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Development of gluten free *buckwheat* cake and optimization of its baking process

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Abstract
Fasting is an integral part of Indian culture. Most of the people keep fast for one or another reason. *Buckwheat* eggless cake is a cake made from whole *buckwheat* flour. RSM was used successfully to optimize the baking time and temperature for the development of *buckwheat* cake. *Buckwheat* contains high protein, antioxidants, fibre, flavonoids, flavons and phytosterols. Response surface methodology was used to optimize the baking conditions by studying the effect of baking time and temperature on five responses such as weight loss, moisture content, specific volume, hardness and browning index of cake. Baking temperature and time ranged from 140 ˚C to 160 ˚C and 50 to 70 min respectively. Moisture content of *buckwheat* cake decreased from 42.41± 0.35% (batter) to 27.13 ± 1.30%, 24.61 ± 0.50% and 16.93 ± 0.28% at 140 ˚C, 150 ˚C and 160 ˚C respectively. Specific volume of *buckwheat* cake increased with rise in baking time and temperature from 1.98 ± 0.17$cm^3.g^{-1}$ to 2.35 ± 0.03 $cm^3.g^{-1}$.Weight loss, browning index and hardness of *buckwheat* cake increased significantly. The optimum time and temperature was selected as 156.82 ˚C for 63.01 min with desirability 1.00 using face centered composite response surface design.

Keywords: Baking, *Buckwheat*, cake, gluten, RSM

Introduction
Buckwheat is a pseudo-cereal and a very valuable alternative crop for the production of functional foods. *Buckwheat* seeds and other tissues contain many nutraceutical compounds. The presence of low non-toxic prolamine content make it suitable for use in celiac patient diet. It is a good source of non- saturated fatty acids mainly oleic and linoleic acid. The use of *buckwheat* in baking is bit difficult as it is gluten free and without gluten the change in shape, texture, colour and flavour as well as in quick drying of crumb which is unacceptable to the consumer. The role of food technologists is to design such recipes for gluten-free products, which would improve their expansion, structure and taste (Gambus *et al*. 2009; Gallagher *et al*. 2004) [4, 5] and would help the people with celiac disease to fulfill the nutritional directions, which imply everyday consumption of dietary fibre, minerals and other food constituents (Bojnanska *et al*. 2009) [2].
Some authors studied the beneficial role of *buckwheat* in baked products. It was reported that a substitution of 30% wheat flour with *buckwheat* flour yielded a buckwheat-enhanced wheat bread acceptable from the technological, sensory and health point of view (Bojnanska *et al*. 2009) [2]. Another author described an increase in the antioxidant activity and rutin content in dough and breads with a growing percentage of Tartary *buckwheat* flour (Vogrinćić *et al*. 2010) [11]. Tartary *buckwheat* flavones have been used to enrich wheat bread reported that buckwheat-enriched wheat bread had the highest phenolic content and antioxidant activity in comparison with amaranth and quinoa enriched wheat bread (Gawlik-Dziki *et al*. 2009; Chlopicka *et al*. 2012) [6, 3]. Moreover, it was investigated that an increase in the plasma antioxidant capacity after four weeks of 30% buckwheat-enriched wheat bread consumption. They also reported that with the addition of *buckwheat* in bread proteins, minerals, fibers as well as rutin content increased (Bojňanská *et al*. 2009) [2].
Response surface methodology (RSM) is a collection of statistical and mathematical techniques used for development, improvement and optimization of processes or formulations (Malcolmson *et al*. 1993; Turabi *et al*. 2008) [8, 10]. It is an attractive tool for the optimization of baked products. It helps to detect the level of ingredients and the process parameters. It is frequently reported that RSM is really a helpful tool to detect the optimal levels of baking conditions and formulation without the necessity of testing all possible combinations.

Therefore, the objective of present work was to develop a gluten free *buckwheat* cake and optimization of its baking conditions. All the ingredients were selected such that it can be acceptably consumed by the people who practice fasting. So this is a good option for the individual who is undertaking a fast. Present product is gluten free. Hence it can be also beneficially consumed by celiac prone patients. This research work could be a better option for vegetarian people.

Materials and methods

Buckwheat flour, sugar, skim milk powder, white butter, baking powder, emulsifier and stabilizer were used in the making of gluten free *buckwheat* cake. *Buckwheat* flour, refined flour, sugar, eggs and baking powder were purchased from local market of Allahabad. White butter, Skim milk powder and Emulsifier-stabilizer blend was procured from student experimental learning plant "Aggies", Warner College of Dairy technology, SHUATS, Allahabad.

Preparation of cake batter: The gluten free *buckwheat* cake contained 100% *buckwheat* flour, 110% sugar, 55% butter, 5% baking powder, 2.5% emulsifier and stabilizer blend and 12% SMP (all % were given in flour weight basis). All dry ingredients were mixed as a first step in preparation of the cake batter. Then, melted fat was added to the powdered sugar and creamed well. Then all the dry ingredients were added and blend with the help of hand mixer (ORPAT, Model no. OTGW 2735 R, India) with the addition of water. The final moisture content of batter was adjusted in such a way that it contains 42% moisture (on dry basis).

Baking of cake: Baking of *buckwheat* cake was carried out in an electrical baking oven (Lexus, USH, Oven, Toaster, Griller and Warmer, Model no. OTGW 2735 R, made in China) at air temperature 140 ˚C, 150 ˚C and 160 ˚C. Exactly 110 g of cake batter was filled in all 7 aluminium vessels (11×8.2×3.2cm) and then placed in pre-heated oven. As the baking progress the samples were drawn at each 10 min time interval of baking process up to 70 min.

Experimental Design: Optimization of baking conditions of *buckwheat* cake was carried out using Design-Expert (Trial Version) v. 10.0.10 software. A face-centered central composite design (FCCCD) was used with two process variables and five responses for the optimization of baking process. The two independent process variables studied were baking time (t) and temperature (T). The five (SV) responses (dependent variables) were moisture content, weight loss, specific volume, hardness and browning index. The variable levels were selected on the basis of preliminary trials. The actual and coded levels of independent factors used in the experimental designs are given in Table 1.

Cake Analysis: The specific volume of *buckwheat* cake was analysed using rapeseed displacement method.

The mass of the seeds (M_{seed}) was calculated as follow:

$$M_{seed} = M_{total} - M_{sample} - M_{vessel} \quad (1)$$

The volume of the sample (V_{sample}) was calculated as follow:

$$V_{seed} = M_{seed} / p_{seed} \quad (2)$$

$$V_{sample} = V_{vessel} - V_{seed} \quad (3)$$

Specific volume of cakes were calculated by using given Eq.,

$$(SV)\ \text{Specific volume of sample} = \frac{V_{sample}}{M_{sample}} \quad (4)$$

Where, M (kg) is mass, V (m^3) is volume, and SV (m^3/kg) is the specific volume.

The moisture content was determined using gravimetric method (AOAC, 2000) [1].

The percentage of weight loss was calculated by measuring the weight of cake before and after baking.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight of the sample - Final weight of the sample after baking}}{\text{Initial weight of the sample}} \times 100 \quad (5)$$

The browning index of cake was measured by using image analysis. A square piece of cake was scanned at 300 dpi using a flatbed scanner (HP Deskjet Ink Advant $K209_{a-z}$). It was then imported into Adobe Photoshop 7 software and the mean value of colour parameters 'L', 'a' and 'b' values were obtained from the histogram window. 'L^*', 'a^*' and 'b^*' were calculated by using the following equations.

$$L^* = \left[\frac{L}{255}\right] \times 100 \quad (6)$$

$$a^* = \left[\frac{240 \times a}{255}\right] - 120 \quad (7)$$

$$b^* = \left[\frac{240 \times b}{255}\right] - 120 \quad (8)$$

The browning index (BI) was calculated from the following formula:

$$BI = \frac{[100 \times (x - 0.31)]}{0.17} \quad (9)$$

Where,

$$x = \frac{(a_t^* + 1.75L_t^*)}{(5.645L_t^* + a_t^* - 3.012b_t^*)} \quad (10)$$

Determination of textural properties Hardness of the *buckwheat* cake was determined by using texture analyser (TA-HD *plus*, Stable Microsystems, surrey, U.K.). The instrument was fitted with a 50 kg load cell and a 75 mm dia. compression platen (P/75 probe) was used to compress the samples. The product at different stages of baking was cut into pieces of 15×15×10 mm size. The sample was positioned centrally over the platform and the computer was allowed to

execute the program by activating 'run a test' option. The texture-profile-analysis (TPA) test involved a two-bite compression to a depth of 8.5 mm with a time lapse of 120 s between the two bites to yield the force-time curve. The settings used for measuring textural properties were as follows: Pre-test speed: 1.0 mm/s; test speed: 0.5 mm/s; post-test speed: 5.0 mm/s and trigger force: 2 g.

Statistical analysis: Design-Expert v.10.0.10 (Trial Version) software was used to fit second order polynomial equations to all the dependent variables by multiple regression.

$$Y=\beta_o+\beta_1X_1+\beta_2X_2+\beta_3X_1^2+\beta4X_2^2+\beta_5X_1X_2 \quad (11)$$

Where, 'Y' is the response, 'β_0' is the constant, 'β_1' and 'β_2' are linear coefficients 'β_3' and
'β_4' are the squared coefficients and 'β_5' is the interaction coefficient and X_1 (Baking temperature) and X_2 (Baking time) are independent variables. The significance of the model terms contributing to regression sum of squares was evaluated. The reduced model was then obtained by analyzing the regression model coefficients using ANOVA (p<0.05) and excluding the non-significant coefficients from the initial model. Contour plots were used to explain the effects of independent factors ('T'and 't') on the response variables (Y_1, Y_2, Y_3, Y_4 and Y_5).

Results and discussion

Effect of baking time and temperature on moisture content

The effect of different baking time and temperature on the moisture content of *buckwheat* cake are reported (Table 2) by the coefficient of second order polynomials. From Table 3, it is evident that the quadratic predictive model for moisture content was significant (p<0.001) at both baking time and temperature and at their interaction effect also. Therefore, it could be concluded that time and temperature had a prominent influence on the moisture content of *buckwheat* cake. Moisture content of the gluten-free *buckwheat* cake decreased with increase in baking time and temperature. It decreased from 42.41± 0.35% (batter) to 27.13 ± 1.30%, 24.61 ± 0.50% and 16.93 ± 0.28% at 140 ˚C, 150 ˚C and 160 ˚C. The regression model describing the effect of baking time and temperature on the moisture content of *buckwheat* cake (in terms of actual levels) is given as:

$$\text{Moisture content (\% d.b.)}=-319.94+5.61T-0.90t+5.92\times10^{-3}Tt-0.02T^2-1.17\times10^{-3}t^2 \quad (12)$$

The mean relative percent deviation modulus (%P) of the developed model was 1.56% for moisture content. Since the 'P value' was less than 5%, the developed model was considered to have a good fit of the experimental data (Lomauro *et al*. 1985).

Effect of baking conditions on Specific volume

The predictive quadratic model for specific volume showed significant (p<0.001) linear effect on both time and temperature. The mean specific volume of *buckwheat* cake baked at different temperatures was 1.98 ± 0.17$cm^3.g^{-1}$, 2.36 ± 0.01$cm^3.g^{-1}$ and 2.35 ± 0.03$cm^3.g^{-1}$ at 140 ˚C, 150 ˚C and 160 ˚C. These values show that at higher temperature the specific volume decreases. The reason for the decrease in volume of the cake at higher temperature may be due to the thicker crust formed at the surface on the cake compressed the structure more and resulted in lower volume (Sevimli *et al*. 2005). The regression model describing change is specific volume with time and temperature by the 'P value' of 3.74% which is less than 5%.

$$\text{Specific volume (cm}^3\text{/g)} = -54.20+0.69T+0.07t-3.03\times10^{-3}T^2-2.04\times10^{-4}t^2 \quad (13)$$

Effect of baking conditions on weight loss

The weight loss was up to 13.90 ± 1.42%, 15.35 ± 0.75% and 18.10 ± 0.38% at 140 ˚C, 150 ˚C and 160 ˚C, respectively. The effect of baking time and temperature on weight loss of *buckwheat* cake showed a linear model which was significant (p<0.001) at both time and temperature of baking. The P% value was 3.81% which shows that experimental data was fitted good. The regression equation of weight loss is given as:

$$\text{Weight loss (\%)} = -34.58+0.21T+0.27t \quad (14)$$

Effect of baking conditions on Hardness

As the temperature raised, the amount of moisture loss increased and this resulted in an increase in hardness of the prepared *buckwheat* cake. The hardness values were 110.74 ± 3.52g, 126.73 ± 5.11g and 260.18 ± 26.87g at 140 ˚C, 150 ˚C and 160 ˚C, respectively. The effect of different time and temperature of baking on the instrumental data hardness was significant (p<0.001) and P% was found 1.61%. The interaction effect between time and temperature was also significant and positive.

$$\text{Hardness (g)} = 5065.11-61.28T-25.57t+0.19Tt+0.17T^2-7.70\times10^{-3}t^2 \quad (15)$$

Effect of baking conditions on Browning index

Browning index of the prepared *buckwheat* cake was increased with rise in temperature and time during baking. It increased from the initial value of 31.99 to 54.02, 66.04 and 72.89 at 140 ˚C, 150 ˚C and 160 ˚C. This could be due to caramelization reaction occurred during baking. Independent factors showed significant positive linear as well as quadratic effect on browning index. The interaction effect was also significant. The developed model based on baking time and temperature for browning index was highly adequate with a 'P value' of 1.22%.

$$\text{Browning index} =427.46-5.92T-0.28t-2.60\times10^{-3}Tt+0.02T^2+9.41\times10^{-3}t^2 \quad (16)$$

Fig. 1 shows the contour plot of different responses showing the effect of baking time and temperature on quality of *buckwheat* cake. The optimum baking conditions of *buckwheat* cake baked at different time and temperature were found by multiple optimization using the response optimizer in Design-Expert v. 10.0.10 software. In determination of these optimum points, specific volume was set to be maximized and other four responses were set in range. When the optimum points were examined 156.82 ˚C and 63.01 min with desirability 1 was selected as optimum baking temperature and time, respectively. The proximate composition of *buckwheat* cake prepared at optimum baking time and temperature was shown in fig. 2.

Table 1: Coded and actual levels of process variables

Process variable	Code	Coded values		
		-1	0	1
Baking Temperature, ˚C	X_1	140	150	160
Baking Time, min	X_2	50	60	70

Table 2: Regression coefficients of the second order polynomial for the response variables

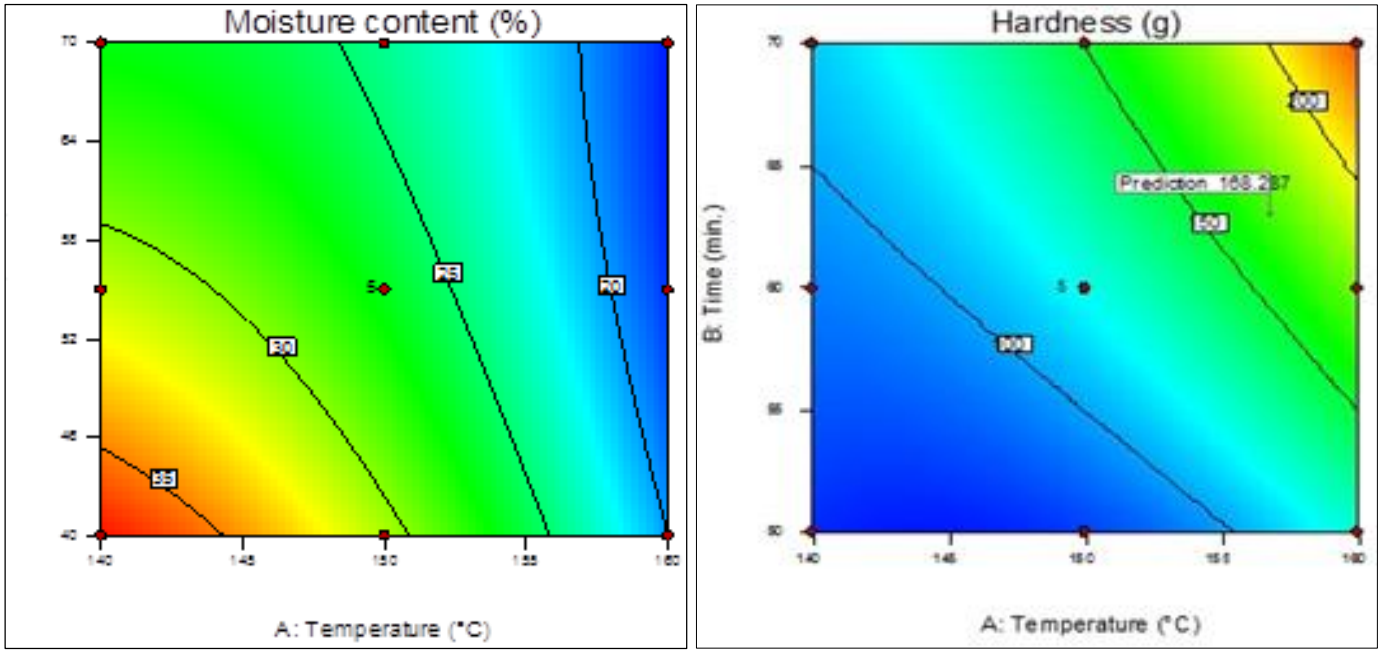
Coefficients	Moisture content (%d.b.)	Specific volume (cm^3/g)	Hardness (g)	Weight loss (%)	Browning Index
β_0	26.04^{***}	2.32^{***}	117.22^{***}	13.22^{***}	57.76^{***}
β_1	-5.77^{***}	0.23^{***}	41.89^{***}	2.11^{***}	9.28^{***}
β_2	-1.58^{***}	0.084^{***}	33.79^{***}	2.70^{***}	4.56^{***}
β_3	-2.18^{***}	-0.22^{***}	17.84^{*}	-	2.34^{*}
β_4	-0.12^{NS}	-0.020^{NS}	-0.77^{NS}	-	0.94^{NS}
β_5	0.59^{***}	-0.030^{NS}	19.92^{**}	-	-0.26^{NS}
R^2	99.87%	98.68%	94.91%	94.81%	97.58%
Adjusted R^2	99.79%	97.74%	91.28%	93.77%	95.86%
CV%	0.82	1.42	9.88	4.70	2.59

*Significant at $p<0.05$, **Significant at $p\leq0.01$, ***Significant at $p<0.001$, NS-Non Significant $p>0.05$

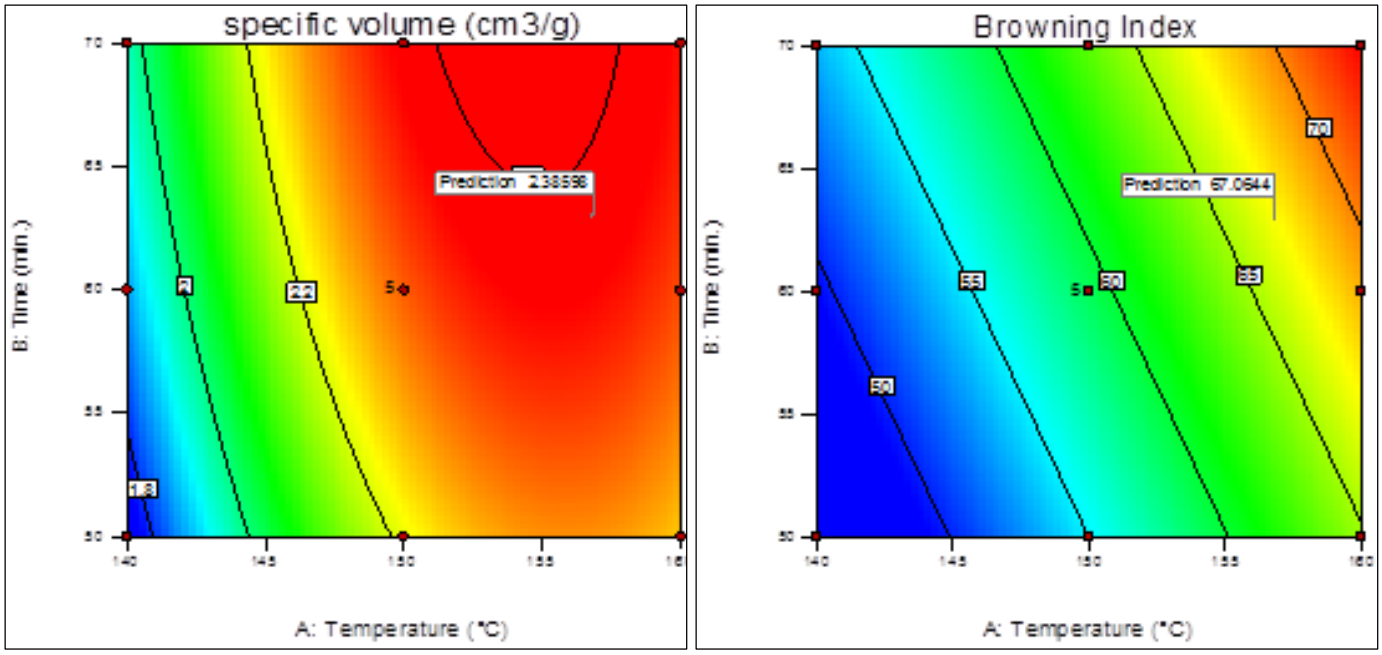
Table 3: Anova for various responses using modified regression model

Variables	F-value				
	Moisture content	Hardness	Specific volume	Weight loss	Browning index
Reduced model	1118.03^{***}	26.11^{***}	105.03^{***}	91.33^{***}	56.51^{***}
X	4808.57^{***}	68.86^{***}	309.11^{***}	69.07^{***}	218.74^{***}
Y	360.77^{***}	44.81^{***}	43.20^{***}	113.60^{***}	52.72^{***}
XY	33.82^{***}	10.38^{*}	3.74^{NS}	-	0.11^{NS}
X^2	316.90^{***}	5.75^{*}	133.83^{***}	-	6.38^{*}
Y^2	0.92^{NS}	0.011^{NS}	1.17^{NS}	-	1.04^{NS}
Lack of fit	4.26^{NS}	1.95^{NS}	5.78^{NS}	0.77^{NS}	2.66^{NS}
Adj. R^2	0.99	0.91	0.97	0.93	0.95

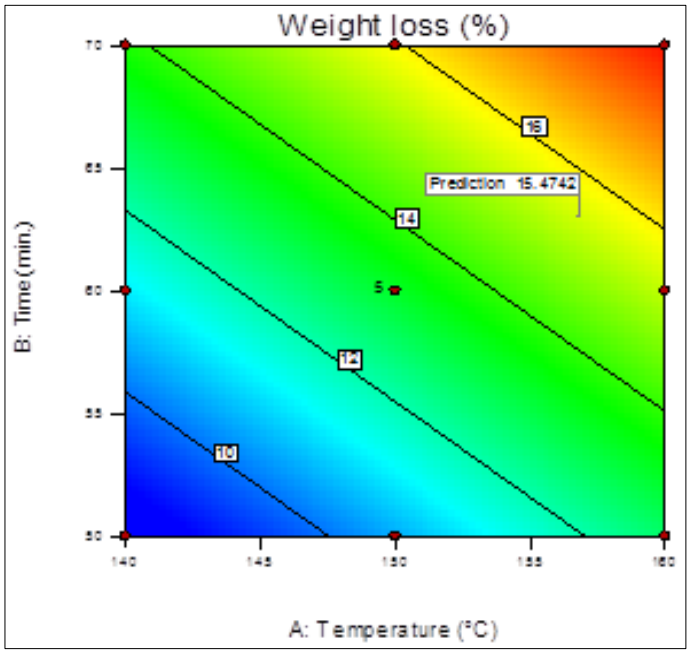
*Significant at $p<0.05$, **Significant at $p\leq0.01$, ***Significant at $p<0.001$, NS-Non Significant $p>0.05$



(a) **(b)**



(c) **(d)**



(e)

Fig 1: Contour plots (a), (b), (c), (d) and (e) showing the effect of baking conditions on *buckwheat* cake quality

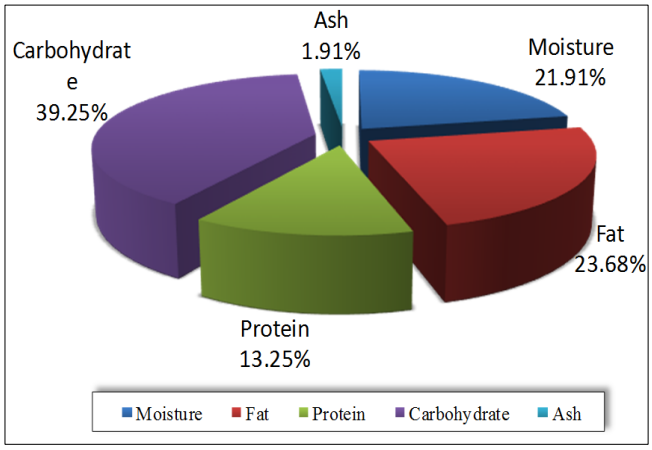


Fig 2: Proximate composition of *buckwheat* cake

Conclusion

Buckwheat is a pseudo-cereal and people can eat during fasting. It has many health benefits and contains many nutritional components. No such fasting foods are available in the market. Hence, the present study can be useful in the development of commercialized product as *buckwheat* cake – a fasting purpose cake.

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