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Utilisation of Potato Peel in Fabricated Potato Snack

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Abstract

To address the problem of dietary restraint of health-conscious people, a techno-feasible process for development of low-fat and high-fibre fabricated potato snack has been standardised. The product was optimised on the basis of fat and fibre content, browning index, hardness, crunchiness, and overall acceptability (OAA) by using the central composite rotatable design (CCRD) of response surface methodology (RSM). The fabricated snacks with an average thickness of 2.06 mm contained 5.04–5.24% moisture. Hardness and browning index of baked potato snack was significantly influenced by peel incorporation followed by fat content and leavening agent. Maximum crunchiness was achieved at lower peel (~1.5%) and fat (~2.25%) addition. Leavening agent and fat demonstrated a positive effect on the overall acceptability of the snack. The maximum OAA (8.58) was achieved when both peel and fat were in range but at maximum level of leavening agent. Incorporation of 1.84% potato peel, 4.80% fat, and 1.60% leavening agent resulted in a well-accepted fabricated potato snack which can be categorised as 'low fat' and 'good source of fibre' since a 30-g serving of this fabricated snack provided < 3 g fat and 2.5–4.9 g fibre. The developed technology can diversify the present processed potato product range with effective utilisation of its peel.

Keywords Kufri Chipsona 1 · Potato peel · Fabricated snack · Low fat · Fibre

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Introduction

Potato snacks available in the market are mostly fried and contain high fat content. Oil consumption, especially of saturated and semi-saturated fat (palmolein), is recognised as one of the major factors that adversely affect human health causing coronary heart disease, cancer, diabetes, and hypertension. Presence of trans-fatty acids increases concentration of plasma low-density lipoproteins with simultaneous reduction in high-density lipoproteins. According to Dueik and Bouchon (2014), there is a high intake of oil/fat by people of USA with 6.5 billion pounds of snack food consumed annually, indicating the consumption of more than four snacks per day. Vinaixaa et al. (2005) have reported a rejection of fried products by calorie conscious consumers, the phenomena being termed dietary restraint. The deep fat frying process has also been shown to shorten the shelf stability of potato chips due to development of rancidity. Processes involving utilisation of low fat for food manufacture and products with higher phytochemical properties are the new health trends in niche markets. Development of fabricated foods with desirable attributes such as low fat and enriched with fibre is gaining momentum for providing adequate nutrition while breaking the monotonous featured product in the market.

Peel, the major and unavoidable waste of potato processing industries, is a good source of nutritional and pharmacologically important compounds such as dietary fibre, phenolics, and glycoalkaloids. When discarded, it is an environmental pollutant because of its high biological oxygen demand potential and is mostly used as animal feed or raw material for biogas production. The utilisation of this by-product can substantially reduce the waste disposal problem of the potato industries and also help in extraction of beneficial compounds and enrichment of other food items with essential nutrients. Potato peel flours have been previously used for development of various value-added baked products (Camire1994; Jeddou et al. 2017), extraction of phytochemicals (Maldonado et al. 2014), and ethanol production (Arapoglou et al. 2010). Moreover, Azizi et al. (2020) have demonstrated that traditional processing methods such as boiling can alter the techno-functional properties of the potato peel powder to be used in foods. The present investigation was carried out to develop a novel low-fat, high-fibre potato snack with additional health benefits and good sensory attributes for widening the scope of utilisation of peel fibre, as well as adding a diversified potato product to the consumers' food basket. For nutritional claim of 'low fat' and 'good source of fibre', a snack should provide ≤3 g fat and 2.5–4.9 g fibre from 30 g serving which is RACC (Recommended Amount Customarily Consumed) of any snack (Potter and Hotchkiss 2006). Vacuum frying, microwaving, combined method of pre-frying and pulsed-spouted microwave vacuum drying, and hydrocolloid coatings are the strategies that have been reported for reduction of fat uptake during frying of potato snacks (Garmakhany et al. 2008; Troncoso et al. 2009; Joshi et al. 2016; Quan et al. 2016). In the present study, a baking technique was tried to develop the fabricated snack since it is feasible to scale up and adopt by food industries and small and marginal entrepreneurs.

Materials and Methods

Procurement of Raw Material

To develop the snack, potato cv. 'Kufri Chipsona 1', a processable variety having more than 20% dry matter was procured from Central Potato Research Institute, Regional station Modipuram, Meerut, Uttar Pradesh (India). The peel of the selected variety is having low glycoalkaloid (0.59 mg/100 g FW) content (Singh et al. 2016). Chemicals were procured from Sigma and Merck India Pvt. Ltd. Salt and spices were procured from the local market.

Preparation of the Snack

Fabricated potato snack was developed using potato powder of raw tubers of 'Kufri Chipsona 1'. Shreds of the peeled raw tubers were dried in a cabinet dehydrator at 65 °C for 7 h. The obtained dried material was powdered in a grinder and stored in low-density polyethylene (LDPE) pouches till further use. Peels obtained were also dried and converted to powder and stored in a similar way. Development of fabricated baked potato snack was optimised by using central composite rotatable design (CCRD) with the help of Design Expert 8.0.4.1 software with 3 factors at 5 levels using response surface methodology (RSM) technique. On the basis of preliminary experiments, the levels of all the independent variables, i.e., amount of peel incorporation (on potato flour replacement basis), fat addition, and leavening agent, were set to analyse the effect of independent variables on responses for optimisation of fabricated potato snack. The product was optimised on the basis of the response of fat content, fibre content, browning index, hardness, crunchiness, and overall acceptability (OAA) of the snack made. The results for the CCRD were analysed for a second order polynomial equation by a least squares technique. The response function (Y) was partitioned into linear, quadratic and interactive components as mentioned below:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i>j}^{k} \beta_{ij} X_i X_j$$

where Y is the response, X_i, X_j are input variables, β_0 is the intercept, β_i is linear coefficient, β_{ii} is quadratic coefficient, and β_{ij} is interaction coefficient.

The response surface plots of the model were plotted as a function of two variables, while keeping the third variable at constant or optimal level. A total of 20 runs (trials) were carried out and the responses were taken by repeating each trial thrice to see the change in responses (Table 1). Analysis of variance was performed for each response to access suitability of the selected model.

The peel powder, fat (oil), and baking powder were mixed in the proportions as obtained in the experimental design to form different formulations. A total weight of 15 g was maintained of potato flour and peel powder combined. The formulated mixes were further added with preset ingredients, i.e., common salt (0.3 g) and spice mix (0.75 g). The dry ingredients were thoroughly mixed with fat (oil) followed by the

Table 1 Experimental range and level of independent variables used in RSM in terms of coded and actual factors and their corresponding responses

Run	Coded factors			Independent variables			Responses					
	Peel (%)	Fat (%)	Leavening agent (%)	Peel (g)	Fat (g)	Leavening agent (g)	Fat (%)	Fibre (%)	Browning index	Hardness (N)	Crunchiness (No. of peaks)	OAA (score out of 9)
1	0 (3)	0 (4.5)	+∞ (2)	0.543	0.8145	0.362	16.01	9.56	69.89	57.84	22.00	8.58
2	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	15.06	9.64	81.52	97.97	22.66	7.20
3	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	16.22	9.64	82.34	80.81	21.66	7.65
4	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	15.73	9.72	68.89	83.63	23.00	7.28
5	1 (4.5)	1 (6.75)	−1 (0.5)	0.8145	1.221	0.0905	22.43	9.42	115.37	82.55	14.33	6.42
6	1 (4.5)	−1 (2.25)	−1 (0.5)	0.8145	0.407	0.0905	7.71	9.79	114.16	96.77	20.33	5.88
7	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	16.02	9.59	80.33	77.17	21.00	5.78
8	−∞ (0)	0 (4.5)	0 (1)	0	0.8145	0.181	15.03	9.79	70.32	44.91	21.66	8.01
9	−1 (1.5)	−1 (2.25)	1 (1.5)	0.2715	0.407	0.2715	7.68	9.86	84.22	77.94	26.00	8.33
10	−1 (1.5)	−1 (2.25)	−1 (0.5)	0.2715	0.407	0.0905	7.68	9.95	106.13	104.59	24.00	6.52
11	−1 (1.5)	1 (6.75)	1 (1.5)	0.2715	1.221	0.2715	22.4	9.49	84.78	64.74	16.66	7.88
12	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	15.06	9.64	82.91	77.57	17.66	7.66
13	−1 (1.5)	1 (6.75)	−1 (0.5)	0.2715	1.221	0.0905	21.8	9.57	75.90	80.49	20.33	6.52
14	0 (3)	−∞ (0)	0 (1)	0.543	0	0.181	0.33	10.41	76.36	109.94	13.66	5.22
15	1 (4.5)	−1 (2.25)	1 (1.5)	0.8145	0.407	0.2715	7.70	9.71	97.33	76.67	25.33	7.74
16	1 (4.5)	1 (6.75)	1 (1.5)	0.8145	1.221	0.2715	22.42	9.33	94.66	71.43	15.00	7.28
17	0 (3)	0 (4.5)	0 (1)	0.543	0.8145	0.181	14.99	9.64	84.00	80.58	23.33	7.35
18	0 (3)	+∞ (9)	0 (1)	0.543	1.63	0.181	29.81	9.26	77.66	82.97	10.00	7.32
19	0 (3)	0 (4.5)	−∞ (0)	0.543	0.8145	0	14.92	9.72	81.34	112.5	23.66	5.18
20	+∞ (6)	0 (4.5)	0 (1)	1.086	0.8145	0.181	15.09	9.31	128.53	87.93	16.66	6.52

addition of water (17–17.5 ml) to make consistent pliable dough. The dough was rested for 20 min, rolled, sheeted to 1.8–2.0 mm thickness, and cut into desired triangular shape. The pieces were baked at temperature of 170 °C for 20 min to a golden brown colour. The control samples were prepared following the same procedure, without incorporation of peel powder. The baked potato snacks were packed in LDPE pouches prior to sensory and proximate analysis. Different formulations of baked potato snack were analysed for the responses, i.e., fat content, fibre content, hardness, crunchiness, browning index, and OAA. The data for formulations along with responses were analysed using statistical software of the best-fit design to obtain the optimised compositions.

Physical Characteristics of the Snack

Thickness of the baked snack was measured using a vernier calliper in triplicate (Bishai et al. 2015). Weight of the snack was measured by taking average weight of 10 snacks in an electronic balance. Hardness and crunchiness of the fabricated snack were determined using a texture analyser (Stable micro systems, UK) by measuring the maximum compression force required for rupturing the snack. The pretest speed was kept at 5 mm/s while the test speed and post-test speeds were 0.5 mm/s and 5 mm/s for a rupture distance of 60%. Three pieces from each trial were used for assessment. Crunchiness was measured as the number of positive peaks obtained during the compression of the snack.

The browning index of the snack was calculated from the L^*, a^*, b^* coordinates as per the following formula:

$$\mathrm{BI} = [100(x{-}0.31)]/0.172$$

where

$$x = \left(a^* + 1.75 \times L^*\right)/\left[\left(5.646 \times L^* + a^* - \left(3.012 \times b^*\right)\right]\right.$$

Chemical Attributes of the Snack

Moisture content of the snack was determined by the gravimetric method (AOAC 2000). Fat content of the potato tubers and flour was estimated by using the Soxhlet apparatus (Ranganna 2007) and expressed as percentage. Fibre content was determined by digesting 1 g sample in 1.25% H_2SO_4 followed by 1.25% KOH solution through fibre extractor (Velp Scientifica make) as described in method 32-10 (AACC 2000).

Organoleptic Evaluation

The overall acceptability of the fabricated potato snack was done by a semi-trained panel of 25 judges from the division aged between 25 and 45 years, using a 9-point Hedonic scale (Ranganna 2007). The overall rating was calculated by averaging the scores.

Results and Discussion

Snack items have become an integral part of the eating habits of the majority of world's population. There is a paradigm shift in the consumers' preferences with rise in demand of reduced-fat and high-fibre products having added functionality. We have developed a fabricated potato snack through baking technique to counter the high fat acquired during the traditional frying process.

The moisture content of the baked snacks amongst the twenty trials conducted was in the range of 5.04–5.24%. The dough was sheeted to a thickness of 1.8–2.0 mm. The resultant snack after baking had an average thickness of 2.06 mm. with a range of 1.95–2.23 mm. The incorporation of different proportion of ingredients such as fat may have affected the spreadability of the dough, thus yielding differences in thickness. Previously, Caetano et al. (2016) and Palazoglu et al. (2010) also reported variation in thickness of fried potato chips (1.4 to 1.5 mm). The baked fabricated potato snack from all the twenty runs had an average weight of 0.915 g that varied non-significantly with the trials.

Total fat content of baked potato snack followed linear model with all the three factors having positive effect on the fat content (r^2 = 0.98). Minimum fat content (0.33%) in the snack was achieved at the lowest level of fat in the formulation (Table 2). Similarly, crude fibre content of the baked snack also followed a linear model with r^2 = 0.84 and was in the range 9.26–10.41%. Fibre content increased corresponding to the increase in peel incorporation. Gupta and Premavalli (2012) and Jeddou et al. (2017) also reported an increase in the dietary fibre content in snack and cake developed with addition of radish and potato peel powder, respectively.

Baked products are a suitable matrix for addition of potato peel as a source of fibre. This however may negatively affect the colour of the snack. Browning index of baked potato snack followed quadratic model which is significant at 95% confidence level with r^2 = 0.78. The model for browning index of baked potato snack could be explained by relation given as follows:

$$\text{Browning index} = 79.60 + 12.33A - 2.12B - 5.11C + 3.53AB - 3.06AC + 3.36BC + 9.47A^2 + 1.54B^2 + 1.05C^2$$

where A = peel (%), B= fat (%), and C= leavening agent (%).

Both level of fat and leavening agent demonstrated a negative effect on the browning index. We observed that increased darkening of the baked potato snack developed with corresponding increase in the peel incorporation. Similar findings were also reported by Toma et al. (1979) with increasing substitution of potato peel for wheat flour to make bread. Similarly, Jeddou et al. (2017) also observed higher L^* values for cakes having no potato peel incorporation as compared to those with substituted potato peel powder. The high values for a^* and b^* indicate a significantly brighter and more saturated brown orange colour (Joshi et al. 2018).

For the optimisation of independent variables, the major responses, i.e., hardness, crunchiness, and OAA, were selected on the basis that these responses had direct effect on the acceptability of the snack and were dependent directly on the specific composition of the product. Prinyawiwatkul et al. (1993) also reported texture to be a

Table 2 Predicted optimisation values for baked potato snack optimised using design expert software 8.0.11

Factors			Responses						Desirability
Peel (%)	Fat (%)	Leavening agent (%)	Fat (%)	Fibre (%)	Browning index	Hardness (N)	Crunchiness (No. of peaks)	Overall acceptability	
1.84	4.80	1.60	7.54	9.75	91.03	79.51	23.01	7.30	0.741
1.83	4.78	1.60	7.54	9.75	90.75	79.60	23.02	7.31	0.741
1.83	4.74	1.60	7.54	9.75	90.17	79.77	23.04	7.31	0.740

primary attribute, which consumers use to judge quality of the snack product. The effect of all the variations in levels of independent factors in the design, on different responses, can be seen in the predictive graphs for each response for the product. The 3D graphs showed the deviation of response, i.e., hardness, crunchiness, and OAA, from the reference point.

The texture of snack items can be determined by either objective methods, i.e., by use of instruments or subjective ones, i.e., by sensory evaluation. Textural analysis of the snack is primarily characterised by evaluation of mechanical attributes such as hardness and crunchiness when it is subjected to a controlled force in response to which a deformation curve is generated (Mnif, et al. 2012). Hardness of baked potato snack followed quadratic model which is significant at 95% confidence level. The model for hardness of baked potato snack could be explained by relation given as follows:

$$\text{Hardness} = 82.98 + 5.27A - 7.48B - 12.12C + 2.23AB + 1.40AC + 2.48BC - 6.01A^2 + 4.61B^2 + 0.62C^2$$

where A= peel (%), B= fat (%), and C= leavening agent (%).

The r^2 value was 0.80 for the model and the F-value was 4.58, which implied that the model was significant. The coefficient of estimation of hardness showed that level of peel incorporation had a positive effect on the hardness of baked potato snack. Both fat and leavening agent demonstrated a negative effect on the hardness values.

Figure 1 shows that the lowest value of hardness (44.91) was achieved at the lowest level of peel in the formulation. The product with varied formulations had a hardness range of 44.91–112.5 N. High insoluble fibre content in peel imparts structural rigidity to the snack thus yielding a hard snack. Also, fat (oil) is a known tenderising agent in baked products and makes the dough more pliable. A lower fat (oil) content in the formulation thus tends to harden the dough. Arora and Camire (1994) have also recorded an increase in the compression force for the muffins developed by addition of potato peels. Addition of peels to the developed product increases the density of the product and reduces the air pockets, thereby increasing the force needed for compression. Jeddou et al. (2017) also reported a decrease of hardness of cakes by 30.24 and 36.12% upon 5% substitution of wheat flour with peel of potato variety Spunta and peel of an unknown commercial potato variety procured from the market, respectively.

Crunchiness, in terms of the number of peaks depicting the mastication processes, also varied with the different levels of fat, peel, and leavening agent. Crunchiness of

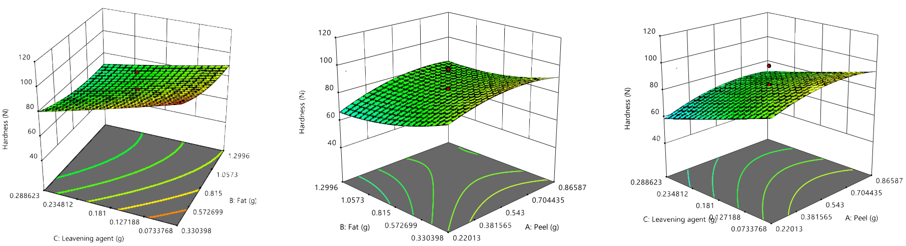

Fig. 1 Response surface plots showing effect on the hardness of the fabricated potato snack

baked potato snack followed quadratic model which is significant at 95% confidence level. The model for crunchiness of baked potato snack could be explained by relation given as follows:

$$\text{Crunchiness} = 21.47 - 1.49A - 2.60B + 0.09C - 0.41AB + 0.91AC - 1.25BC - 0.31A^2 - 2.90B^2 + 0.98C^2$$

where A= peel (%), B= fat (%), and C= leavening agent (%).

The r^2 value was 0.80 for the model and the F-value was 4.73, which implied that the model was significant. The coefficient of estimation of crunchiness showed that both level of peel and fat incorporation had a negative effect on the crunchiness of baked potato snack. Maximum crunchiness (26) was obtained by addition of slightly lower peel (~1.5%) and fat (~2.25%) addition (Fig. 2). Leavening agent on the other hand demonstrated a positive effect on the crunchiness of the snack. Crunchiness in terms of number of peaks was observed to be 13.66 to 26.

Assessment of snack acceptability by sensory evaluation is largely governed by personal judgment and biasness. A semi-trained panel adjudged the acceptability of the developed snack. The OAA of the baked snack followed a quadratic model which is significant at 95% confidence level. The model for overall acceptability of baked potato snack could be explained by relation given as follows:

$$\text{OAA} = 7.14 - 0.32A + 0.23B + 0.85C + 0.06AB - 0.05AC - 0.18BC + 0.10A^2 - 0.25B^2 - 0.03C^2$$

where A= peel (%), B= fat (%), and C= leavening agent (%).

The OAA of the product was mainly influenced by addition of fat followed by leavening agent. The level of peel incorporation had a negative effect on the overall acceptability of baked potato snack owing to the increased hardness and darker brown colour. Leavening agent and fat on the other hand demonstrated a positive effect on the overall acceptability of the snack. OAA of the fabricated snack across all the 20 combinations ranged between 5.18 and 8.58 on a nine-point hedonic scale. Figure 3 shows that the maximum overall acceptability (8.58) was achieved when both peel and fat were in range but at maximum level of leavening agent.

Increase in the peel or decrease in the leavening agent and fat resulted in snack with lower overall acceptability. Arora and Camire (1994) have reported a reduced sensory acceptability of both muffins and oatmeal cookies prepared by adding 25% and 15%

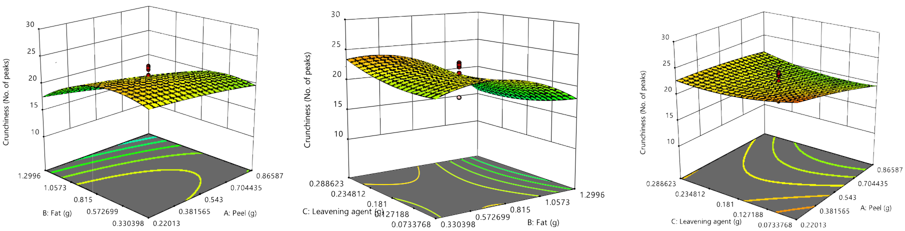

Fig. 2 Response surface plots showing effect on the crunchiness of the fabricated potato snack

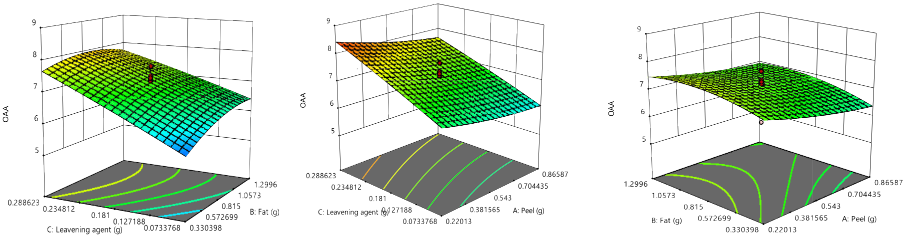

Fig. 3 Response surface plot showing effect on the OAA of the fabricated potato snack

potato peel, respectively, owing majorly to the dark colour of the formulation and also the texture. Muffins with added potato peel had an objectionable gritty mouthfeel.

Optimisation of Fabricated Potato Snack Development

The method adopted for process optimisation was based on a numerical method. On the basis of constraints suggested (minimum fat, maximum fibre, crunchiness and overall acceptability), design expert software selected 3 solutions with desirability of 0.741, 0.741, and 0.740 (Table 2). Maximum desirability (0.741) was obtained at 1.84% peel, 4.80% fat, and 1.60% leavening agent. Jackson et al. (1996) used a factorial design for optimising the time and temperature for blanching of green bananas for preparation of fried chips, while vacuum frying was tried in preparation of fried apple chips by Shyu and Hwang (2001). Thus, RSM has been shown to be an effective tool for optimising product formulations. It basically uses regression equations that describe interrelation between input parameters and product properties (Colonna et al. 1984).

The analysis of variance was calculated for each model as well as response to assess how well the model represented the data. For hardness, crunchiness, browning index, and OAA, *F*-value of 4.58, 4.73, 4.03, and 3.25 (Table 3) implied that the models were

Table 3 ANOVA and model statistic for baked potato snack

Term	Responses					
	Fat (%)	Fibre (%)	Hardness (N)	Crunchiness (No. of peaks)	Browning index	OAA (score out of 9)
Model	Linear	Linear	Quadratic	Quadratic	Quadratic	Quadratic
F-value	439.29	28.96	4.58	4.73	4.03	3.25
Mean	15.20	9.65	82.45	19.95	87.83	7.02
Standard deviation	0.80	0.11	10.07	2.61	10.57	0.68
CV%	5.29	1.13	12.21	13.06	12.04	9.69
R^2	0.98	0.84	0.80	0.81	0.78	0.74
Adjusted R^2	0.98	0.81	0.63	0.64	0.59	0.51
Lack of fit	0.14	0.01	0.18	0.22	0.03	0.55

Table 4 Actual response values obtained against predicted response values for baked potato snack

Product	Responses					
	Fat (%)	Fibre (%)	Browning index	Hardness (N)	Crunchiness (No. of Peaks)	Overall acceptability
Predicted	7.54	9.75	91.03	79.51	23.01	7.30
Recorded	7.54	9.82	89.88	81.24	23.00	7.50

significant. The model of polynomial equation from the software fitted well and lack of fit was insignificant.

Validation of the results obtained was done by running a trial again of the optimised formulation. Table 4 gives the actual response values obtained against predicted response values for baked potato snacks.

Conclusion

A large quantity of potatoes is being processed for human consumption in the form of flakes, chips, dehydrated products, and boiled and par fried products. This results in the production of a large amount of potato peels that can be used as a potential source of fibre in processed products such as the snack we developed. Optimum quality baked potato snack with low-fat and high-fibre attribute could be developed by the incorporation of 1.84% potato peel, 4.80% fat, and 1.60% leavening agent. Therefore, the developed fabricated snack can be categorised as 'low fat' and 'good source of fibre' since 30 g serving of developed fabricated snack would have <3 g fat and 2.5–4.9 g fibre. The fabricated snack can serve as a tasty alternative source of fibre and is a feasible approach for effective utilisation of potato peel obtained as a by-product from potato processing industry.

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Author contribution Ahmad Farid Azizi, Shruti Sethi, and Alka Joshi collected raw material, planned and carried out the experiments, prepared fabricated snacks, interpreted and discussed the results, and worked on the manuscript writing. Bindvi Arora analysed and interpreted the experimental data.

Data availability Supplementary sheet will be provided if required

Declarations

Conflicts of Interest The authors declare that they have no conflict of interest.
Ethics approval and consent to participate
This article does not contain any studies with human or animal subjects

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