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Utilization of Mustard Leaves (*Brassica juncea*) Powder for the Development of Cereal Based Extruded Snacks

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Abstract**—**Mustard leaves are rich in folates, vitamin A, K and B-complex. Mustard greens are low in calories and fats and rich in dietary fiber. They are rich in potassium, manganese, iron, copper, calcium, magnesium and low in sodium. It is very rich in antioxidants and Phytonutrients. For the optimization of process variables (moisture content and mustard leave powder), the experiments were conducted according to central composite Face Centered Composite design of RSM. The mustard leaves powder was replaced with composite flour (a combination of rice, chickpea and corn in the ratio of 70:15:15). The extrudate was extruded in a twin screw extruder at a barrel temperature of 120°C. The independent variables were mustard leaves powder (2-10 %) and moisture content (12-20 %). Responses analyzed were bulk density, water solubility index, water absorption index, lateral expansion, antioxidant activity, total phenolic content, and overall acceptability. The optimum conditions obtained were 7.19 g mustard leaves powder in 100g premix having 16.8% moisture content (w.b).

Keywords**—**Extrusion, mustard leaves powder, optimization, response surface methodology.

I. Introduction

CEREALS and legumes play an important role in human nutrition. Recent studies have shown that cereals and beans contain constituents that have health benefits for humans, such as antioxidants and anti-disease factors [1]. Generally, cereals and legumes, such as chickpea, soy and corn, have been used to make highly nutritious products [2]. Extrusion processing has become one of the major processes for producing convenience foods. Extruded foods range from breakfast cereals to snack foods containing modified starches and flour [3]. Extruded snack products are predominantly made from rice flour or starch and tend to be low in protein and have a low biological value, as they have a low concentration of essential amino acids. Rice flour, corn flour, chickpea flour are used as these provides the positive health benefits [4]. Consumers have expressed concern about the functional properties, as well as the nutritional quality of products. A great deal of attention has been paid to fortifying the extruded food with cereals high in protein and lysine to improve the essential amino acids content. Several researchers have studied the effect of the extrusion process on antioxidant capacity. Camire et al. [5] studied the functionality of fruit powders in extruded corn breakfast cereals. Dlamini et al. [6] studied the effect of extrusion cooking on the antioxidant activity of sorghum-based products and compared it with raw grain. Recently, the use of agricultural products has been gaining more attention. In this study, the use of mustard leaves powder was used to study its effect on the product quality and functional properties of extruded product.

The largest and most commonly consumed groups of edible plants within the family Cruciferae are the vegetables of the Brassica genus. Cruciferous vegetables contain a range of potentially anti-carcinogenic dietary factors including carotenoids, vitamin C, fibre, flavonoids and glucosinolates [7]. Importantly, glucosinolates are present in almost every member of the Cruciferae family and the presence of glucosinolates distinguishes cruciferous vegetables from other vegetables [7], [8]. The mustard leaves are important green leafy vegetable belongs to cruciferous family. In India this crop is mainly grown for the oil seed purpose. Before maturity the leaves of the mustard plant are used as a vegetable in specific northern area of India for specific duration. As the plucking of the green leaves does not affect the final yield of the crop these leaves can be used in the daily meal for cooking as vegetable purpose, otherwise these leaves will be waste in making manure or as a fodder. Once it is harvested, the mustard leaves are edible for only a limited time, which can vary from a few days to week. During the harvest season, fresh mustard leaves are available in abundance, but at other times it is scarce. Moreover, these mustard leaves as green leafy vegetables are only edible for a very short time, unless they are promptly and properly preserved. Dried leaves can be stored for a long time and can be used for manufacturing of various products.

In the present study, functional product was developed by the extrusion process using mustard leaves powder. Further, the products were evaluated for their functional properties with reference to bulk density, water solubility index, water absorption index, lateral expansion, antioxidant activity, total phenolic content and overall acceptability.

The fresh and undamaged mustard (*Brassica juncea*) leaves were sorted, washed with water to remove the foreign matter and dirt etc. Then the cutting of large sized leaves was done up to15 mm size. The convective dehydration of fresh leaves was carried out at 60°C drying air temperatures. Rice, chickpea and maize flour were screened by using the screen of 0.5 mm

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and packed in plastic bags and stored at 4°C until further use. For the optimization of extruded products formulation, face centered experimental design of response surface methodology (RSM) was applied by using a set of experimental design having two independent variables at three levels each. The experimental range of independent variables i.e. percentage of mustard leaves powder and moisture content were selected from result obtained during preliminary trails. The low and high level of percentage proportion of mustard leaves powder content was 2 and 10 % and the remaining proportion were premix (Rice: Maize flour: Chickpea flour in the ratio 70:15:15). The premix was replaced by the mustard leaves powder to make the final blend 100g. Moisture content 12 and 20 % was then adjusted for the final blend flour. The optimization process was aimed at finding the optimum level of independent variables i.e. percentage proportion of mustard leaves powder and moisture content that would give maximum lateral expansion, minimum bulk density, and maximum overall acceptability.

II. Results and Discussion

The experiments plan along with results given in Table I. The experiments were conducted randomly to minimize the effect of unexplained variability in the observed responses because of external factors. The relative effects of dependent variables on various responses have been shown in Figs. 1–8. The detail analysis of the response for the above parameter is described below:

The bulk density, a major physical property of the extrudate products, ranged from 0.058 to 0.131 g/cm^3. The values of β coefficients of mustard leaves and moisture content (Table II) showed positive effect which indicates that with increase in mustard leaves and moisture content and there will be increase in bulk density. The increase in feed moisture content would change the macromolecular structure of the extruded melt reducing the melt elasticity thus decreasing the expansion and favoring the formation of more compact extrudates. The incorporation of mustard leaves powder in the mixture may led to products with increased density as mustard leaves powder is high in fiber.

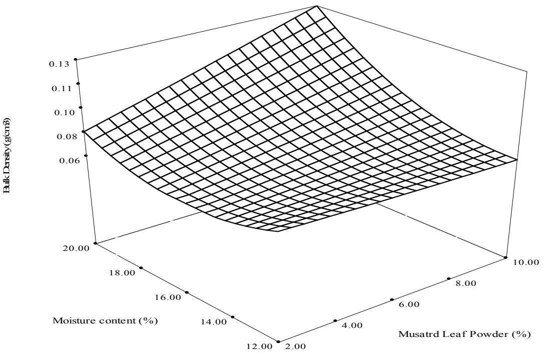

Fig. 1 Response surface plot for the variation of Bulk Density of extrudate as a function of feed mustard leaves powder and feed moisture

The measured expansion of extrudate varied between 3.2 and 5.32. Starch, the main component of cereals, plays major role in expansion process [9]. The magnitude of β coefficients (Table II) indicates that the mustard leaves powder has negative effect and feed moisture content positive effect on lateral expansion of extrudate. The decrease of expansion of extrudate with increase of mustard leave powder might be due to increase in fiber content. The presence of the fiber ruptures the walls of air cells and prevented the air bubbles from expanding to their full potential [10]. Also the fiber interferes with bubble expansion by reducing the extensibility of vapour cell walls, causing premature rupture at a critical thickness related to the fiber particle size which leads to the more broken small cells [11], [10]. The lateral expansion initially increased with increase in moisture content, which may be due to proper gelatinization and higher expansion due to vaporization of water vapors [12].

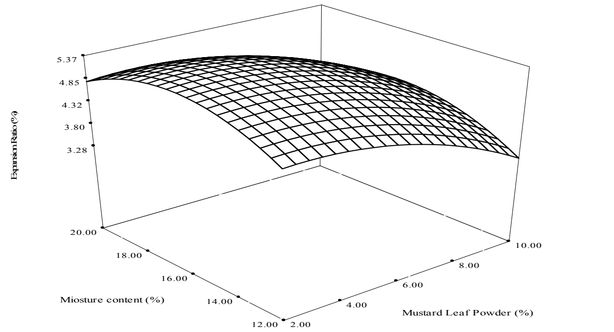

Fig. 2 Response surface plot for the variation of Expansion Ratio of extrudate as a function of feed mustard leaves powder and feed moisture

The WAI measures the amount of water absorbed by starch that can be used as an index of gelatinization. It is generally agreed that barrel temperature and feed moisture exert greatest effect on the extrudate by promoting gelatinization [12], [13]. Water absorption generally attributed to dispersion of starch in excess of water and the dispersion is increased by degree of starch damage to the gelatinization and extrusion induced fragmentation, i.e. molecular weight reduction of amylose and amylopectin molecules [14]. The WAI of extrudate ranged from 6.2 to 7.65 g/g of extrudate. The value of β coefficients in Table II shows that the mustard leaves powder has negative and the moisture content has positive effect on WAI of extrudate. The decrease of WAI of extrudate with increase of mustard leaves powder may be due to the reason that with increase in fiber content of extrudate, which will decrease the amount of water absorbed during starch gelatinization. An increase in WAI with increase in moisture content might be due to the reason that during gelatinization of starch more water will be absorbed and bound to the starch molecules due to more availability of water. Lawton and Henderson [15] also reported that the maximum gelatinization i.e. WAI occurs at high moisture and low temperature or vice versa.

TABLE I
EFFECT OF PROCESS VARIABLES ON VARIOUS RESPONSES

Variables		Responses						
Mustard Leaves powder (%)	Moisture content (%)	Bulk density (g/cm^3)	Lateral expansion (%)	WSI (%)	WAI (g/g)	Antioxidant Content (%DPPH RSA)	Total phenolic content (mgFAE/g)	Overall Acceptability
2	12	0.06	5.32	14.40	6.85	8.02	12.02	7
10	12	0.07	3.20	17.60	6.21	21.50	25.50	7.10
2	20	0.07	4.61	18.80	6.20	9.75	11.75	6.80
10	20	0.13	3.75	9.20	6.85	18.35	22.35	7.30
2	16	0.08	4.25	11.05	6.74	19.73	23.73	7.20
10	16	0.08	4.82	12.80	7.04	7.10	10.10	7.30
6	12	0.07	5.12	11.60	7.48	11.46	20.46	7.60
6	20	0.07	5.25	11.00	7.65	12.99	19.99	7.59
6	16	0.07	5.10	12.39	7.41	12.37	20.37	7.62
6	16	0.07	5.13	11.05	7.64	12.01	20.01	7.62
6	16	0.07	4.47	17.60	6.99	14.68	19.68	7.40
6	16	0.07	5.06	11.22	7.56	11.69	18.69	7.61
6	16	0.11	4.67	8.00	7.50	12.85	21.85	7.80

TABLE II
STATISTICAL ANALYSIS AND COEFFICIENTS OF QUADRATIC MODEL FOR VARIOUS RESPONSES

	β coefficients						
	Bulk density	Lateral Expansion	WAI	WSI	AOA	TPC	OA
Model	0.071*	5.15*	7.54*	11.38*	12.29*	20.08*	7.66*
A	0.012*	-0.59*	-0.048	-1.36*	5.79*	6.28*	0.083*
B	0.018*	0.16*	0.33*	-4.00*	-1.27*	-0.44	0.18*
A^2	6.1×10^{-4}	-0.41*	-0.71*	1.53*	1.11*	-2.66*	-0.49*
B^2	0.016*	-0.62*	-0.26*	1.60*	1.00*	0.23	7.93×10^{-3}
A*B	0.015*	0.084	-0.050	-0.60	-0.12	-0.37	-0.075*
R2	0.9888	0.9890	0.9788	0.9722	0.9860	0.9604	0.9270

*Significant at 5% level of significance ($p<0.05$)

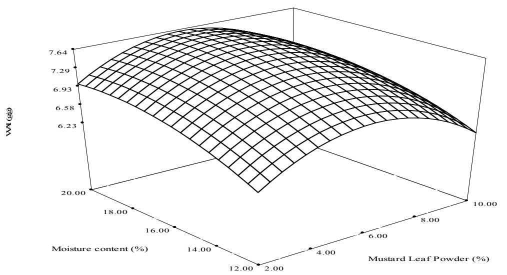

Fig. 3 Response surface plot for the variation of WAI of extrudate as a function of feed mustard leaves powder and feed moisture

WSI, an indicator of degradation of molecular components, measures the amount of soluble polysaccharide released from the starch component after extrusion [12]. The WSI is a measure for starch degradation. Higher the moisture content, lower will be the starch degradation, thus lower will be the WSI [16]. Yuliani et al. [17] and Sawant et al. [18] also reported decrease in water solubility index of the extrudate with increase in moisture content in case of cereal based extrusion process. The WSI ranged from 8.0 to 18.8 for extrudates. The values of β coefficients of mustard leaves powder and feed moisture showed significant negative effect on WSI. The decrease of WSI (i.e. reduction of solubility of starch and other molecules) with increase of mustard leaves powder might be due to the structural modification as a result of interaction between the fiber and starch. The mustard leaf proteins may interact with starch through the formation of cross linking that prevents the solubilization of amylose, thus decrease the WSI. Hashimoto and Grossman [10] also reported the decrease of WSI with increase of cassava bran fiber during extrusion cassava starch. With increase in moisture content the decrease of WSI might be due to the reason that the higher moisture content can diminish protein denaturation which subsequently lowers WSI values [19].

The mustard leaves powder (A) showed significant positive effect and feed moisture content (B) negative effect on antioxidant activity of the extrudate. With increase in mustard leaves powder proportion, an increase in antioxidant activity of extruded snack might be because the mustard leaves powder is rich source of antioxidants [7]. The increase in feed moisture content resulted in decrease of antioxidant content of the extrudate. The increase in feed moisture at higher (extrusion) temperature may result in the alteration in molecular structure of phenol compound.

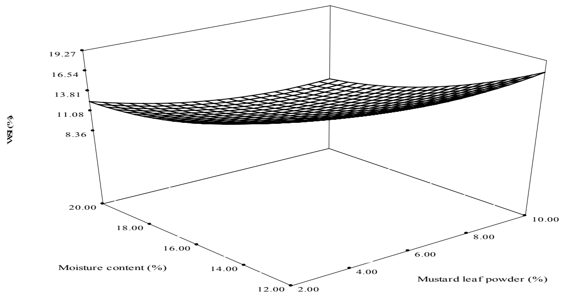

Fig. 4 Response surface plot for the variation of WSI of extrudate as a function of feed mustard leaves powder and feed moisture

The decrease of total phenolic content with increase of moisture content may be due to the reason that the moist heat is more destructive and have synergistic effect along with higher temperature. As the moisture content increases the large amount of moist heat is produces at higher rate and subsequently, the increase of heat transfer rate will result in total phenolic content of extrudate [20]). Sharma et al. [20] also reported 8-29% decrease in total phenolic content in barley extrusion (at 180°C extrusion temperature) with increase of moisture from 15 to 20%. Further, with increase of moisture content, the solid content get decreased, thereby a reduction in the availability of the phenolic and flavonoids [20].

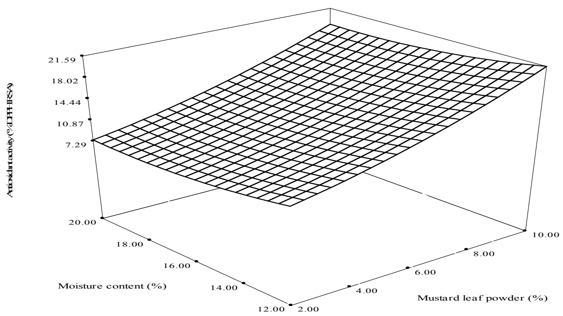

Fig. 5 Response surface plot for the variation of antioxidant activity of extrudate as a function of feed moisture and feed mustard leaves powder

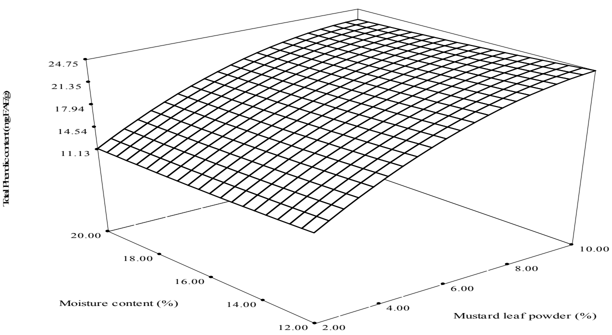

Fig. 6 Response surface plot for the variation of total phenolic content of extrudate as a function of feed mustard leaves powder and moisture content

With increase in mustard leaves powder there will be increase in acceptability and after optimum amount of mustard leaves powder addition there will be decrease in acceptability as the color of the extrudate goes darker and darker green as well as the taste also goes to some extent grassy. The presence of the fiber ruptured the walls of air cells and prevented the air bubbles from expanding to their full potential so that the expansion of extrudate decreases thereby the crispiness decreases [10]. With increase in feed moisture at specific point, there will be increase in overall acceptability as the expansion will be good so that the crispiness will be good after that decrease in acceptability will be seen as the extrudate expansion will be less, as the moisture content increases the expansion decreases due to the dilution effect i.e. the starch on gelatinization get thinner and thinner on increase of moisture so that the expansion decreases. Due to the lesser expansion, the crispiness of extrudates decreased which is the major quality parameter in snack products.

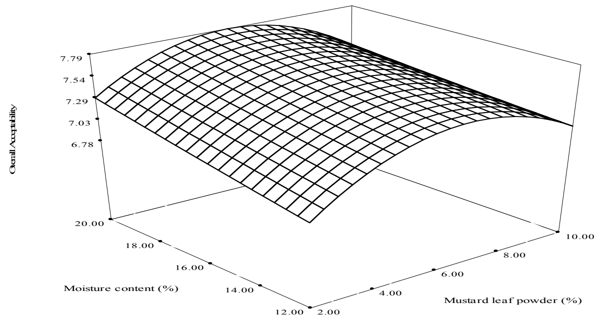

Fig. 7 Response surface plot for the variation of overall acceptability of extrudate as a function of feed mustard leaves powder and feed moisture

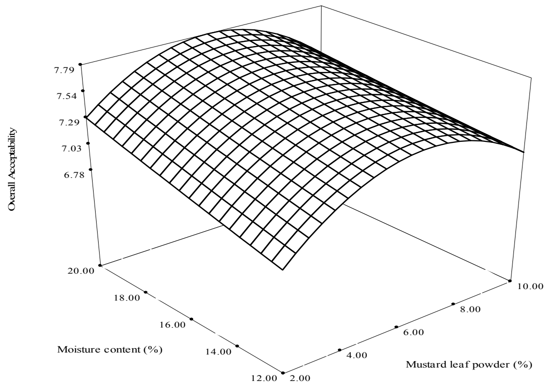

Fig. 8 Response surface plot for the variation of overall acceptability of extrudate as a function of feed mustard leaves powder and feed moisture

III. Optimization

The compromised optimum condition for the development of extruded products with premix flour, mustard leaves powder and moisture content was determined using the following criteria by Design Expert software. The product should get the maximum score in sensory characteristics so as to get good market acceptability, minimum bulk density, minimum water solubility index, maximum water absorption index, maximum expansion, maximum antioxidant activity, maximum total phenolic content.

After numerical optimization design expert gives solution containing 7.19 g mustard leaves powder, 16.80 % moisture content. Total 100 g of blend was prepared by adding 92.8 g premix flour into mustard leaves powder. Optimized values of process variables and responses are given in Table III.

It was observed that addition of mustard leaves powder resulted in increase in protein, crude fiber, antioxidant content and total phenolic content of optimized extruded product. The energy value of optimized product was 355.33 kcal.

TABLE III
OPTIMIZED VALUES FOR PROCESS VARIABLES AND PRODUCT RESPONSES

Process variables	Optimized values	Responses	Optimized values
Mustard leaves powder (%)	7.19	Bulk density(g/cm3)	0.08
Moisture content (%)	16.80	Expansion ratio (%)	4.95
		WAI (g/g)	7.51
		WSI (%)	10.34
		Antioxidant activity (% DPPH RSA)	13.88
		Phenolic content (%)	21.61
		Overall acceptability	7.62
		Desirability	0.737

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