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Utilization of By-product from Tomato Processing Industry for the Development of New Product

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Abstract

Extrusion cooking is recognized as a smart technology for food processors. It is a low cost, high temperature, short-time process. In this the starchy ingredients are input to create a puffed snack. However it contains multiple parameters that need to be rigorously controlled to develop an optimal process. Present study investigated the blends of corn flour, rice flour and tomato pomace (peel and seed), processed in a co-rotating twin-screw extruder and examined the effect of incorporation of tomato by-product derivatives on final extruded product quality of the ready -to-eat expanded product. Furthermore, the physio-chemical properties, post cooking quality were analyzed for the extruded product. As tomato pomace, corn and rice flour are naturally gluten free, the extruded product would appeal to people who suffer from gluten intolerances, allergies and celiac disease. Dried and milled tomato peel and seed at levels of 0 - 30% and 0 - 5%, respectively were added to the formulation mix. D-optimal mixture design was chosen, which generated 17 combinations; within these combinations, the control formulation existed. The formulations were processed in a twin-screw extruder with a combination of parameters including: solid feed rate kept constant, water feed adjusted to 14%, screw speed of 300 rpm - 350 rpm and process temperatures 30°C to 140°C. It was observed that the addition of tomato pomace significantly increased the crude fiber content and level of protein content in the final product. The expansion ratio, hardness, colour, and overall acceptability varied significantly with respect to tomato pomace addition. Sensory test panel indicated that tomato pomace extrudate could be incorporated into ready-to-eat expanded products up to the level of 30% and it was acceptable. Optimization using D-optimal mixture design suggested that the best formulation extruded product with high desirability was the one consisting of 40% corn flour, 30% rice flour, 25% tomato peel and 5% tomato seed. The results suggest that tomato pomace can be extruded with corn and rice flour into an acceptable and highly nutritious fiber enriched snack food.

Keywords: Extrusion; Tomato peel; Seed; D-optimal design

Introduction

Effective utilization of food by-product/waste as secondary source for the new product development is an emerging area of research. Residues from food industry waste (solid as well as liquid) have some potential benefits on health aspects. So recent research has been focusing on these food wastes for utilization as nutraceuticals and pharmaceuticals, and also for energy generation in the form of production of biogas, hydrogen and bio-ethanol etc. [1].

In food processing industry, food wastes require further processing before being used in food products. This transformation from food waste to value products implies high costs in research and development. Hence, it is essential to obtain important and high value-added products in order to justify the investment.

During the production season large quantities of tomato waste are generated, this may be from the insufficient processing of agricultural products. In recent years due to increase in population food production have increased and have led to over-consumption of processed food. However, this over production and consumption produce different category of tomato waste and these are generally remains largely underutilized, waste produced may be from households, losses occur in the food manufacturing industry, during food sector (ready to eat food, catering and restaurants) lost along distribution chain the waste consist of lot of nutrients and can be a promising sources for food supplementation therefore these should be investigated for further beneficiation for the industrial processing of food waste. In developing countries about 15% of population is starving [2], this large amount of food waste implies an increasing great loss of valuable materials. It also raises management problem due to associated resource consumption and pollutant emission. It has been estimated that for each ton of food waste there is an emission of about 2 tons of CO_2 [3].

In recent years, there is an increasing demand for conversion of fruit and vegetable wastes into useful products. The primary motivation is to minimize environmental impact of these by-products from food industry to avoid environmental problems and to utilize valuable constituents that remain, such as lycopene and dietary fiber. One viable method for utilization of fruit and vegetable by-products into useful products is extrusion processing due to its versatility, high productivity, relative low cost, energy efficiency and lack of effluents. Successful incorporation of tomato pomace into extruded products that deliver physiologically active components represents a major opportunity for food processors providing the consumer a healthy tomato pomace-based product to choose from which is currently lacking in the marketplace. Extrusion cooking is a popular food-processing technique, especially for the production of fiber-rich products, such as breakfast cereals, flat breads, dextrinized or cooked flour. Due to its high content of Total dietary fiber (TDF) and a high proportion of soluble dietary fiber (SDF), food processors are taking steps for an investigation into the use of tomato peel in a variety of extruded products which may be of importance from a nutritional point of view for the consumers.

Therefore, the objective of this research was to investigate process ability of mixing the tomato pomace into the rice and corn flour as a major ingredient to produce snack food in a twin-screw extruder. And to optimize the effect of the independent variables such as tomato

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pomace (peel and seed) content, rice and corn flour on the functional properties and physical properties of extrudates by using Mixture design, D-optimal.

Materials and Methods

Ingredients used for ready- to-eat snack preparation were: Maize flour and Rice flour. They were obtained from the local market, and were sieved to a particle size of 0.355 μm (mesh 44). The flours were stored at 4°C until used. Tomato pomace (TP) a byproduct from the tomato processing industry was obtained from the Sakthi Fruits tomato paste processing plant located in Erode, TN, India. Sample preparation flow chart given in Figure 1.

D-optimal mixture design was employed by fixing lowest and highest percentage of each independent variable for the design. These ranges were considered as the lower and upper bounds resulting in the constrained representing formulations (1-17) prepared for the experiment. A quadratic model with one centre point was selected, resulting in 17 combinations generated via the Design Expert software. Within these 17 combinations, the control was created, and two combinations were repeated twice to assess error within the model. The model that best fitted the response was selected during analysis of measurements. Analysis of variance (ANOVA) was carried out on each response model to identify the coefficient (R^2), and significant difference ($p < 0.0001$).

In four mixture Corn flour (A), Rice flour (B), Peel (C), Seed (D) made upto total of 100% of the actual formulations. The lower and upper boundaries of ingredients were determined to be as corn flour (40 - 60%), rice flour (30 - 40%), peel (0 - 30%) and seed (0 - 5%) added to 100% of the mixture design. The raw ingredients were weighed separately according to the formulation made by mixture design and blended in a mixer for 10 min. Moisture content of samples were determined by IR moisture meter (Kett, FD-240). These blends were chosen according to preliminary study and for the acceptable product's physical characteristics.

These samples were conditioned to 14% moisture (w.b.). Moisture content was chosen based on preliminary trials, to ensure least variations in hardness of the final product. Water addition was conducted by spraying calculated amount of water prior to extrusion and mixing continuously in a mixer, this preconditioning procedure was employed to ensure uniform mixing and hydration and to minimize variability of the feed material [4].

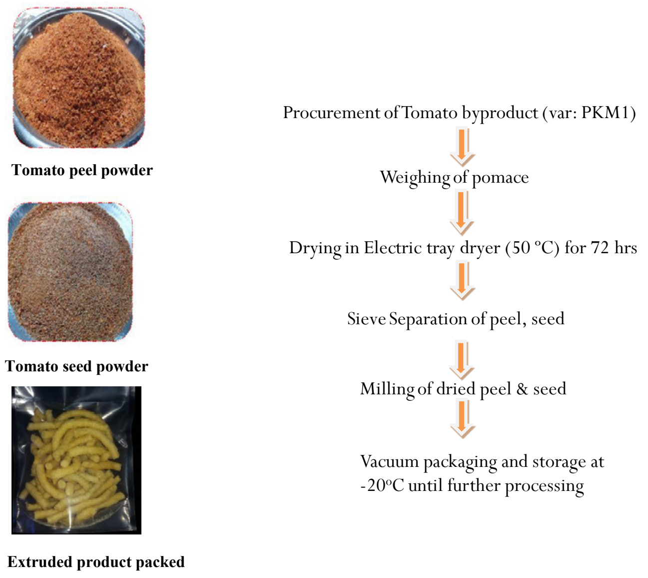


Figure 1: Sample preparation flow chart.

Constant variables were screw speed set at 300 rpm, die head temperature 130°C. The tomato pomace level was restricted to 0 - 30% range; this was based on the previous studies reported by Hsieh et al. [5]. Dependant variables (or responses) were selected based on descriptors that would best describe a high-quality puffed extruded snack on sensory quality. These were hardness, colour, protein, fat, crude fiber, expansion ratio (ER) and overall acceptance. The generation of response surface plot and statistical analysis were performed using Design Expert software. The main advantage of design is that it reduces the number of experimental runs needed to provide sufficient information for statistically acceptable results. ANOVA was adopted in the design of experimental combinations for the identification of significant difference in the formulations.

Extrusion cooking

Extrusion cooking trials were performed using a laboratory-scale Co-rotating twin-screw extruder (model SYSLG-IV) the barrel consisted of three independent temperature zones, zone 1 (entering zone), zone 2 (kneading zone), and at the barrel end, indicated as zone 3. Screw diameter was 30 mm. The exit diameter of the circular die used was 4.5 mm. The extrusion was carried out with following conditions; 300 rpm - 350 rpm screw speed and barrel temperature zone 30°C, 60°C, 100°C, 140°C respectively while feeder screw speed was set at 30 rpm throughout the experiment. The extrudates were dried in a hot air oven at 50°C. Final dried samples contained a maximum of 4%-5% (w.b.) moisture. Dried samples were stored in polythene bags at room temperature and used for further analysis.

Analysis of extruded products

Sectional Expansion index (SEI): The diameter of 20 pieces of extruded products was measured using a caliper (Mitutoyo, Tokyo, Japan), and the expansion ratio was calculated by dividing the average diameter of the products by the diameter of the die [6].

$$SEI = \frac{De^2}{Dd^2}$$

Where, De^2 is the diameter of the extrudate and Dd^2 is the diameter of the die.

Bulk density: Bulk density (BD) (g/cm^3) of 10 pieces of extrudates were calculated according to Alvarez-Martinez et al. [6] method, where m is mass (g) of a length L (cm) of extrudate, with diameter d (cm).

$$BD = \frac{4m}{\pi d^2 L}$$

Texture: The hardness of the sample was measured with a TA.XT plus, Texture Analyzer (Stable Micro System, Surrey, UK) equipped with 5 kg load cell. Hardness in N was determined by measuring the maximum force required to break the extruded samples (50 mm long) using three point bend test with a sharp-bladed probe (90 mm wide, 32 mm high and 9 mm thick). The test speed was 1 mm/s and the distance between two supports was 22mm. A force –time curve was recorded and analysed by Texture Exponent 32 software programme (version 5.0). Ten measurements were performed on each sample and averaged.

Colour: Hunter Lab Color Flex XE (Hunter Associates Laboratory

Inc., Reston, VA, USA) was used to determine colour values of the ground extruded in terms of L, a and b as measures of lightness, redness and yellowness respectively. The colorimeter was calibrated against a standard white tile ($L = 91.43$, $a = -0.74$, $b = -0.25$). The extrudates were ground in a mixer and passed through a 40 mesh sieve prior to colour analysis, in triplicate.

Water absorption and solubility indices: The water absorption index (WAI) is the weight of gel obtained per gram of dry ground sample. The WAI of extrudates was determined according to the AACC method 56-20. The ground extrudate was suspended in water at room temperature. After standing for 10 min, gently stirred during this period, samples were centrifuged for 15 min at 1000 g (REMI Centrifuge, REMI Elektrotechnik Ltd, Maharashtra, India). The supernatant was decanted into a tarred aluminum pan. The WAI was calculated as the weight of sediment obtained after removal of the supernatant per unit weight of original solids as dry basis. The water solubility index (WSI) is the percentage of dry matter recovered after the supernatant is evaporated from the water absorption determination. The supernatant was dried in a vacuum oven at 84.4°C and 20 - 24 mmHg gauge pressure for 24 h and weighed. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample on dry basis [7,8].

Analytical methods

To characterize the chemical composition of the corn flour, rice flour, tomato peel and seed and the final extruded products, the protein content was measured using the Kjeldahl method [9], and fat content was determined using the Soxhlet method [9]. Ash content was obtained by drying the samples in a muffle furnace at 550°C for two hours. Crude fiber was determined by the acid sequence method using 1.25% H_2SO_4 and 1.25% NaOH for acid and alkaline hydrolysis, respectively. Carbohydrate content was calculated by the difference between the total and the contents of all other ingredients. Each analysis was carried in three replicates.

Sensory evaluation: All formulations were given for sensory evaluation to the panel members. Nine point hedonic scales were adopted and the categories were rated from 1 (absent/dislike extremely) to 9 (very high/like extremely) in order to evaluate the extrudate characteristics. The attributes examined were (Appearence, Colour, Flavour, Initial bite, Texture, Graininess, Tate, Umami, Tangy, Cohesivness, after taste). The panelists consisted of 10 semi-trained panellists (between 20-45 year old males and females) who are students and faculty members of the Department of Food Engineering IICPT, Thanjavur. Panelists were selected in preliminary sessions and experienced with the products and terminology.

Components	Corn Flour (w.b.)	Rice Flour (w.b)
Protein (%)[a]	10.03 ± 0.04	5.81 ± 0.12
Fat (%)	4.37 ± 0.60	0.79 ± 0.23
Ash (%)	0.50 ± 0.00	0.50 ± 0.00
Crude fiber (%)	0.72 ± 0.24	0.45 ± 0.42
Carbohydrate (%)[b]	77.26	82.95

[a]Protein = N × 5.95 for rice
[b]Carbohydrate by difference.
w.b: wet basis

Table 1: Proximate composition of rice and corn flour (Average ± SD).

Components	Tomato peel (w.b)	Tomato seed (w.b)
Protein(%)[a]	16.19 ± 0.00	26.39 ± 1.42
Fat (%)	6.50 ± 0.70	25.03 ± 1.45
Ash (%)	2.50 ± 0.00	3.5 ± 0.00
Crude fiber (%)	29.35 ± 5.79	13.37 ± 1.87
Carbohydrate (%)[b]	40.06	27.31

[a]Protein = N × 5.95
[b]Carbohydrate by difference.
w.b: wet basis

Table 2: Proximate composition of tomato peel and seed (Average ± SD).

Results and Discussion

Proximate analysis of extrudates

Chemical analysis was carried out for the raw material to know their composition (Corn flour, Rice flour, Peel and Seed) as given in Tables 1 and 2. It was observed that Crude fiber content was highest in tomato peel (29%) followed by seed (13%) then corn flour (0.72%) and rice flour (0.5%). Interestingly it was observed that tomato seed contained highest fat content (25%) followed by peel (6.5%) then corn flour (4.4%) and rice flour (0.8%). Similarly protein content was found to be highest in seed (26.4%) followed by peel (16.2%) corn (10%) and lastly rice flour (6%) carbohydrate responsible for expansion was highest in rice flour (82%) followed by corn flour (77.3%) were in peel it was highest about (40%) and lastly seed (27.3%). As illustrated, variation in the initial formulation will affect the properties of the final extruded product depending on changes in fat, protein, crude fiber, and carbohydrate.

Effect of crude fiber on the extruded products

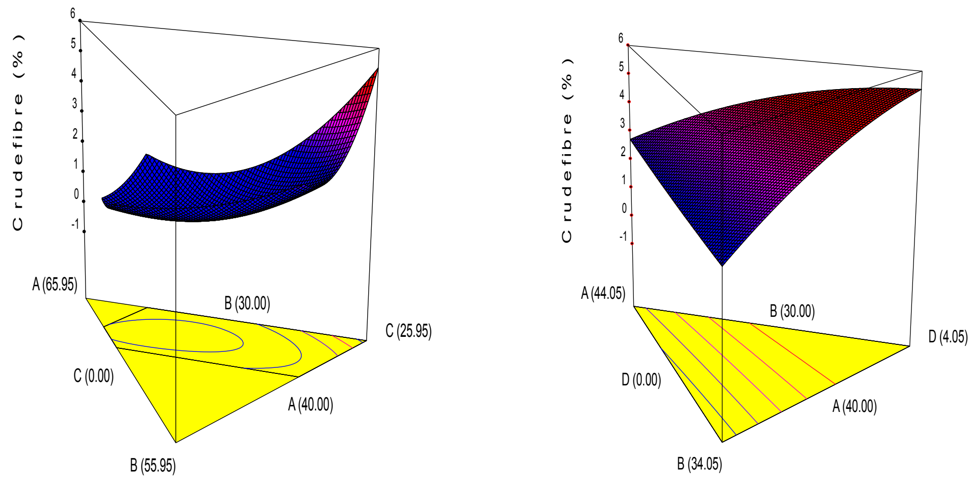
Consumption of dietary fiber has been linked with various health promoting effects and thus has been recommended to be added in the food consumed. In the present study it was observed that crude fiber content was much higher in tomato pomace especially in tomato peel followed by tomato seed (Table 2). Hence it was observed that total crude fiber increased following addition of peel and seed in the extruded product formulation. The statistical analysis confirmed significant effect of the independent variable used in the formulation for extruded product.

The ANOVA showed significant effect ($p < 0.05$) for the mixtures combinations of AD, BC, CD, ABC, ACD (A-corn flour, B-rice flour, C-peel, D-seed) leading to increase in the crude fiber content as tomato peel and seed were added to the product, this effect is not only due to presence of tomato pomace but also due to some fiber content from the corn and rice flours (Table 3).

From Figure 2, it can be seen that the crude fiber content increased significantly following the increase in percentage of peel. To enhance the amount of fiber in food products it is obvious to add higher percentage of peel in the formulations as a source of fiber. Crude fiber, as defined by the association of Official Analytical Chemists is the residue of a feeding material after treatment with boiling sulphuric acid, sodium hydroxide, water, alcohol, and ether. It is a measure of the cellulose and lignin content mainly. The addition of fiber rich components like tomato peel affects the texture of the product such as hardness, moreover this effect is further intensified following thermal treatment during extrusion cooking if the components (corn flour, rice flour, tomato peel, seed) contains high amount of protein. This may also be due to the fact that at higher temperatures protein present in the components may get degraded and become insoluble. Similar results has been reported by several authors, while increasing fiber in the extruded product ultimately increases the hardness of extruded products as a result of its effect on cell thickness [10-12]. Cereal fibers

Run	Corn flour A (%)	Rice flour B (%)	Peel C (%)	Seed D (%)	Crude Fiber (%)	Protein (%)	Fat (%)	ER (%)	Hardness (N)	Colour (a)	OA
1	60	30	5	5	1.18	11.82	2.85	4.00	4.54	10.68	6
2	60	40	0	0	0.24	9.41	1.27	4.78	5.29	4.33	8
3	55.27	36.25	5.83	2.63	1.20	12.04	2.2	3.89	2.48	10.47	6
4	60	30	10	0	1.70	11.83	2.04	4.11	2.38	13.38	6
5	60	30	10	0	1.70	11.83	2.04	4.11	2.38	13.38	6
6	50	35	15	0	1.82	10.75	3.1	3.81	3.00	15.79	8
7	40	40	15	5	1.58	10.03	2.62	3.58	3.97	18.39	5
8	60	37.5	0	2.5	1.60	11.60	2.05	3.39	4.96	12.55	5
9	60	30	5	5	1.18	11.82	2.85	4.00	4.54	10.68	6
10	40	35	25	0	2.05	11.54	2.1	3.79	3.69	16.58	5.4
11	40	35	20	5	1.93	11.60	2.56	3.41	3.39	15.38	5
12	40	30	30	0	3.20	11.83	1.41	3.80	4.72	20.91	6
13	40	40	20	0	2.90	11.16	2.37	3.41	2.79	16.10	4.4
14	50	30	17.5	2.5	2.93	12.76	2.17	3.38	2.73	16.23	5.4
15	47.5	40	7.5	5	0.73	9.60	1.72	3.59	1.84	7.03	5.2
16	40	30	25	5	4.75	11.60	2.5	3.67	2.40	18.27	8
17	55	40	0	5	0.43	10.28	2.2	3.61	4.39	6.37	6

Table 3: Experimental design and results of response variable.



Crude fiber (%) = 0.59467A + 1.82039B + 1.86752C – 24.15462D – 0.045090AB – 0.036075AC + 0.29058AD – 0.083106BC+0.26484BD+0.49100CD+1.13793E-033ABC – 1.62748E-033ABD-3.75759E-003ACD-3.15528E-033BCD.

Figure 2: 3-D contour plots of crude fiber (%) (A-corn flour %, B-rice flour %, C-peel %, D-seed %).

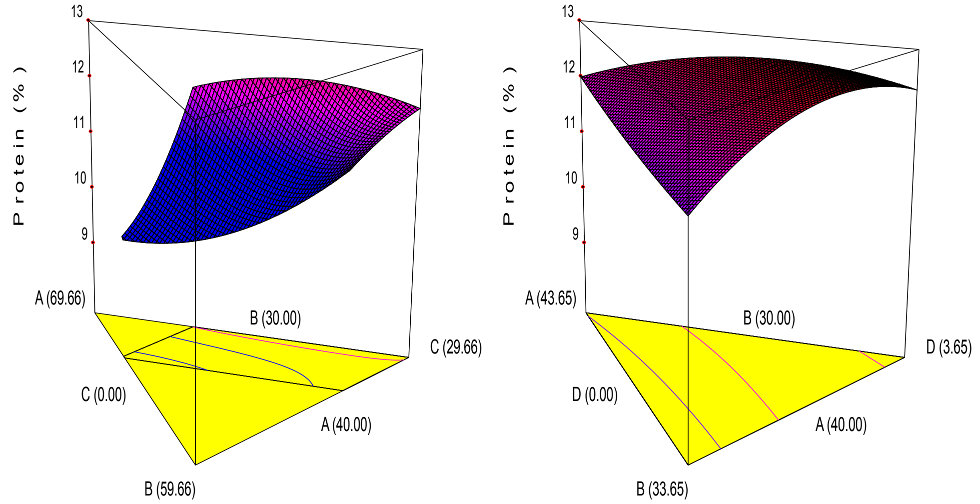
are added to the extruded product due to the fact that the fiber rich foods produces many beneficial effects on the digestive tract, such as the regulation of the intestinal function, improvement of the tolerance to glucose in diabetics, or prevention of chronic diseases as colon cancer. Codex Alimentarius recommends that any product claiming to be a "source" of fiber should contain 3 g of fiber per 100 g of serving or 1.5 g of fiber per 100 kcal of serving or 10% of daily reference value per serving. The extruded product with high fiber is preferable in such a way that it should possess consumer acceptability in terms of hardness. Due to the nature of crude fiber having both insoluble and soluble properties, it can be included in food products with consumer preferences.

Effect of protein on extrudate

The effect of Protein content of the extruded product is studied and all data are significantly different with addition of tomato pomace into the product. The protein content in our study, found to be in range of 9.405 - 12.76% (wb) for all 17 combinations (Table 3 and Figure 3) including replication. The raw material protein content also had a significant impact on product qualities in terms of hardness.

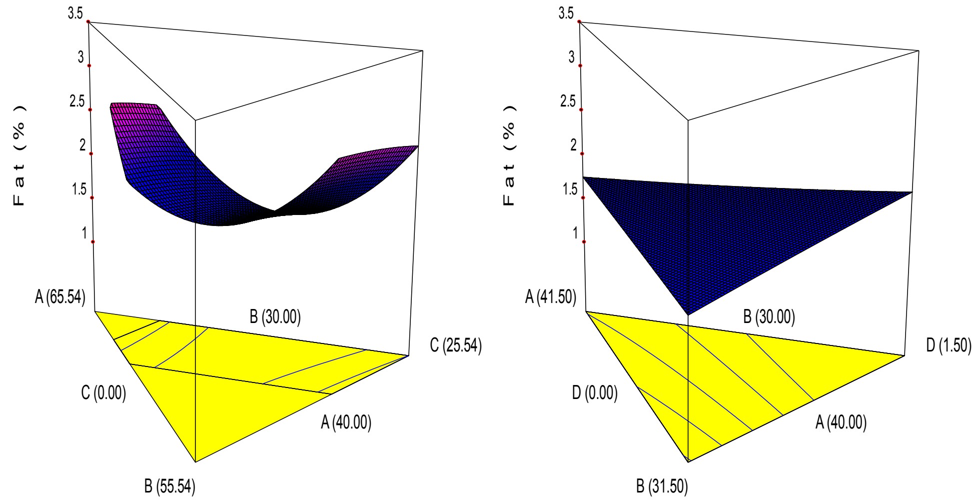
From proximate analysis of raw ingredients it was observed that protein content of corn, rice, peel, seed was observed to be (10.03%, 5.81%,16.19% 26.39%) and Statistical analysis ANOVA showed that there is significance difference ($p \leq 0.01$) between the combinations AD, CD, ABC, ABD, BCD (A-corn flour, B-rice flour, C-peel, D-seed) when compared to control formulations. In treatment without pomace, there was no significant difference ($p > 0.05$) in the protein content between the extrudates. This hardness may be due to the extruders, with their shearing screws operating at high speeds, imparts significant structural changes to food components including proteins. However due to high protein content in (seed > peel > corn > rice) the product obtained also have the effect by the structural changes during extrusion which will increase the hardness and leads to lower expansion.

There are many reports suggested that as higher protein added to starch based- extruded snack, density and hardness are expressed to



Protein (%) =0.21711A + 0.23511B – 0.98028C – 0.31890D – 5.43930 – 003AB + 0.026526AC – 0.0.092231AD – 0.040680 – 7.74813E – 003ABD – 5.48839E – 004ACD + 6.71313E – 003BCD.

Figure 3: 3-D contour plots of protein (%) (A-corn flour %, B-rice flour %, C-peel %, D-seed %).



Fat (%) = – 0.20642A – 0.30476B – 0.47895C – 11.34714D + 0.010768AB + 0.010642AC + 0.21119AD + 7.69345E – 003BC + 0.23817BD – 0.28765CD + 1.55966E – 005ABC – 4.26613E – 003ABD – 4.67595E – 003ACD – 1.63695E – 003BCD.

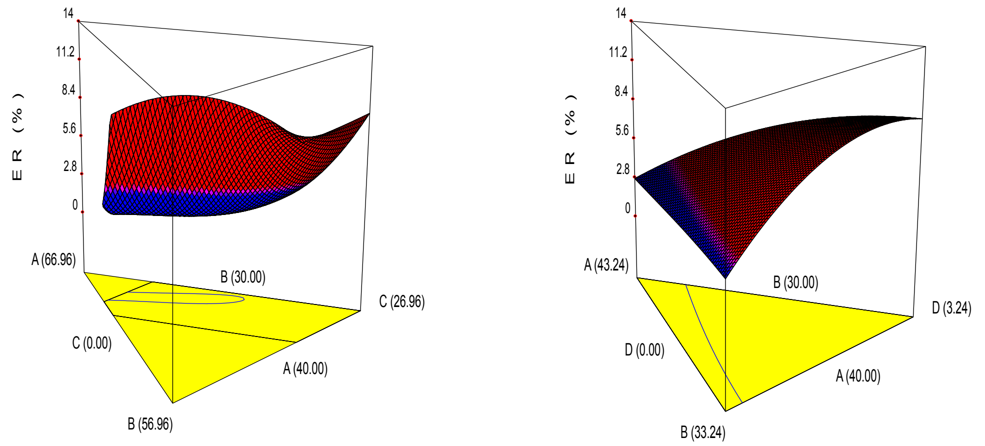
Figure 4: 3-D contour plots of fat (%) (A-corn flour %, B-rice flour %, C-peel %, D-seed %).

increases. Adding proteins to extruded starch-based snacks increases the number of sites for crosslinking, but reduces the starch matrix, resulting in tough, non-expanded crusts [4,13-15]. On the other hand protein is essential for health and it can be suggested that 0%-5% seed is appropriate amount to be included in the extruded product for the consumer acceptance in terms of hardness, expansion and density.

Effect of fat on extrudate

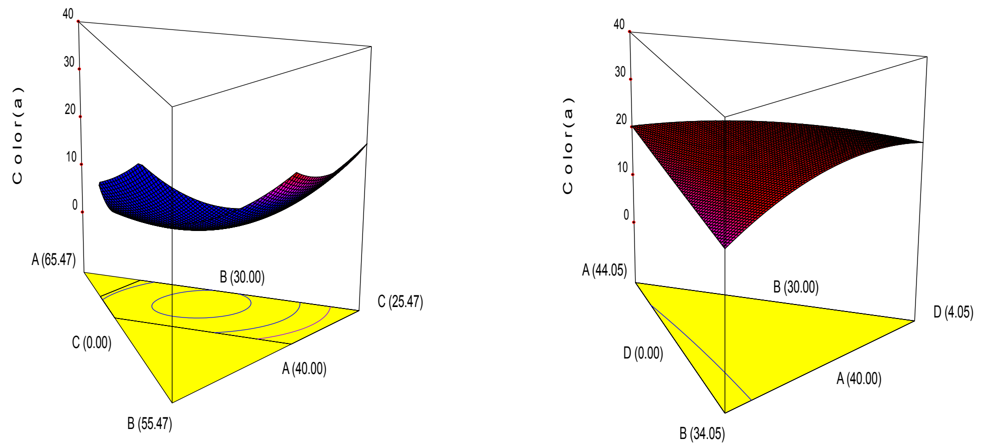
Tomato seed is the important component in the extruded product which also affects the extrudates in a complex manner. The high amount of fat content was observed in seed of tomato as shown in (Table 2). Generally for extruded snack foods, it is desirable to have low levels of fat content [16]. In the present study it was observed that fat content in all extrudates did not exceed more than 3% and hence the product developed could be a low fat and high calorie snack food. However the fat content of extruded product enhances the taste of the product, which is directly proportional to the seed added in the extruded product formulation.

The fat content in the final extruded product varied significantly ($p < 0.001$) and was directly propositional to the percentage of seed present in the initial formulation. Similarly in the case of formulations which included only corn, rice and/or peel flour, no significant difference was observed in terms of fat content. This observation may be explained by the fact that less amount of fat were present in those formulations where tomato seed was absent as is evident by (Figure 4). Fahim Danesh et al. [17] found that tomato seed consisted of essential fatty acids which are useful for the substitution in new product as a source from by-product. They further stated that palmitic acid (12.26%) was the major saturated fatty acid, followed by stearic acid (5.15%) whereas Linoleic acid (56.12%) was the major unsaturated fatty acid followed by oleic acid (22.17%) in those tomato seeds. Substitution of fat in extrudates more than 10% leads to an increase in hardness of the final



ER % = 9.925819A – 1.769B + 3.796C – 724.282D – 94.22852AB – 16.9765AC + 923.446AD + 6.606BC + 927.748BD + 872.758CD – 46.3771ABC – 573.483ABD – 404.853ACD – 85.968BCD – 299.541AB (A – B).

Figure 5: 3-D contour plots of Expansion ratio (%) (A-corn flour %, B-rice flour %, C-peel %, D-seed %).



Colour (a) = 0.818377A + 2.984478B + 2.87473C – 168.15113D – 0.068337AB – 0.036134AC + 2.36710AD – 0.14561BC + 2.74845BD + 2.75589CD + 1.91089E – 033ABC – 0.033385ABD – 0.012147BCD.

Figure 6: 3-D contour plots of colour (a) value (A -corn flour %; B rice flour %; C peel%; D seed %).

product (citation), considering these factors, in present study it was restricted to 5% (seed) as a substitute for producing low fat snack foods. Hence increasing the amount of seed to 5% which in turn increased the fat% to 3% did not significantly affect the expansion of the extrudate.

Effect of expansion ratio on extruded product

The expansion ratio of the extrudates seeks to describe the degree of puffing undergone by the dough as it exits the extruder. The stored energy was released in the expansion process, increasing the expansion ratio [18]. The extrusion of all combinations of corn flour, rice flour, peel and seed produced expanded snack at most conditions; however blends having higher peel % usually had lower expansion ratio. The expansion ratio measured for all the extruded samples ranged between (3.806 - 4.779%). The expansion ratios of the extruded snacks were similar to the published values of rice-based extrudates [19-21]. The response surface plot for the expansion ratio as a function of components is shown in (Figure 5)

The analytical results indicated that expansion indices were linearly affected ($p \leq 0.0001$) by the tomato pomace. As expected incorporation of tomato derivative reduced the expansion values when compared to the control (without by-product) (Figure 5), similar finding were observed by Dehghan-Shoar et al. [22]. Tomato pomace which is rich in fibers, in the formulation tends to rupture the cell walls before the gas bubbles may expand to their full potential during the process of extrusion cooking. Decrease in the expansion ratio by the addition of products rich in fiber was also observed in studies done by Atlan et al. [7] and Dehghan-Shoar et al. [22]. The decrease in expansion ratio may further be aided by the relative reductions in the amount of starch and protein, mainly responsible for the puffiness of the final product.

Colour

Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extruded products. Results of colour recorded for the extrudates containing different concentrations of tomato pomace obtained using different mixture designs are presented in Figure 6. Among the colour parameters, the redness *a* values showed marked changes due to addition of tomato pomace only.

An increase in tomato peel level in product increased the '*a*' value of samples as expected due to the lycopene pigment in the tomato peel.

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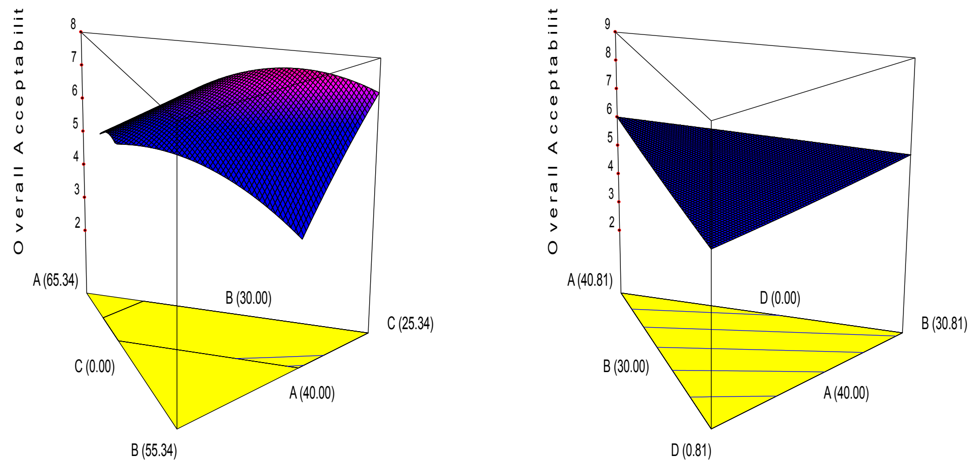

Overall acceptability = – 0.50999A – 0.95199B – 0.043458C + 27.45048D + 0.031987AB + 0.011021AC – 0.27136AD + 5.06584E – 003BC – 0.30404BD – 0.26368CD.

Figure 7: 3-D contour plots of overall acceptability (A-corn flour %, B-rice flour %, C-peel %, D-seed %).

Solutions					
Number	**Corn flour**	**Rice flour**	**Peel**	**Seed**	**Desirability**
1	40	30	25.24	4.76	0.84
2	54.82	30	13.42	1.75	0.58
3	46.78	40	12.04	1.18	0.55
4	60	30	5.72	4.28	0.48

Table 4: Solutions obtained from D-optimal mixture design.

Similar results were reported by Ilo and Berghofer [20], Altan et al. [7], Dehghan-Shoar et al. [22]. Results of ANOVA showed significant difference among the linear mixtures by the addition of pomace in the extrudates ($p < 0.05$).

There were however, some formulations like ABC and BCD which did not show significant difference among them with regards to colour. This phenomenon may be due to the yellowness colour which was not significant in most of the formulations and which are due to the carotenoid content in seed and corn flour may have some effect on the *a* value of the extrudate samples [22].

Overall acceptability

A 9 point hedonic scale was used for the sensory evaluation of the extruded products. The mean scores of overall acceptability showed that all products with tomato pomace were within the acceptable range. Statistical analysis showed that the model was ($P < 0.05$) significant with addition of pomace.

It was observed that tomato pomace had significant effect on final product quality in terms of appearance, colour, flavour and taste. Overall acceptability of the products ranged from (4.4-8), Extrudates with different levels of tomato pomace had higher scores with respect to control sample, combinations which had the Overall acceptability was the one with peel and seed ratio, 15: 0% and 25: 5% respectively (Figure 7).

Furthermore it could be explained that combination with seed also ranged high due to the fact that seed contained fat content which increases the taste of the sample over consumption. Although due to increase in peel and seed percentage some variation of textural properties were observed in all combinations, especially hardness may increase due to increase in fiber and protein content as discussed earlier this certainly affects the crispness of the product. Some product showed Umami flavour after taste which increased when addition of pomace (>20%) was done. Higher the peel percentage eventually increased the colour of the product.

Above all results indicated that extrusion of tomato pomace, in combination with rice and corn flour can produce acceptable extrudate snack food. Moreover the tomato pomace content was the most important parameter affecting the sensory properties of extruded product.

Optimization of formulation based on desirability by using mixture (D-Optimal) design

The optimization tool from the design expert software was utilized to derive the optimal formulations based on response results evaluated. This was implemented by choosing the criteria of maximum limits for both the favorable factors and desirable responses, i.e., tomato peel and seed (factor), corn flour and rice flour were kept in range and response with maximum limits were expansion ratio, protein, fat, crude fiber, colour (a) and overall acceptability. Undesirable responses (e.g. hardness) were minimized to produce formulations with a more crispy texture but less hardness. 17 formulations with predicted quality response values were generated based on these entered parameters. Depending on the best desirability ratings, one formulation was chosen. The details of these formulation can be seen in (Table 4) the combinations were F1, F2, F3, F4 (desirability 0.845 i.e., 84.5%) tomato pomace, corn flour and rice flour, die head temperature of 130°C and screw speed of 300 rpm.

Furthermore the model was validated by comparing the predicted data from the Mixture design with the experimental study, which was observed to be close and the % error was very low.

Conclusion

Using D-optimal mixture design as a tool, the effects of four factors on the physico-chemical characteristics, texture, post cooking quality (WAI & WSI) and chemical properties of extruded snack are highlighted in this study. The design demonstrated the ability of tomato pomace to affect all the responses. In all formulation, it was observed to be significant variation with the addition of tomato pomace on to the extruded product. Tomato pomace affected the expansion ratio, texture and hardness. This is attributed to the high fiber content present in tomato pomace and protein content in seed.

As discussed, fiber is well documented as having hydrophilic properties; beyond a certain limit, it can have a negative impact on the responses due to its ability to absorb excess water and damage aerated bubble structures. Optimization of these four factors was crucial for the development of a high-quality puffed snack. The optimal extrusion conditions and Tomato pomace inclusion to produce a high quality snack were calculated with the aid of the optimization tool to be; corn flour, corn flour and tomato pomace within the range and tomato pomace addition with desirability of 0.84%. The study successfully demonstrates how tomato pomace could be utilized in an extruded puffed snack. It also highlighted how an under-utilized by-product may be substituted for corn, rice flour and incorporated into an expanded puffed snack. Sensory acceptability of the product was showed to be most dependent with the pomace content. However high level of tomato pomace was included into the extruded snack without compromising the expansion characteristics of the snack while potentially improving its nutritive properties with high fiber and protein enriched snack product. These kinds of products could help in utilizing the by-product as a source of fiber for the production of valuable products in the future.

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