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Development of barnyard millet ready-to-eat snack food : Part II

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Barnyard millet (BM) based hot air puffed product has less crispness. Oven toasting improves the crispness of the puffed, roasted or flaked food products. A ready-to-eat (RTE) puffed and toasted snack food product from BM was developed. Toasting experiments were designed using central composite rotatable design (CCRD) at varying temperature (84 – 126 °C) and time (10 – 30 min). There was significant reduction in moisture content, colour and hardness of toasted product with increase in toasting temperature and time whereas there was higher increase in crispness at lower levels but less increase at higher levels of toasting parameters. The influence of temperature was dominant over toasting time for all responses. Reduction in moisture content and improvement in microstructure of the product during toasting resulted in the significant increase in crispness. The process parameters were optimized using response surface methodology (RSM). The quality attributes like moisture content, colour, crispness and hardness of the optimally toasted snack food were 0.046 kg kg^{-1} dm, 69.79, 18.45 and 362.64 g, respectively at the optimum temperature and time combination of 116.26 °C and 20.23 min, respectively. The total energy content of the BM snack food was 380.74 kcal per 100 g product.

Key Words : Toasting, Crispness, Haedness, Responses, Quality attributes

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INTRODUCTION

Millets are a rich source of minerals, nutraceuticals, dietary fibers and which contain 9-14 per cent proteins and 70-80 per cent carbohydrates (Hadimani and Malleshi, 1993). Barnyard millet (*Echinochloa frumentacea*) is traditionally used as special food by people who practice fasts, who are suffering from acidity, indigestion, allergy to gluten and recommended for diabetic patients (Arora and Srivastav, 2002; Kamath and Belavady, 1980). The appropriate nutritional composition of BM can be utilized in developing a snack food and thereby exploiting the health benefits of millets in the diet of consumer. In thermal processing, the hot air puffing offers an opportunity to develop products from composite flour prepared from broken kernels. In the present study the BM puffed product was good quality ready-to-eat (RTE) product but its moisture content (0.106 kg kg^{-1} dm) was not safe for long storage (below 0.05 kg kg^{-1} dm) and its crispness was less than what could be. For this purpose further thermal processing in the form of toasting was essential.

Toasting is an important processing step for improving the texture in the manufacture of RTE puffed and toasted snack foods. In toasting the dry puffed products are subjected to thermal treatment at high

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temperature for desired period to improve structural and organoleptic properties like moisture content, colour, flavour, bulk density and crispness. Among the various quality attributes, texture is one of the most important parameter (Mazumder *et al*., 2007; Mariotti *et al*., 2006). Uniform soft crisp texture and bright yellow colour are the desired features of the toasted flakes (Sumithra and Bhattacharya, 2008). Mukherjee (1997) and Nath and Chattopadhyay (2007) reported increase in crispness with decrease in moisture content of the dehydrated puffed product from potato during toasting. Therefore, in order to improve the textural properties of puffed product from BM flour, the present study on oven toasting was carried out in Agriculture and Food Engineering Department, Indian Institute of Technology, Kharagpur, India to prepare optimally toasted snack food.

METHODOLOGY

In order to have input product samples for oven toasting experiments, the puffed product was prepared cooled and immediately packed in plastic boxes to prevent moisture absorption from surrounding atmosphere.

Preparation of hot air puffed product:

Three ingredients *viz.* BM flour, tapioca powder and potato mash were mixed in the proportion of 60:37:3 and kneaded in Dolly Mini P3 Pasta machine (LaMonferra, Italy) for 20 min and extruded to prepare cold extrudates of size 20 x 12 x 1 mm (Fig. A). These extrudates were steamed in autoclave and then puffed in specially designed hot air puffing machine at optimum process conditions of steaming pressure, 0.85 kg cm^{-2}, steaming time, 10.0 min, air temperature, 234 °C and puffing time, 39 s to prepare RTE puffed product.

Oven toasting of puffed samples:

Oven toasting experiments were conducted in household electrical oven (Electronics and Electrical Engg. Co., Kolkata, India, GCO - 250, 230 V AC, 2.5 kW, 1-ph) having temperature range of 50–250 °C. The air temperature inside the oven was measured by digital temperature indicator Model No. DTC PR with a least count of 1 °C. In each oven toasting treatment, 250 g of puffed product was placed over a perforated tray in single layer inside the oven at desired temperature and time. The toasted product was taken out from the oven and cooled for measurement of final moisture content, colour (L-values), crispness and hardness.

Measurement of quality attributes of oven toasted snack food:

The moisture content (MC, kg kg^{-1} dm) of the samples at every stage of the process was determined by hot air oven method as described by AOAC (2005). After

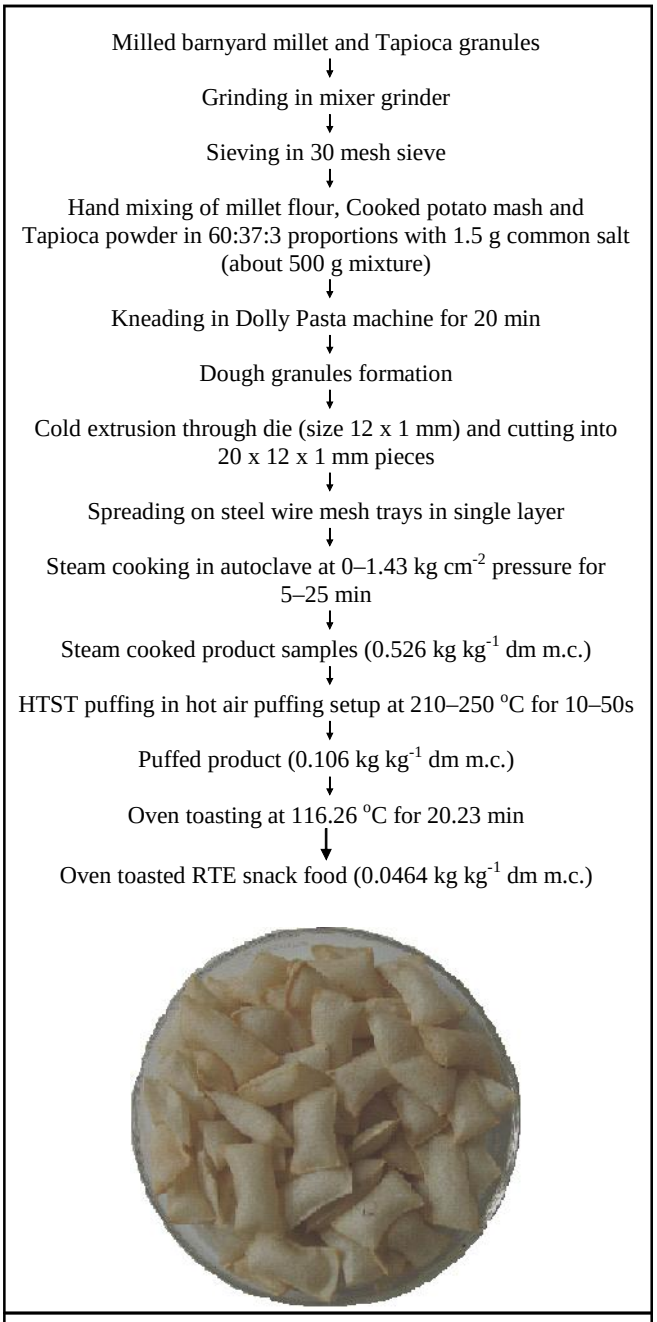

Fig. A : Process flow chart for preparation of barnyard millet RTE snack food at optimum process conditions

24 h of drying, the sample weights were taken and calculated moisture contents were expressed in kg kg^{-1} dm. The colour (C, L-value) was measured using Chromameter (Model CR – 400/410, Konica Minolta, Japan). Each product sample was prepared in powder form and the L values (lightness of colour) were obtained (there was not much variation in the 'a' and 'b' values with change in the process parameters). Mean of three replications was taken for each experimental sample. The texture properties of toasted product were measured in terms of crispness and hardness by compression test using a Stable Micro System TA-XT2 texture analyzer (Texture Technologies Corp., UK) fitted with a 25 mm cylindrical probe. The number of positive peaks on the force-time deformation curve (Fig. B) was counted as crispness (Crp, +ve peaks) of the sample (Prince *et al.*, 1994; Cruzycelis *et al*., 1996) and compression force at the highest peak was taken as hardness (Hd, g) of product (Vincent, 1998). Average of five replications was taken in each experiment for both the parameters.

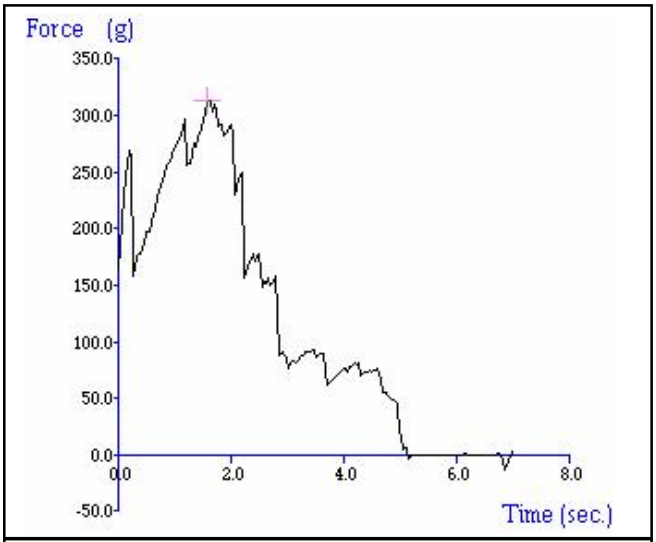

Fig. B: Typical force-time curve of toasted barnyard millet RTE snack food

Experimental design and statistical analysis:

In the present study, the ranges of experimental parameters were selected based on literature review and preliminary trials. The independent variables considered were oven toasting temperature, OT (84–126 °C) and time, Ot (10–30 min). Thirteen experiments were performed according to a second order CCRD with two variables and five levels of each variable (Das, 2005).

The experimental data were analyzed by multiple regression analysis using *Design Expert - version 7.0* (Stat-ease Inc., U.S.A.) for fitting the models represented by Eq. 1.

$$Y_k = b_{k0} + \sum_{i=1}^{2} b_{ki} X_i + \sum_{i=1}^{2} b_{kii} X_i^2 + \sum_{i \neq j=1}^{2} b_{kij} X_i X_j \qquad (1)$$

where, b_{k0}, b_{ki}, b_{kii}, and b_{kij} are the constant, linear, quadratic and cross-product regression co-efficients, respectively and X_i's and X_j's are the coded independent variables of X_1 and X_2.

From regression analysis and analysis of variance (ANOVA) the effect process parameters on responses was examined. The oven toasting process parameters were optimized by numerical and graphical optimization techniques of the Design-Exepert software (Ushakumari *et al*., 2004; Nath and Chattopadhyay, 2007).

Nutritional and sensory evaluation:

The nutritional composition of the optimally developed barnyard millet snack food was calculated for 100 g sample (Ranganna, 1977; Jones *et al*., 2000). The overall acceptability (OAA) of the final product was crried out by a panel of available thirty members of trained and untrained judges consisting of students and staff. A nine point hedonic scale (BIS, 1971) was employed for all the quality attributes evaluated where sample scoring 9 was rated as "liked extremely" and those scoring 1 as "disliked extremely". The data on the sensory attributes like colour, flavour, taste, mouthfeel and overall acceptability were analyzed by analysis of variance (ANOVA) by *Indostat 8.5* Software to find preferences given to the sample. In the present study, two samples of the oven toasted product *viz*. RTE millet snack without spice (S1) and with spice (S2) were prepared and compared with commercial puffed chisels (S3) in terms of sensory qualities.

OBSERVATIONS AND ASSESSMENT

The experimental values of the response variables at different combinations of OT and Ot are presented in Table 1. Obtained data were analyzed to study the effect of toasting parameters on product quality in terms of moisture content, lightness of colour, crispness and hardness as given below.

Moisture content (MC):

From the response data it was evident that MC

Table 1: Treatment combinations for oven toasting with 2 variables using CCRD and values of responses

Expt. No.	Independent variables[a]		Responses[b]			
	Temperature (°C)	Time (min)	MC (kg kg^{-1} dm)	C (L-value)	Crp (+ peaks)	Hd (g)
1	120(1)	27(1)	0.021 ± 0.002	64.29 ±3.96	18 ±2.40	289.7 ±2.65
2	120(1)	13(-1)	0.054 ± 0.005	70.28 ±1.83	15 ±3.32	450.5 ±4.78
3	90(-1)	27(1)	0.061 ±0.008	68.60 ±2.56	14 ±4.42	372.5 ±3.57
4	90(-1)	13(-1)	0.080 ±0.004	71.51 ±1.58	13 ±4.83	457.0 ±6.40
5	126(1.414)	20(0)	0.030 ±0.006	62.21 ±3.36	17 ±1.17	288.9 ±2.63
6	84(-1.414)	20(0)	0.079 ±0.004	71.22 ±1.61	14 ±5.15	459.3 ±5.72
7	105(0)	30(1.414)	0.038 ±0.003	68.23 ±1.70	15 ±2.36	346.2 ±3.74
8	105(0)	10(-1.414)	0.076 ±0.003	72.12 ±1.32	13 ±4.37	456.5 ±4.75
9	105(0)	20(0)	0.066 ±0.004	74.72 ±1.41	17 ±3.23	451.0 ±3.42
10	105(0)	20(0)	0.062 ±0.005	74.12 ±2.33	18 ±2.41	402.5 ±3.53
11	105(0)	20(0)	0.058 ±0.003	74.42 ±1.34	18 ±2.39	393.3 ±4.60
12	105(0)	20(0)	0.064 ±0.007	70.31 ±1.65	18 ±2.42	380.0 ±3.48
13	105(0)	20(0)	0.061 ±0.002	73.82 ±1.44	20 ±2.45	391.8 ±4.33

MC – moisture content, C – colour, Crp – crispness, Hd – hardness
[a] Values of independent variables in parenthesis are coded values
[b] Values of responses are means ± standard deviation of three replicates

Table 2: ANOVA data showing the effect of toasting parameters on BM snack food

Source	df	F values			
		MC	C	Crp	Hd
Model	5	121.79***	10.28**	14.43***	12.55***
OT	1	356.63***	13.68**	16.85**	14.56**
Ot	1	217.92***	8.51*	7.46*	21.54**
OT x Ot	1	7.64*	0.78 ^{NS}	1.28 ^{NS}	1.56 ^{NS}
OT^2	1	20.14**	25.36***	14.98**	–
Ot^2	1	9.82*	5.72*	36.91***	–
Lack of Fit	3	0.29^{NS}	0.85 ^{NS}	0.18 ^{NS}	1.40 ^{NS}
Model R^2		0.99	0.87	0.90	0.78
Adjusted R^2		0.98	0.80	0.85	0.73
Predicted R^2		0.97	0.63	0.80	0.59
APR		34.04	9.23	9.79	12.11
CV (%)		4.38	2.44	5.56	7.93

*, ** and *** indicate signifiance of values at P<0.05, 0.001 and 0.01, respectively NS=Non-significant
OT – toasting temperature, Ot – toasting time, APR – adequate precision ratio

Table 3 : ANOVA of sensory data evaluation and overall acceptability (OAA) scores of three RTE snack foods

Sources of variation	df	Sum of square	Mean Squares	F Ratio	OAA
Replicates	29	125.8311	4.339	4.89*	S_1 = 6.24
Sample, S	2	65.5511	32.7755	44.49**	S_2 = 6.70
Quality attributes, Q	4	4.3644	1.0911	1.08	S_3 = 7.07
S*Q	8	16.9822	2.1227	2.88*	
Error (Q)	406	299.1022	0.7367		
Total	449	511.8311	1.1399		
C.V.			12.76%		

* and ** indicate significance of values at P=0.05 and 0.01, respectively

decrease was relatively slow at lower values of temperature and time but it was at high rate when both increased beyond 120 °C and 20 min, respectively. The reduction in moisture content correlated to the corresponding increase in crispness and made the product crunchy (Sumithra and Bhattacharya, 2008).The moisture content of toasted product varied between 0.0286 and 0.08 kg kg^{-1} dm (Table 1). The ANOVA for MC (Table 2) indicated that the quadratic model (Eq. 2) was best fitted at high significance level ($p<0.001$).

$$MC = -0.08991 + 0.00362 \times OT + 0.00403 \times Ot - 3.3 \times 10^{-5} \times OT \times Ot - 1.95 \times 10^{-5} \times OT^2 - 6.04 \times 10^{-5} \times Ot^2 \quad (R^2=0.99) \quad (2)$$

Colour (C):

The experimental values of colour revealed that initially there was slight improvement in colour at low temperatures for around 20 min as the brightness of product increased to some extent but at higher temperatures and for longer duration there was reduction in L-value due to non-enzymatic browning of surface of product. It was observed that decrease in L-value indicating browning of the product occurred only after a certain time of exposure that is just after optimum toasting time which was similar to the trend observed by Mishkin *et al.* (1983) in developing colour difference during dehydration of potato. The L-value in colour of toasted product varied between 62.21 and 74.72 (Table 1). The ANOVA for lightness of colour (Table 2) suggested that second order regression model (Eq. 3) can be fitted to the experimental data at satisfactory level of significance ($p<0.01$).

$$C = -83.8133 + 3.0043 \times OT + 1.0145 \times Ot - 0.0151 \times OT^2 - 0.0317 \times Ot^2 \quad (R^2 = 0.87) \quad (3)$$

Crispness (Crp):

Crispness of the product during toasting experiments varied from 13 to 20 positive peaks within the combination of variables studied (Table 1). The optimum crispness value (18.45) of BM toasted product in present study was higher than 18 for RTE wheat-soy snack food (Pardeshi and Chattopadhyay, 2014) but much lower than 35.6 for rice-soy snacks (Pardeshi, 2009) and 38.7 for potato-soy snacks (Nath and Chattopadhyay, 2007). The experimental data revealed that initially the crispness increased and reached to maxima of 20 at temperature of 110 – 116 °C for toasting time of 20 – 25 min due to loss of moisture from the product. Beyond this range of toasting parameters, crispness decreased due to structural damage caused by excess heating. The second order quadratic model (Eq. 4) can be fitted successfully to the crispness data.

$$Crp = -74.074 + 1.3144 \times OT + 1.7551 \times Ot - 0.00585 \times OT^2 - 0.0408 \times Ot^2 \quad (R^2 = 0.90) \quad (4)$$

Hardness (Hd):

The experimental values of hardness indicated that the effect of oven toasting time was more prominent than that of temperature. The hardness of product reduced with increase in temperature and time. The experimental range of hardness during toasting was between 288.9 and 459.3 g (Table 1). These values were much lower than the values for potato-soy snack (3250 g) found by Nath and Chattopadhyay (2007) and for wheat-soy snack (930.2 g) reported by Pardeshi and Chattopadhyay (2014). This may be due to soft nature of BM pasta after steam cooking and resultant structural breakdown and less thickness of product. The ANOVA data (Table 2) indicated that the linear model (Eq. 5) could be fitted well to the data at high significance ($p<0.001$).

$$Hd = 827.5277 - 2.7597 \times OT - 7.1214 \times Ot \quad (R^2=0.78) \quad (5)$$

Optimization:

Numerical and graphical optimizations were carried out to find the response values that can be obtained at the optimum levels of toasting parameters (Fig. 1). The

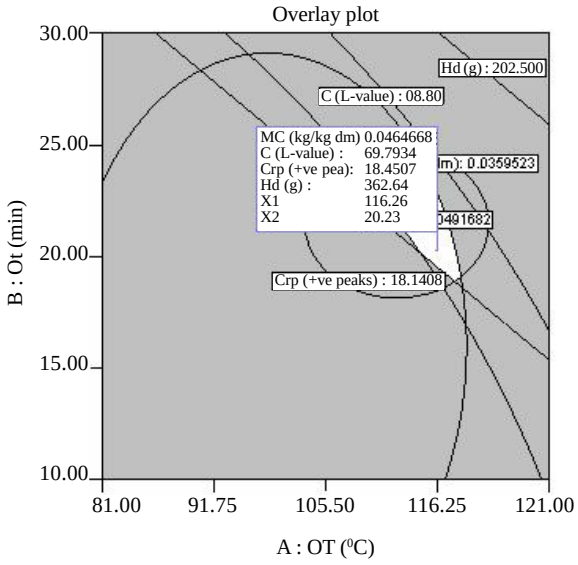

Fig. 1 : Superimposed contours of MC, C, Crp, Hd and optimum oven toasting parameters for barnyard millet RTE snack food

optimum value of oven toasting temperature (OT) was 116.26 °C and that of toasting time (Ot) was 20.23 min. The optimum value of temperature was higher than that of wheat-soy and potato-soy snacks (113.0 and 105.6 °C, respectively) but the toasting time was considerably lower than that required for both the snack foods (27.0 and 27.9 min, respectively). The maximum predicted responses which determine the product quality were moisture content of 0.046 kg kg^{-1} dm, L-value of 69.79, crispness of 18.45 +peaks and hardness of 362.64 g at the optimum levels of toasting parameters.

Nutritional value:

The fat content of optimally toasted snack food was 0.44 per cent db (dry basis) whereas the protein and ash contents were 9.04 per cent db and 1.92 per cent db, respectively. The carbohydrate content was 88.56 per cent db. The total energy content of the BM snack food was 380.74 kcal per 100 g product which was higher than potato-soy (333.77 kcal) snacks (Nath, 2007) and slightly less than that of wheat-soy (381.31 kcal) snack food (Pardeshi, 2009). The mineral and carbohydrate contents of BM snack food were higher than that of wheat-soy snacks (1.5 and 83.35 % db, respectively) while protein content was less (13.64 % db).

Sensory evaluation:

Means of scores for all quality attributes and overall acceptability (OAA) of three samples were significantly different which was evident from the F Ratio (Table 3) at $p \leq 0.01$. The mean values, F Ratio and critical difference of quality attributes for three samples indicated that scores of quality characteristics were not significantly different. The overall acceptability of commercial chesel snack was highest (7.07) than the developed RTE barnyard millet based snack. The OAA scores of sample with spice and without spice application were 6.7 and 6.24, respectively. This indicated that barnyard millet snack with spice was liked more than it without spice and it had acceptability close to the commercial product.

Conclusion :

Toasting temperature and time significantly reduced the moisture content with corresponding increase in crispness. There was improvement in brightness of the product initially but it reduces only after certain time of exposure. Oven toasting temperature of 116.26 °C and time of 21.23 min were optimum process conditions to develop RTE snack food from BM puffed product with optimum product qualities in terms of moisture content (0.0464 kg kg^{-1} dm), lightness of colour (L-value of 69.79), crispness (18.45 +ve peaks) and hardness (362.64 g).

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