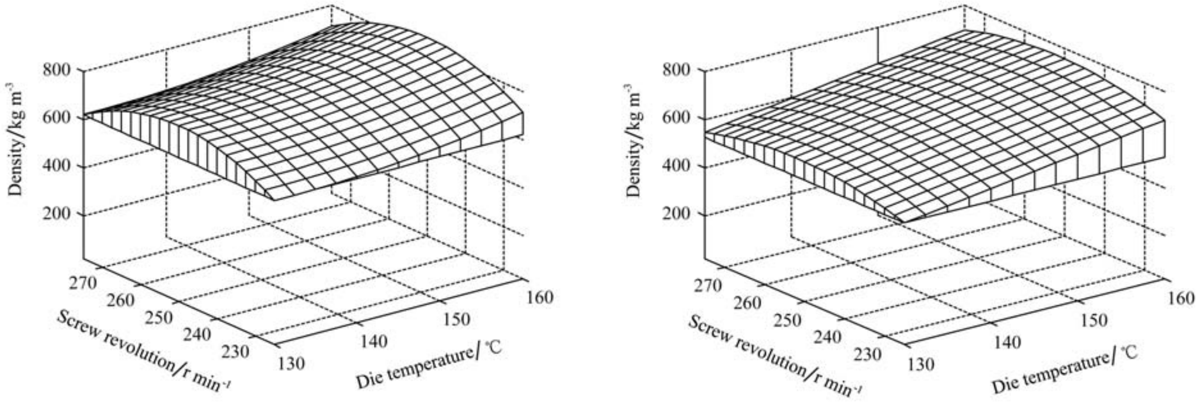


c. Tomato d. Pumpkin

Figure 5 Response on expansion of maize based extrudates as effect of screw revolution and temperature of die;

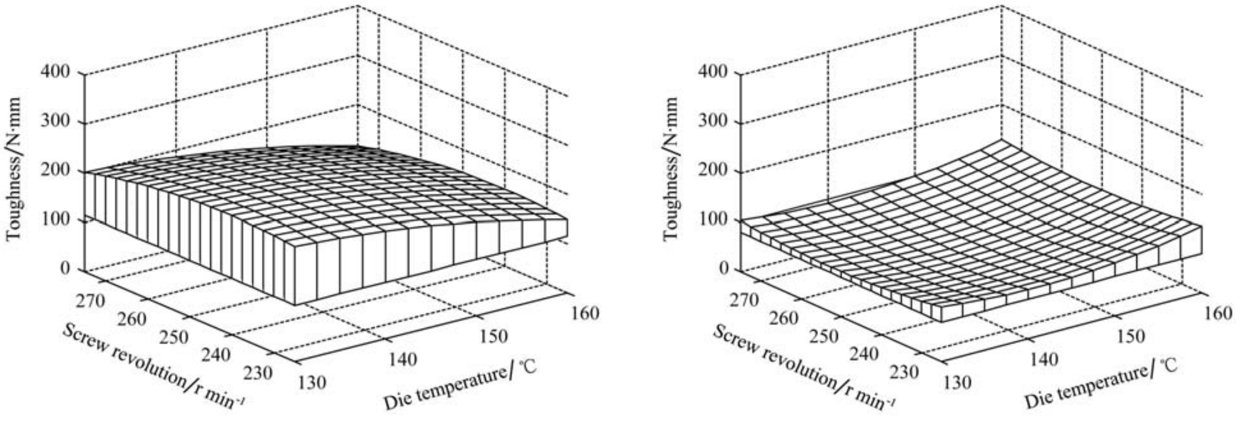


a. Guava b. Banana



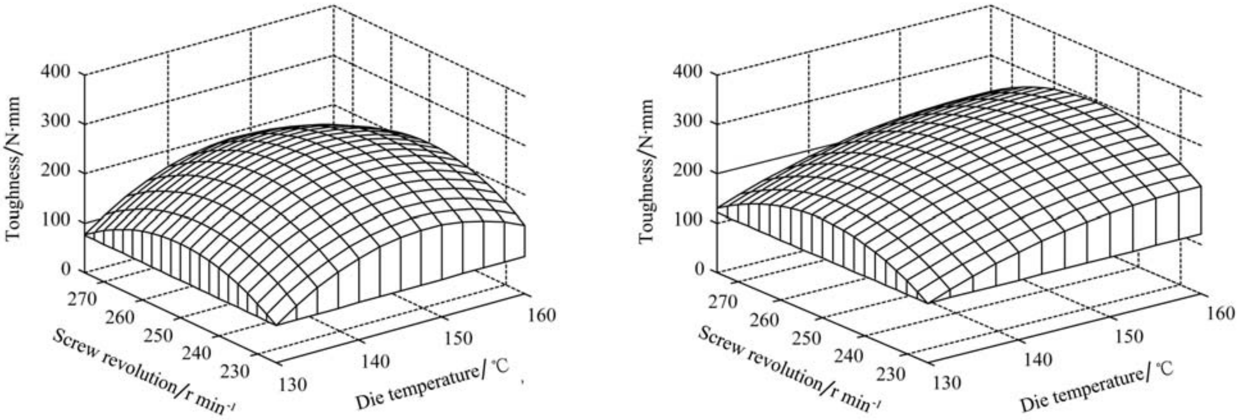
c. Tomato d. Pumpkin

Figure 6 Response on density of maize based extrudates as effect of screw revolution and temperature of die



a. Guava

b. Banana



c. Tomato

d. Pumpkin

Figure 7 Response on texture of maize based extrudates as effect of screw revolution and temperature of die

4.2.3 Density of maize based extrudates

Effect of fruit/ vegetable pulp addition on density of maize based extruded products is given in Figure 6. Both screw revolution and die temperature did not have much variation among various combinations used and almost similar density was observed for all except for pumpkin added extrudate that had nearly 550 kg m^{-3} while others had between 600 kg m^{-3} and 620 kg m^{-3}. The correlation coefficient also shows that minimum r^2 value in case of pumpkin added extrudate. Results revealed a clear relation between expansion and density, a similar trend was also observed for rice based extrudates where pumpkin base product had the lowest density of 400 kg m^{-3}. Since high screw speed increased the barrel temperature while decreased the melt viscosity hence, the sticky and viscous mixture fed into extruder changed its properties producing a product with less dense similar to rice based products.

4.2.4 Toughness of maize based extrudates

Textural changes in maize based product are summarized in Figure 7. Results revealed that guava based extrudates were the hardest among all combinations as force required to break that was nearly 200 N· mm. The toughness was almost constant as the screw revolution increased while it decreased with an increase in die temperature for guava based extrudates. Banana based extrudates had not much affect of machine parameters while for tomato and pumpkin it increased first then decreased on higher screw revolution and die temperature same as in rice based extrudates. The reason behind the hardest product in addition to guava may be pectin present in guava that competes with sugar for water molecule thus lowering the bubble formation and increase in cell shrinkage at die exit.

5 Conclusion

Present study revealed that fruit and vegetable pulp can be added up to 10% enhancing the nutritional requirement. This will also fulfil the required moisture content for preparing extruded products in extruder.

This produces extrudates with little compromise in physical quality compared to products based only on cereal. Machine parameters considered in study were found to affect the physical characteristic of extrudate as an increase in both die temperature and screw revolution, and they increased the value of physical parameters in most of the cases. Since rice and maize varied in composition thus showed difference in interaction with fruit/ vegetable pulp. Among fruit pulp banana there was a better product with both rice and maize while in vegetable pumpkin pulp was found to have an improved product. Hence it can be concluded that extruded products that are usually prepared by a combination of cereals can be improved by addition to fruit/ vegetable pulp. This will further enhance the flavour and nutritional quality without much affecting the physical quality. The modified models of surface response were found statistically valid and adequately depicting the behaviour of responses upon various machine variables. According to the results obtained on physical characteristics of maize and rice based extrudates fortified with fruit and vegetable pulp, the process can be referred for industrial production.

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