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Process optimization for development of extruded product from rice flour–moringa leaf blend

NR Sahoo, MK Panda, Minati Mohapatra* and CK Bakhra

College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar – 751003, Odisha, India

E-mail: minati.agfe@gmail.com

ABSTRACT

Ready-to-eat extruded product blending rice flour and moringa leaf powder (MLP) was developed in a twin screw extruder at different composition (5 – 15 %), moisture content (15 – 25 %) and screw speed (250 – 350 rpm) using response surface methodology (RSM). The effects of extrusion cooking conditions on the product properties like expansion ratio, specific length, particle density, water absorption index (WAI), hardness and overall sensory characteristics were found out. Increasing MLP content from 5- 15 % caused decrease in the expansion and hardness of extrudate and also the consumer preference. Optimized parameters were obtained at 5 % MLP content, 15 % moisture and 350 rpm screw speed based on higher sensory score presuming higher consumer preference and thus recommended for preparation of rice flour-moringa leaf powder extruded product. However, these parameters were entrained with 2.8 % less expansion ratio, 13.9 % more particle density, 17.6 % more hardness and 4.5 % less WAI from the corresponding highest value of parameters which can be compromised looking on to the consumer preference for a better rice-moringa extruded product.

Key words: *rice, moringa leaf, product, process*

Ready-to-eat snacks are becoming more popular due to rapid urbanization, nutrition transition, and increasing sedentary lifestyles. Popular ready to eat (RTE) expanded food products available in the market are mainly starchy products usually prepared from maize or rice flour, oil or fat, different spices, condiments and flavouring compounds. The main consumers of this product are children, who get a high amount of starchy materials along with oil, salt and spices. This type of products are seriously lacking in many essential ingredients which are specially required for children such as protein, dietary fiber, vitamin A, B and C and minerals like calcium, phosphorus and iron etc.

Moringa (*Moringa oleifera* Lam.), native to Indian subcontinent is considered as one of the World's most useful tree, as it is used for food, medication and industrial purposes (Moyo *et al.*, 2011). India is the largest producer of Moringa, with an annual production of 1.1 to 1.3 million tones of tender fruits from an area of 380 km^2.People use its leaves, flowers and fresh pods as vegetables, while others use it as livestock feed (Anjorin *et al.*, 2010). This tree has the potential to improve nutrition, boost food security and foster rural development (Hsu, 2006). Studies from other countries indicate that the leaves have immense nutritional value such as vitamins, minerals and amino acids (Anwar *et al.*, 2007). The leaves are an exceptionally good source of vitamins A, B and C, minerals and of sulphur-containing amino acids like methionine and cystine. In addition, the leaves can serve as rich source of polyphelnolics (Ross, 1999), flavonoid pigments and significantly high oxidative stability leading potential therapeutic against cancer, diabetes, rheumatoid arthritis and other disease.

Ready-to-eat extruded products which are most popular among children seriously lack many essential nutritional components is of a major concern, Therefore, attempts have been made to develop a suitable RTE extruded product with moringa leaves and rice flour blend producing a soft, crunchy texture similar to snacks food available in the market. The present study aims at standardization of the process parameters for development of ready to eat expanded snack product from rice flour-moringa leaf powder blend and study its physical properties with consumer acceptability.

MATERIALS AND METHODS

Fresh moringa leaves were collected, washed thoroughly and dried in hot air convective dryer at 60°C. The dried leaves were ground, passed through 120 ìm sieve and the final moringa leaf powder (MLP) was packed in polyethylene bags. Broken rice was procured from a local mill, ground to pass through 840 ìm and packed in polyethylene bags. Required proportion of moringa leaf powder was added to rice flour and mixed well. The moisture content (MC) of mixed flour was determined by (AOAC, 1976) and calculated amount of distilled water was added by a hand held sprayer to the flour and mixed thoroughly to assure uniform distribution to obtain desired moisture content. The mixture was then packed in air tight poly-pouches and allowed to equilibrate overnight prior to extrusion. The proportion of moringa leaf powder was chosen according to preliminary tests without jamming of extruder and for acceptable physical and sensory characteristics of the product as well as better nutritive value in the final product.

Extrusion was performed in a laboratory-scale co-rotating twin screw extruder (M/S. BTPL, Kolkata, India). The screw had five sections with total 18 turns, and out of these five sections, four had a length of 75 mm each and the fifth section had a length of 43.5 mm. There was a clearance of 1.5 mm between barrel and screw. The extruder had self wiping system for easy cleaning of the machine. The temperature of the barrel of extruder was set at 110°C. Screw speed was also set at desired level and equipped with 2 mm restriction die or nozzle to extruder. Constant feeding rate was maintained throughout the experiments. Three replication of the samples were taken. After extrusion samples were dried in a tray dryer at 60°C to about 6 - 7% (w.b.) final moisture. The dried samples were then cooled to room temperature and sealed in polyethylene bags until further use.

Response surface methodology (RSM) (at three variables, three levels) was used to investigate the effects of extrusion cooking conditions. Total 15 runs of experiments were designed, of which three were for the centre point (Montgomery, 1984). The independent variables included the MLP content in rice flour (5 – 15 %), moisture content (15 – 25 %) and screw speed (250 – 350 rpm). The process variables coded as -1, 0, +1 (Montgomery, 2001) and their actual values are given in Table 1. The parameters and their levels were chosen based on the literature available on rice based extrudates (Yagci and Gogus, 2008; Ibanoglu et al., 2006; Ding et al., 2005; Upadhyay, 2008). Responses were expansion ratio, specific length, particle density, water absorption index, hardness and sensory characteristics. Statistical Analysis Systems, SAS software (SAS Institute, USA) has been used to analyze the data and the second order polynomial models (equation 1) were developed to predict responses at different input parameters.

Table 1. Actual and Coded values of Process Parameters for rice-moringa leaf extruded Products

Variables	Actual (Coded) values		
MLP proportion (%), X_1	5 (-1)	10 (0)	15 (+1)
Feed moisture (%), X_2	15 (-1)	20 (0)	25 (+1)
Screw speed (rpm), X_3	250 (-1)	300 (0)	350 (+1)

$$y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_1X_2 + B_6X_1X_3 + B_7X_1X_4 + B_8X_2X_3 + B_9X_2X_4 + B_{10}X_3X_4 + B_{11}X_1^2 + B_{12}X_2^2 + B_{13}X_3^2 + B_{14}X_4^2 \quad (1)$$

The ratio of diameter of extrudate and the diameter of die was used to express the expansion ratio. The diameters of 20 extruded products were measured using Vernier calipers. Expansion ratio (%) of the samples was determined by dividing the average diameter of the products with the diameter of the die and multiplying the result by 100.

It is the ratio of unit length per mass of one extrudate. Average of 20 pieces of extrudate from the same lot was taken for calculation.

$$SL = \frac{L_e}{m_e} \quad \text{..(2)}$$

Where L_e and m_e are the length and mass of one piece of extrudate.

Particle density of the extrudates was calculated by measuring the actual dimensions of the extrudate. The diameter and length of 20 pieces of randomly selected extrudate samples were measured by Vernier caliper. The weight of these extrudate pieces were taken in an electronic weighing balance having an accuracy of 0.001 g. The shape of the extrudate was assumed cylindrical. Then the particle density of extrudate was calculated using the following formula

$$PD = \frac{L_e}{m_e} \quad \text{...(3)}$$

Where m_e and V_e are mass and volume of one piece of extrudate

The textural characteristics of extrudate were measured using a Stable Micro System TA-XT2 texture analyzer (Surrey, UK) fitted with a 2 mm cylinder probe. A force–time curve was recorded and analyzed by Texture Exponent 32 (Surrey, UK) to calculate the peak force and area. The peak force, i.e. the resistance of extrudate, and the area under the curve were chosen to represent the textural properties of extrudate. Twenty randomly collected samples of each extrudate were measured and an average value was taken.

The hardness of samples was measured using texture analyzer (Stable Microsystems, London) fitted with a 50 kg load cell. Samples were prepared according to the method of Hardacre *et al.,* 2006 and were gently packed into a Kramer shear cell to 80% of the cell height (about 200–300 g). The Kramer probe (5 blades, 3 mm thick, 64 mm high, 82 mm wide, 11 mm apart) was set to move at a test speed of 0.5 mm/s up to a distance of 50 mm representing about 30% of the sample height in the cell. Maximum force needed to break the samples was recorded and analyzed by Texture Exponent software associated with the Texture Analyzer.

The (WAI) was measured using a technique developed for cereals (Anderson et al., 1969). The ground extrudate was suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3000 ×*g* for 15 min. The supernatant was decanted into an evaporating dish of known weight. The WAI is calculated as the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. Determinations are based on three replications of sample.

A semi-trained panel of 15 members evaluated the extruded snacks for appearance, taste, color, and overall acceptability on a 9-point hedonic scale. Samples were coded using random numbers and served. Written instructions were given to the judges and asked to evaluate the products for overall acceptability based on its appearance, texture, taste, and color using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely; Meilgaard *et al.*, 1999).

RESULTS AND DISCUSSION

The experimental arrangements and values of responses such as expansion ratio (ER), specific length (SL), particle density (PD), hardness, sensory score and water absorbance index (WAI) of extruded products were measured (Table 2). Second order polynomial regression equations were established and the co-efficients and their level of significance were calculated (Table 3 and 4). The established equations show empirical relationship between dependent variable and coded value of independent variables. The goodness of fit of the models was evaluated using the correlation co-efficient (Table 3 and 4). An analysis of variance (ANOVA) was done to analyze the impacts of independent variables of MLP content, moisture content and screw speed on the physical, textural and sensory parameters of extruded product. The response surface graphs of ER, SL, PD, hardness, sensory score and WAI are plotted (Fig. 3 to 8).

Expansion of extruded products ranged between 3.36 to 5.34. The highest expansion ratio was 5.34 for extrusion processing at 300 rpm screw speed with 5% MLP and feed moisture content of 15 %; on the other hand, the lowest expansion ratio was 3.36 at 300 rpm with 15 % MLP and feed moisture content of 25 %. MLP of feed significantly affected the expansion of extrudate whereas, the effect of screw speed was insignificant (p=0.77). Ding *et al.* (2005) also reported that screw speed had no significant influence on

Table 2. Physical parameters of extrudate obtained from different experimental run

Run	MLP level	MC	RPM	ER	SLcm/g	PDg/cc	Hardness(Kgf)	WAI	Sensory
1	-1	-1	0	5.34	5.08	0.42	12.19	5.34	8.57
2	-1	1	0	4.10	5.27	0.42	16.51	5.47	7.64
3	1	-1	0	3.90	5.27	0.35	19.30	5.68	6.71
4	1	1	0	3.36	5.31	0.46	17.88	5.70	6.78
5	0	-1	-1	4.60	5.39	0.35	13.52	4.92	8.49
6	0	-1	1	4.80	5.82	0.33	12.67	5.44	7.28
7	0	1	-1	3.46	5.00	0.34	13.25	5.56	7.28
8	0	1	1	3.89	5.75	0.23	12.73	6.16	5.43
9	-1	0	-1	4.98	6.53	0.36	13.68	5.44	6.71
10	1	0	-1	4.48	5.78	0.39	13.50	6.20	6.75
11	-1	0	1	4.92	5.58	0.34	8.70	6.20	5.43
12	1	0	1	4.40	5.05	0.34	13.20	6.63	5.07
13	0	0	0	4.75	5.99	0.35	9.14	5.41	6.01
14	0	0	0	4.93	5.14	0.46	10.36	5.64	6.34
15	0	0	0	4.58	5.32	0.39	11.74	6.11	8.11

Table 3. Regression coefficients and their level of significance of second order polynomial equation for ER, SL and PD

Coefficients	ER		SL		PD	
	Coeff, value	P	Coeff, value	P	Coeff, value	P
X_1(MLP)	- 0.264	0.0236	0.253	0.019	0.252	0.025
X_2(MC)	0.670	0.008	- 0.511	0.016	- 0.922	0.043
X_3 (RPM)	- 0.005	0.773	0.0302	0.507	- 0.009	0.232
X_1^2	- 0.001	0.952	- 0.002	0.781	- 0.005	0.334
X_1X_2	0.007	0.273	- 0.001	0.857	-	0.967
X_1X_3	-	0.904	-	0.575	-	0.533
X_2^2	- 0.022	0.051	0.015	0.071	0.025	0.003
X_2X_3	0.0002	0.698	-	-	-	0.837
X_3^2	-	-		0.558	-	0.6882
R^2	93.05%		86.25%		90.67%	

Table 4. Regression coefficients and their levels of significance of second order polynomial equations for hardness, WAI and sensory scores

Coefficients	Hardness		WAI		Sensory score	
	Coeff, value	P	Coeff, value	P	Coeff, value	P
X_1(MLP)	0.992	0.031	0.145	0.005	- 0.021	0.020
X_2(MC)	- 2.607	0.012	0.118	0.589	- 0.164	0.261
X_3(RPM)	- 0.109	0.368	0.042	0.228	- 0.06	0.951
X_1^2	- 0.004	0.887	0.002	0.403	0.003	0.703
X_1X_2	- 0.024	0.337	0.001	0.687	0.005	0.487
X_1X_3	- 0.001	0.776	-	0.714	- 0.001	0.333
X_2^2	0.063	0.044	0.003	0.267	0.002	0.765
X_2X_3	-	0.973	-	-	-	-
X_3^2	-	0.487	-	0.039	-	0.754
R^2	87.00%		87.78%		74.97%	

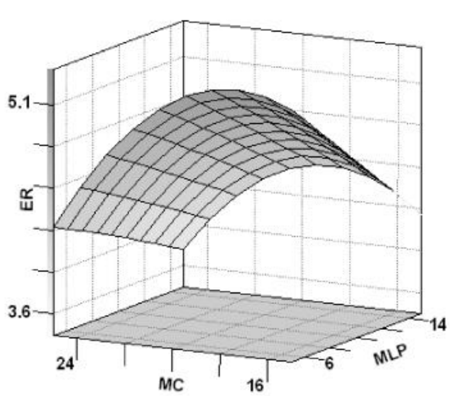
expansion of rice based extrudate. The moisture content had significant effect on expansion ratio and decrease in radial expansion with increase in moisture content was observed which might be due to lower melt temperature, specific mechanical energy (SME) and viscosity.

The response surface plot (Fig. 1) showed that the expansion ratio of extrudate increased with increase in MLP content and after reaching a maximum, the ER decreased with further increase of MLP content. The linear term of MLP content ($p<0.05$) and feed moisture content ($P<0.01$) had significant effect on expansion ratio. MLP composition (%) was the most significant factor affecting ER. Extrudate resulting from flour with higher moisture content were harder after cooling than those with lower moisture. Expansion ratio decreased significantly with increase in MLP proportion in the feed ($p<0.05$) as indicated by the negative co-efficient. Incorporation of MLP into extruded snacks changes the chemical composition of the melt by reducing the starch content and adding fiber, protein and probably other polysaccharides. The presence of components other than starch has a lubricating effect on the melt and drops the torque and specific mechanical energy leading to decrease in expansion. This interferes with the air cell formation and limits the starch gelatinization required for expansion of the snacks, as a result the snacks will be less expanded and hard in texture (Ainsworth *et al.*, 2007, Brennan *et al.*, 2008, Camire, 1998 and Yanniotis*et al.*, 2007). Decrease in radial expansion for various starch-fiber systems has also been previously reported. The presence of fiber from moringa leaf would tend to reduce the elastic properties of starch and extensibility of the melt leading to lower radial expansion.

There was slight expansion with the increase in moisture content, which may be due to gelatinization of starch, whereas, further decrease in expansion with increase in moisture content may be attributed to the reduction of elasticity of dough through plasticization of melt as observed by Ding *et al.* (2005). As gelatinization increases, the volume of extruded products increases and bulk density decreases. Bulk density increased with an increase in moisture content at low extrusion temperature.

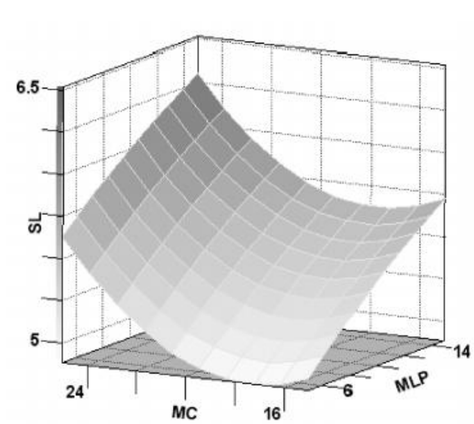
The measured specific length of rice flour and MLP extrudate in the response surface experiments ranged from 5.0 to 6.5.The effects of independent variables on specific length showed that only linear terms of MLP and moisture content had a significant effect ($p<0.05$). The positive co-efficient of linear MLP term indicates increase in specific length with increase in MLP proportion in the feed. Karkle *et al.* (2012) reported increase in specific length with increase in apple pomace in feed. Increase in longitudinal expansion as indicated by the specific length has also been reported earlier in other starch-fiber system (Hashimoto and Grossmann, 2003, Moraru and Kokini, 2003). Decrease in specific length with increase in moisture content was also indicated by the negative co-efficient of the variable.

Expansion phenomena are basically dependent on the viscous and elastic properties of melted dough. The dough elasticity forces attempt to expand the extrudate in the radial direction, and contract in the



Fixed levels: RPM=300

Fig. 1. Response surface plot for ER



Fixed levels: RPM=300

Fig. 2. Response surface plot for SL

axial direction. In the present study, as in all experiments with rice flour-moringa leaf powder we found a contraction in the radial direction and expansion in the longitudinal direction. It was observed that highest SL was obtained at highest MLP content and moisture content (Fig. 2).

The particle density (PD) which is a measure of volumetric expansion was used to compare the void spaces in the extruded products and the extent of puffing. The particle density ranged between 0.23 and 0.46 g/cc. The extrudate density was found to be most dependent on MLP content and feed moisture. ANOVA shows that both MLP and Moisture content significantly affected PD in linear form. The thickness of the wall of the pores becomes thinner when amount of protein increases which absorb high amount of water. So PD of extrudates increases with increase in protein and moisture content. Increased feed moisture content caused increase in the density of extrudate which was also reported by many researchers (Karkle *et al.,* 2012). Screw speed was observed to have no significant effect on the particle density of extrudate. In other reports, feed moisture has been found to be the main factor affecting extrudate density and expansion (Faubion & Hoseney, 1982; Fletcher *et al.,* 1985; Ilo *et al.,* 1999; Launay & Lisch, 1983), which is also in consistent with this work. The particle density initially decreased with moisture content, which may be due to proper gelatinization and higher expansion, whereas further increase in density may be because of reduction in elasticity of dough and lower expansion as reported by Ding et al. (2005, 2006).

Hardness of the extruded products within the operating range varied between 8.7 and 19.3 kgf. Linear terms of moisture content, MLP proportion was found to have significant effects on extrudate hardness. Increasing MLP proportion in feed significantly increased the hardness of the extrudate. Fibre might be interfering with air bubble formation and increases air cell wall thickness (Ainsworth *et al.,* 2007 and Altan *et al.,* 2008) resulting in a harder product. The higher protein of MLP might be responsible for the higher value of hardness of the extruded product. The negative co-efficient of linear term of feed moisture indicates decrease in hardness with feed moisture content. Increasing feed moisture content significantly decreased the hardness of rice extrudate owing to more expansion ratio. However, screw speed had no significant effect (0.37) on hardness of the sample.

From the response surface graphs (Fig.4) it is seen that increasing moisture content above 20% (w.b.) almost had a constant hardness of the extruded product. In order to get a less harder extruded product the moisture content should be maintained "e 20 % and lower levels of MLP i.e. < 6%. Shear force per unit weight of extrudate decreased with increase in the feed moisture. High moisture content i.e., e” 20% in the blend with high temperature extrusion processing helps in expansion of the products due to release of superheated steam. This phenomena helps to make hollowed and low density product that decrease the hardness.

The WAI measures the volume occupied by

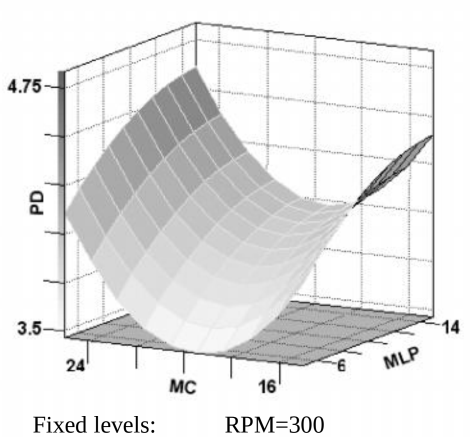


Fig. 3. Response surface plot for PD

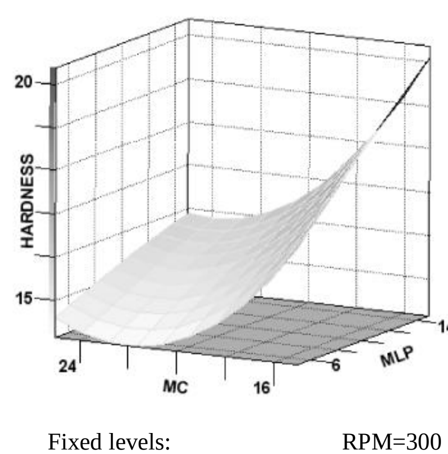


Fig.4. Response surface plot for hardness

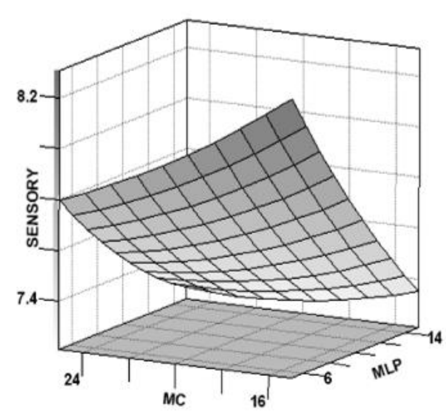
the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion (Mason & Hoseney, 1986). Only linear term of MLP content ($p<0.01$) and quadratic term of screw speed had significant effect on WAI with positive co-efficients that increases WAI. The feed moisture had no significant effect on the WAI of the extrudate. The presence of MLP probably reduces the degradation of starch granules and these results in an increased capacity for water absorption.

Increase in MLP proportion significantly reduced the sensory score ($p=0.02$), whereas moisture content and screw speed had no significant effect. So MLP proportion in feed is the most important factor for consumer acceptance of the product. Response surface plot of sensory scores (Fig.5) of extruded products with respect to moisture content and MLP shows that the sensory score was highest for lower moisture content and lower MLP composition of the mix. With increasing MLP% the overall acceptability/ sensory score drastically decreased showing consumer preference for low MLP%. Natural flavouring additives like black pepper, coriander powder and garlic powder or mint powder have also been tried along with other processing parameters to obtain a product of acceptable sensory quality. The extruded with a 3% seasoning of black pepper, coriander powder and mint powder mixture in equal proportion gave better consumer acceptability.

Highest sensory score was obtained at 5 % MLP content, 15 % moisture and 350 rpm screw speed and recommended for preparation of rice flour-moringa leaf powder extrudate with compromisation of 2.8 % less expansion ratio, 13.9 % more particle density, 17.6 % more hardness and 4.5 % less WAI from the highest value of parameters obtained from other combinations of experiments conducted. Increasing MC and MLP content caused decrease in the expansion and hardness of extrudate and also the consumer preference.

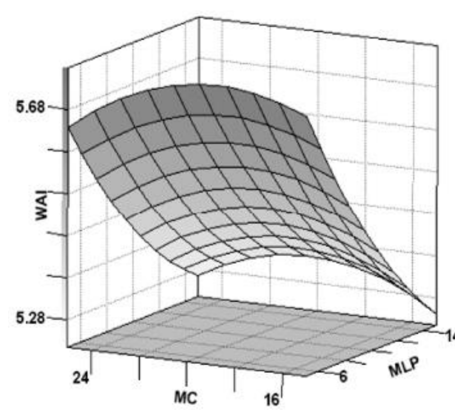
The physical, functional and sensory parameters of developed products at different moringa leaf powder concentration (i.e., at 5, 10 and 15% MLP), along with control sample were compared with popular available extruded products from the market. Four such market products are taken and the highest values of physical, functional and sensory properties of these products are compared with developed products at different MLP% and control (Table 5).

The particle density and specific length of extrudate from RF-5 % MLP were at par with the market sample. The hardness of market sample was less which might be due to precise processing condition and ingredients. The hardness increased with addition of MLP but at 5 % MLP level the value was similar to the control. Taking expansion, particle density and hardness into consideration, addition of 5 % MLP was recommended (Fig. 5). Addition of higher levels of moringa leaves caused change in colour and taste. Highest sensory scores in terms of overall acceptability were obtained with the extrudate samples produced from 5 % moringa leaves. Lower concentration of moringa leaves in the sample resulted in higher



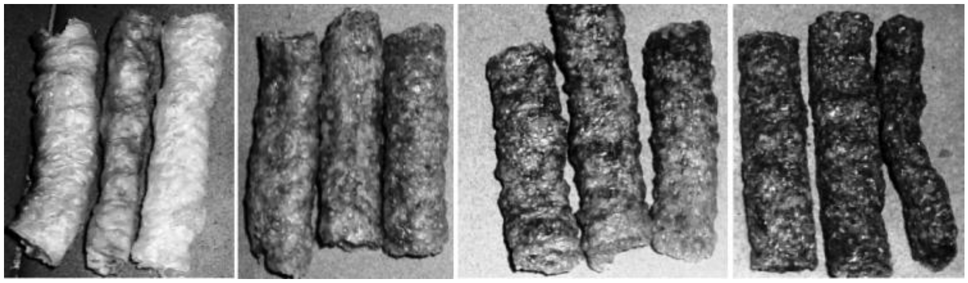
Fixed levels: RPM=300

Fig.5. Response surface plot for sensory



Fixed levels: RPM=300

Fig. 6. Response surface plot for WAI



0% MLP 5% MLP 10% MLP 15% MLP

Fig.7 Extruded products developed at different levels of MLP-rice flour

Table 5. Comparison of physical parameters of developed product with available popular market samples

	Control(0% MLP)	RF-MLP 5%	RF-MLP 10%	RF-MLP 15%	Market Product
Expansion ratio	4.34	5.34	4.80	3.90	-
Specific length, cm/g	5.21	5.08	5.39	5.78	5.32
Particle density, gm/cc	3.16	3.44	3.52	3.86	3.20
Hardness, kg	7.53	8.73	12.7	17.8	5.97
WAI	5.24	5.34	5.56	6.20	4.69
Sensory	8.57	8.57	7.28	6.75	8.82

acceptability. It was found that the overall acceptability values of RF-5 % MLP extrudate was at par with the control and market samples. Similar type of result was also reported by Kumar *et al.*, 2010 with addition of 5 % carrot pomace powder for maximum acceptability of extrudate product.

The proportion of moringa leaf powder to be added to rice flour for preparation of extrudate have been standardised based on desired physical, functional properties and better sensory attributes. Natural flavouring additives like black pepper, coriander powder and garlic powder or mint powder have also been tried along with other processing parameters to obtain a product of acceptable sensory quality. Highest sensory score was obtained at 5 % MLP content, 15 % moisture and 350 rpm screw speed and recommended for preparation of rice flour-moringa leaf powder extrudate with compromisation of 2.8 % less expansion ratio, 13.9 % more particle density, 17.6 % more hardness and 4.5 % less WAI from the highest value of parameters obtained from other combinations of experiments conducted. Increasing the level of MLP could well increase the nutritional value but at the expense of textural and sensory qualities.

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