Development of radish fibre based snack by response surface methodology (RSM)

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Abstract This study aimed at optimization and development of radish fibre-rich snack using response surface methodology (RSM). The effect of ingredients on the quality of refined wheat flour (*maida*) based fried snack was studied. As the concentration of ghee in the formulation increased, the product became soft and lost its crispiness, thus affecting the overall acceptability. Radish fibre (5–20 g) was incorporated in the *maida* and the central composite design used to develop models for the responses. It was observed that ghee and fibre significantly ($p \leq 0.05$) affected the acceptability and texture of fried product. Based on surface responses and 3D plots, level of fibre (20 g), *maida* (100 g) and ghee (15.12 g) were optimized to form a fibre-rich product, with high acceptability and better texture profile. The fibre-rich snack product contained nearly 8% more total dietary fibre (12.24%) than the control (4.25%). The product was stored for 6 months under ambient conditions during which it was stable and acceptable up to 4 months. At 5°C, it was stable up to 6 months in tri-laminated paper/Al-foil/polyethylene (PFP) pouches.

Keywords Dietary fibre · Radish · Fried product · Response surface methodology · Product acceptability · Storage studies

Introduction

Radish is a health promoting vegetable and is well known for its excellent antioxidant properties. It is a good source of ascorbic acid, vitamins and mineral salts. Normally, radish juice is useful in hemorrhoids, asthma, jaundice, inflammation in urinary bladder and thus is used as diuretics and laxatives and also as blood purifier (Charandas 2006). Our preliminary studies revealed radish fibre to exhibit a balanced dietary fibre profile with 15.26% soluble fibre and 33.77% insoluble fibre content. This fibre showed an excellent water binding capacity (15.61 g/g) and swelling capacity (18.71 g/ml) (Gupta and Premavalli 2010). The objective of the present study is to incorporate radish into processed food products as a source of dietary fibre. The residue after juice extraction is left as a by-product which can be ideally used as a novel source of dietary fibre in health foods.

Dietary fibre (DF) acts as a thickening agent in the stomach, increasing the volume of ingested foods and the time of gastric performance. The soluble dietary fibre increases the viscosity of the gastric content, delaying the emptying stomach and reducing the proportion of absorption of the carbohydrates in the small intestine, thus reducing the level of serum glucose (Larrea et al. 2005a). DF also acts as a bulking agent, normalizing intestinal mortality and preventing diverticular disease. Some times it may also be important in reducing colonic cancer and in preventing hyperglycemia in diabetic patients (Larrea et al. 2005a, b; Singh et al. 2007). In recent years, diverse products with high fibre content have been developed. Various researchers have shown the potential use of fibre in preparation of bread (Gomez et al. 2003), muffins (Grigelmo and Belloso 1998), cereal bars (Dutcosky et al. 2006), cookies (Larrea et al. 2005a), extruded products (Artz et al. 1990) etc., where mostly cereal bran is used as

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the source of fibre. DF from several sources certainly increases the nutritional and functional value of food, but usually alters the rheological properties of the dough and hence the quality and sensory properties of the end product (Wang et al. 2002; Monro 2004).

The development of functional foods is a unique opportunity for improvement of the quality of food and to consumer health and well-being. Statistical design tools such as response surface methodology (RSM) are quite effective and most suitable in optimizing the ingredient levels in products as well as the process parameters. The design uses a central composite design to fit a polynomial model by least-square technique (Wadikar et al. 2008). The main advantage of the design is that it enables the study of one or more variables simultaneously in a single experimental design of practical size (Gupta et al. 2008). Consumer has always preferred to have deep-fat fried products because of their unique flavour and texture. Incorporation of functional ingredients such as dietary fibre makes it more practical to impart the benefits. Almeida Domiguez et al. (1990) suggested snack food to serve as a vehicle for important nutrients while being readily accepted by the population. The objective of this study was optimization and development of fibre-rich snack using response surface methodology (RSM).

Materials and methods

Good quality raw materials i.e. radish (*Raphanus sativus*), maida, ghee, ajwain (*Trachyspermum copticum*), green chilli and common salt were procured from the local market.

Isolations of fibres Radish (*Raphanus sativus*), was washed thoroughly, peeled and cut into small pieces and was further

blanched in boiling water for 2 min. Further, the pieces were subjected to juice extraction (3 times) using a juice extractor (RayLons Metal Works, Bombay, India). The residue obtained was dehydrated in a cabinet drier (Ever-flow Tray Drier, Chennai, India) at 60–70 °C to obtain a moisture content of 5–7%. The fibre sample was passed through 60 mesh sieve to get uniform particle size sample. This sample was packed in paper (42 GSM)/Al foil (0.02 mm)/polyethylene 60 µ pouch. All the chemicals and reagents used for analysis were of AR grade.

Experimental design A central composite design was used without any blocking. The number of points in the design were obtained on basis of the number of independent factors (variables) decided for the product. The parameters that influence the product quality and acceptability or functionality were taken as responses. The statistical software package design expert® 6.09, Stat-Ease Inc., Minneapolis, USA (www.statease.com) was used to construct the experimental design as well as analyze the data. In case of this product, 3 independent variables (ingredient factors) viz. fibre, maida and ghee were used and the codes of these variables were A, B and C, respectively. The factorial design consisted of 4 factorial points, 6 axial points and 5 central points leading to 15 sets of experiments. Optimized ranges of the variable are shown in Table 1. Each independent variable investigated in this experiment had five levels which were −1.4142, −1, 0, +1 and +1.4142. A total of 15 level combinations (design points) were generated for the three independent variables. The center point (the level combination in which the value of each coded variable was 0) was repeated five times for the three-variable design and was selected keeping the ingredients at levels expected to yield, at least, satisfactory experimental results. The overall

Table 1 Experimental ranges and levels of independent variables used in RSM in terms of actual and coded factors

Run	A	B	C	Fibre, g	Maida, g	Ghee, g	OAA*	Texture, Kg cm ⁻²
1	+1	+1	−1	20.0	100	15.0	8.0±0.11	1.7±0.06
2	0	0	0	12.5	90	22.5	7.1±0.45	1.4± 0.03
3	+1	−1	+1	20.0	80	30.0	6.2±0.09	0.6± 0.01
4	0	0	−α	12.5	90	11.89	6.5±0.32	1.9±0.05
5	−α	0	0	1.89	90	22.5	7.1±0.41	1.2±0.07
6	0	0	0	12.5	90	22.5	7.1±0.25	1.3±0.02
7	−1	−1	−1	5	80	15.0	6.8±0.50	1.6±0.04
8	0	0	0	12.5	90	22.5	7.0±0.35	1.4±0.09
9	0	0	+α	12.5	90	33.11	6.4±0.42	0.3±0.02
10	0	+α	0	12.5	104.14	22.5	6.9±0.081	1.5 ±0.06
11	0	0	0	12.5	90	22.5	7.0±0.17	1.3±0.05
12	+α	0	0	23.11	90	22.5	7.4±0.92	1.5±0.08
13	−1	+1	+1	5.0	100	30	6.4±0.27	0.7±0.02
14	0	0	0	12.5	90	22.5	7.0±0.42	1.4±0.05
15	0	−α	0	12.5	75.86	22.5	7.2±0.36	1.0±0.08

*Overall Acceptability (OAA) on 9— point Hedonic Scale (n=10)

acceptability (OAA) and texture were selected as the responses (Thompson 1982; Shyu and Hwang 2001).

Preparation of the fibre-rich fried product The radish fibre, maida and ghee were mixed in the proportions as obtained in the experimental design to form different formulations. These formulated mixes were further mixed with fixed ingredients i.e. common salt (2.8 gm), green chilly powder (2 gm) and ajwain (3.5 gm). The dry powder was thoroughly mixed, followed by the addition of molten ghee (according to the combinations) and hot water (65–75 ml), to make good consistency, pliable dough. Ghee was used during the dough preparation to enhance the stability of the product as well as improve the texture of the end-product, in terms of mouthfeel. Moreover, ghee adds desired flavor to the product. Small round balls were made from the dough, rolled and flattened into circular shape (15 cm diameter) and cut into desirable shape. These pieces were fried in refined sunflower oil heated up to 160 ± 5 °C for 3 min to a golden brown colour. The control samples were prepared following the same procedure, without incorporation of radish fibre. The fried snacks were packed in paper/Al-foil/polyethylene (PFP) pouches prior to sensory and proximate analysis. Different formulations of radish fibre based fried products were analyzed for the planned responses i.e. OAA and texture. The data for formulations along with responses were analyzed using statistical software of the best-fit design to obtain the optimized compositions.

Organoleptic evaluation The samples (15 combinations) resulting from the experimental design were evaluated in relation to the sensory preference using 9-point hedonic scale with anchor points, 1 (dislike very much) and 9 (like very much). A semi-trained panel of 10 judges evaluated the samples which were randomly presented for over all acceptability. All panelists were between the age of 25 to 50 years. The order of presentation of samples was randomized and different 2-digit number codes were used for the sample sets. The coded samples were served at room temperature (25 °C) on a white disposable plastic plates and taste-neutral water was provided for rinsing. The order of presentation between the coded samples was varied from one storage time to another. The results were presented as mean of 10 evaluations.

Texture measurement The texture was measured on a shear press (Chatillon, the G. R. ELEC. MFG. Co. Kansas, USA). The sample was placed horizontally over the bottom of the sample plate. 10 kg×20 g capacity load cell was used to measure the shear value (texture) in all the fried samples. Results were based on an average of quadruplicate analysis.

Proximate and dietary fibre analysis of snack The fibre-rich snack samples as well as the control samples were analyzed for moisture, ash, fat and protein contents by standard AOAC methods (2000). Total protein content was estimated by kjeldahl method using Gerhardt nitrogen digestion (turbotherm) and distillation (vapodest) apparatus from Bio-incorporation, India (Roopa and Premavalli 2008). The defatted residues obtained during the course of analysis of crude fat were finely powdered to pass through a 60 mesh standard sieve using a sieve shaker (Jayant Scientific, Mumbai). The material thus obtained was utilized for the analysis of insoluble, soluble and total DF content using the enzymatic-gravimetric method as described by Asp et al. (1983). Resistant starch and total starch contents were estimated in radish fibre as described by Hom's et al. (1986) and Goni et al. (1996), respectively. The results presented are mean values from triplicate determinations.

Shelf stability of fibre-rich snack Storage changes in fibre-rich snack were monitored by determining sensory evaluation, thiobarbituric acid value (TBA), free fatty acid value (FFA), peroxide value (PV) and induction time (IT), for 6 months. Fat extraction was conducted using 100 ml portions of chloroform (AR). The mixture was filtered and chloroform was evaporated from the filtrate using flash evaporator (Superfit 02295). The residual fat was used for PV and FFA analysis (AOCS 1973). TBA value was estimated by distillation method (Tarledgis et al. 1960). The induction time of the product during storage was measured as reported by Majumdar et al. (2007). The oil (3 g) was extracted with chloroform (1:3) using wrist action mechanical shaker (Culture Instruments, Bangalore, India) for 2 h. Thereafter, the sample was filtered using Whatman No.1 filter paper and the chloroform was evaporated using flash evaporator (Superfit 02295). The oil was used for determining the oxidative stability in terms of induction time using Rancimat

Fig. 1 Proximate composition (%) of radish fibre

Fig. 2 3D plots depicting effect of independent variables on OAA (a, b) and Texture (c, d) of the fried product

equipment (Metrohm Ltd. CH-9101 Herisau (Switzerland)) as described by Majumdar et al. (2007).

Results and discussion

Snack food has become an integral part of the eating habits of the majority of world's population. In our study, radish fibre-rich snack food was prepared from natural ingredients to yield products with specific functional properties. The proximate composition of radish fibre clearly showed that it contained

high amount of protein and starch i.e. 9.38% and 22.89%, respectively (Fig. 1). The fibre content was relatively high i.e. 51.03% in this by-product, thus incorporation of this natural vegetable fibre in food products will certainly improve the dietary fibre profile of popular day-to-day food products, thus, increasing the fibre consumption in daily diet. The optimized fibre-rich fried product was developed using Central Composite Design with minimum possible number of points. The experimental design with different independent variables and respective responses along with the coded variables for the product is given in Table 1. Ozer et al. (2004) also used RSM to analyze the effect of screw speed

Table 2 Anova and model statistics for radish fibre based snack

Term	Response	
	OAA*	Texture
Model	Quadratic	Quadratic
F value	130.34	115.80
P>F	<0.0001	<0.0001
Mean	6.94	1.25
Standard deviation	0.049	0.05
CV%	0.71	4.00
R squared	0.9958	0.9952
Adjusted R squared	0.9881	0.9866
Predicted R square	0.9922	0.9689

*OAA— Overall Acceptability

(220–340 rpm), feed moisture (11.0–15.0%) and feed rate (22–26 kg/h) on the physical properties of nutritionally balanced extruded snack food, while Larrea et al. (2005a) evaluated the effect of some operational extrusion parameters on selected functional properties of orange pulp and its use in preparation of biscuit-like-cookies.

In the present study, for the optimization of independent variables, the responses i.e. texture and OAA were selected on the basis that these responses had direct effect on the quality and were dependent directly on specific composition of the product. Prinyawiwatukul et al. (1993) also reported that texture to be a primary attribute which consumers use to judge quality of the snack product. The product with varied formulations had an OAA range of 6.2 to 8.0 on nine point hedonic scale and the texture hardness ranged from 0.3 to 1.9 kg cm⁻². The results for the central composite designs were analysed for a second order polynomial equation by a least square technique. The regression analysis of the responses was conducted by fitting linear and quadratic models (equation 1 & 2) as suitable in the case of the respective responses.

$$Y = \beta_0 + \sum_{i=1}^n \beta_{i \ x_i} \quad (1)$$

$$Y = \beta_0 + \sum_{i=1}^n \beta_{i \ x_i} + \sum_{i=1}^n \beta_{ii \ x_i^2} + \sum_{i \neq j=1}^n \beta_{ij \ x_i \ x_{ij}} \quad (2)$$

where, β_0 was the value of the fitted response at the center point of the design, while β_i , β_{ii} , and β_{ij} were the linear, quadratic and interactive-effect regression terms, respectively, and n denoted the number of independent variables i.e. in this case n is 3, and x_i , x_{ij} are independent variables in coded values represented by A, B, C in Table 1.

The response surface plots of this model were plotted as a function of two variables, while keeping the third variable at constant or optimal level. 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 (Fig. 2). The 3D graphs showed the deviation of response i.e. OAA and texture, from the reference point. The OAA of the product was mainly influenced by ghee content followed by the level of fibre, while *maida* had little effect showing minimal deviation. The ghee content influenced the texture and an increase in the ghee content decreased the crispness of the product, while increase in *maida* and radish fibre slightly contributed towards the hardness of the product (Fig. 2). The variation in OAA and texture, with reference to ghee, fibre and *maida* levels, keeping the minor variable at constant level has been represented in the 3D plot (Fig. 2a, b, c, d). The product was developed using statistical software where 'n' number of variable can be used for optimization of the product. In this case two variables i.e. fibre and ghee could have been taken as variables, but our interest was to optimize level of fibre, ghee and *maida* because all these 3 major ingredients of the product effect its texture. Thus, these 3 ingredients were taken as independent variables while OAA and texture were chosen as responses. The maximum OAA and desirable texture were achieved with 20 g fibre, 100 g *maida* and 15 g ghee. Jackson et al. (1996) used the factorial design for optimizing 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 (Shyu and Hwang 2001). Jauregui et al. (2000) used RSM to optimize the conditions for an extruder processing an amaranth-based snack food, while Vatsala et al. (2001) optimized the ingredients and process conditions for preparation of *puri* using RSM. Thus, RSM has been shown to be an effective tool for optimizing

Fig. 3 Proximate composition (%) of fibre-rich snack

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 selected model as well as response to assess how well the model represented the data. For OAA and texture, Model F-value of 130.34 and 115.80 (Table 2) implied

that the models were significant. The model of polynomial equation from the software fitted well and lack of fit was insignificant (sensory score and texture, for Quadratic model: $P>F$ were <0.0001). However, the predicted R-squared was in reasonable agreement with adjusted R-squared (Table 2). The multiple coded equations in terms of coded factors generated for their responses are shown below:

$$\begin{aligned}\text{OAA (Y)} &= +7.04 + 0.11*A - 0.11*B - 0.035*C + 0.10*A^2 + 0.003*B^2 - 0.3*C^2 + 0.51*A*B - 0.46*A*C - 0.14*B*C \\ \text{Texture (Y)} &= +1.36 + 0.11*A + 0.18*B - 0.57*C - 0.01*A^2 - 0.06*B^2 - 0.14*C^2 - 0.066*A*B + 0.13*A*C + 0.11*B*C\end{aligned}$$

The response optimization was achieved as per the desired criteria based on the acceptance of the product. The solutions could be achieved from the software with the maximum desirability as well as the acceptance and the optimum variable levels by being at random starting points and proceeding on the path of the steepest slope to a maximum. The best among them was taken as the optimum. Radish fibre 20.00 g, maida 100.00 g with 15.12 g ghee achieving the desirability of 1 and OAA of 8 on nine point hedonic scale was the optimized ingredient composition with the best fit. The predicted response value of acceptability score was 8.17 as against actual value 8.0 score and response texture predicted value was 1.88 as against actual value 1.72 which were in concurrence with each other. Jackson et al. (1996) used RSM to predict that maximum crispness of banana chips could be produced by blanching at 69 °C and 22 min, while Shyu and Hwang (2001) optimized the conditions for vacuum frying of apple chips at temperature of 100–110 °C for 20–25 min and immersing in fructose solution of 30–40%.

The proximate composition of radish fibre based snack is shown in Fig. 3. A slight increase in the protein content was observed in the optimized product containing 20 g

radish fibre (8.62%) as compared to the control (7.53%). As seen in Fig. 1, the radish fibre showed 9.38% protein, which might have contributed to the increased protein content of the optimized product. It is a calorie-dense fibre rich product with 12.24% DF out of which 10.23% is insoluble fibre fraction, which might possibly give pronounced effects on intestinal regulation and stool volume while soluble fibre content was 2.01%, which have been proven to have good health benefits such as maintaining hypocholesteremic & hypolipidemic actions (Sudha et al. 2007). The product was stored in tri-laminate pouches at different temperatures to establish the shelf life. The results are presented in Table 3. It was clearly observed that the product was stable and well accepted till 4 months. Thereafter, rancid flavour was noticed in samples stored at room temperature (RT), due to which the OAA score showed a sudden decrease. After 4 months storage, though there was significant ($p \leq 0.05$) increase in TBA value and peroxide value at RT, as compared to samples stored at 5 °C, no undesirable flavour was reported during sensory evaluation (Table 3). But after 6 months storage, the flavour change was predominant in samples at RT as compared to samples at 5 °C. Thus, low temperature stored sample

Table 3 Storage stability of radish fibre rich snack in PFP pouches** ($n=3$)

Parameters	Initial	2 months		4 months		6 months	
		RT*	5 °C	RT*	5 °C	RT*	5 °C
OAA	8.6±0.36 ^a	8.4±0.51 ^b	8.5±0.50 ^a	7.6±0.66 ^c	8.3±0.36 ^a	4.8±0.50 ^d	7.8±0.46 ^b
TBA (mg malonaldehyde/kg sample)	0.03±0.01 ^a	0.08±0.02 ^a	0.05±0.03 ^a	0.26±0.04 ^b	0.09±0.03 ^a	0.58±0.05 ^c	0.14±0.04 ^b
PV (meq O ₂ /kg fat)	0.07±0.02 ^a	0.41±0.06 ^b	0.22±0.03 ^b	3.87±0.12 ^d	1.64±0.06 ^c	12.61±0.52 ^e	4.35±0.33 ^d
FFA value (% oleic acid)	0.04±0.02 ^a	0.09±0.04 ^b	0.05±0.03 ^a	0.16±0.05 ^c	0.08±0.04 ^b	0.47±0.06 ^d	0.18±0.05 ^c
IT (h)	22.47±1.54 ^a	15.38±0.46 ^b	19.55±0.50 ^b	6.32±0.41 ^c	12.58±0.62 ^c	1.21±0.58 ^d	5.16±0.52 ^d

RT*— Room Temperature (15–35 °C)

TBA— Thiobarbituric acid value; PV— Peroxide value, FFA— Free Fatty Acid value, IT— Induction time

**For each temperatures individually, the mean±SD within a row superscripted with different alphabets are significantly ($p \leq 0.05$) different

were quite well acceptable. Fatty acids were also influenced by the temperature of storage, showing significant ($p \leq 0.05$) increase from 0.04 to 0.47% oleic acid at RT and 0.04 to 0.18% oleic acid at 5 °C. The increase was higher after 6 months with a significant ($p \leq 0.05$) decrease in sensory score showing the product to be unaccepted. Similar pattern of oxidative and hydrolytic parameters have been reported in various processed foods (Madhura et al. 1998; Premavalli et al. 2005). Induction time is a characteristic value, which reflects the oxidative stability of the sample. Initially the induction time was 22.47 h, but gradually it decreased with the storage period, especially in samples at RT. Hudson (1983) also studied the induction time of soybean oil and correlated the results with the PV. He reported that quantitative aspect of this relationship exhibit both enhanced peroxide value and corresponding fall in induction time. Similar trend was observed in our studies also, wherein the induction time significant ($p \leq 0.05$) decreased with increase in PV (Table 3). Thus, in radish snack, the changes during storage in PV, TBA value, FFA value and decreased induction time with decreased acceptance revealed the established shelf life of 4 months at RT and 6 months at 5 °C packed in tri-laminate PFP pouches.

Conclusion

Radish fibre based snack developed after optimization of formulation by RSM had a shelf life of 6 and 4 months at 5 °C and ambient temperature, respectively. Thus, fibre-rich snack product contained nearly 8% more total dietary fibre (12.24%) than the control (4.25%). The snack can serve as a good source of dietary fibre and is a worthy approach for by-product utilization obtained after radish juice extraction.

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