ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(8): 937-943
www.agriculturaljournals.com
Received: 22-05-2025
Accepted: 26-06-2025

Rachana Rathwa
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Jarita Mallik
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Ajay Gokhale
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Amit Patel
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Dhinal Patel
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Corresponding Author:
Ajay Gokhale
Dairy Technology Department, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India

Process optimization for manufacture of multigrain gluten-free *Ladoo*

Rachana Rathwa, Jarita Mallik, Ajay Gokhale, Amit Patel and Dhinal Patel

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i8h.662

Abstract
Cereals and millets are globally important staple foods, providing affordable energy, protein, fiber, vitamins and minerals. Previous studies have reported various multigrain *Ladoo* formulations using combinations of pulses, grains and seeds to improve nutrient density. However, most of the reported studies involved use of wheat flour / semolina as one of the major ingredients for multigrain *Ladoo*. Traditionally, *Ladoo* is prepared from single or multiple grain flours with sugar, ghee, and optional milk solids or functional ingredients and is an important sweetmeat prepared during important festivals in India. Catering to the rising demand for healthy food alternatives especially addressing celiac-diseased conditions, the present investigation was carried out. In this study, a gluten-free, khoa-based multigrain *Ladoo* was developed using open pan roasting method. The optimized formulation included ragi flour (15%), pearl millet flour (54.76%) and chickpea flour (30.24%), with sugar at 80% and khoa at 60% on flour weight basis. The optimized product obtained was gluten-free, contained 3.43% crude fiber along with goodness of milk constituents and exhibited excellent sensory properties. The multigrain gluten-free *Ladoo* achieved flavour score of 8.36 and overall acceptability score of 8.21 on 9-point hedonic scale.

Keywords: Pearl millet, chickpea, ragi, khoa, multigrain, *Ladoo*, gluten

Introduction
Cereal and millets form the basic diet for millions of people throughout the world. They are major sources of inexpensive dietary energy and nutrients world-wide. When compared to other fermentable substrates, cereals and millets are superior in nutritional quality as these abundant resources contain some of the essential minerals, vitamins, sterols, growth factors, proteins and dietary fibres thus satisfying essential nutrient needs of mankind (Kaur *et al.*, 2009) [4]. Hence from a nutritional perspective, multigrain flour is very important with respect to health and nutrition. Multigrain flour improves the nutritional quality of food products. Multigrain flour is found to be rich in protein, dietary fiber and mineral content. Naidu *et al.* (2013) [8] has described preparation of multigrain *Ladoo* containing bengal, green and black gram dhal (20:20:10 g each) wheat and ragi flour (10 g each) rava (5 g) and ghee (30 g) along with nuts and dink. Ashwini and Anil (2024) [2] have reported manufacture of nutrient rich mixed seed *Ladoo* in which they have used ragi flour (20,25,30% of the blend) along with various seeds like pumpkin, sunflower, watermelon, flax, chia varying from 10 to 15 % each making the total to 100.0%. Luxita and Kabir (2017) [6] prepared multigrain *Ladoo* from combination of flex seeds and multigrain flour containing 7 grain readymade atta. Singh and Paul (2023) [10] reported use of multigrain flour (Oats flour 20 g, Maize flour 20 g, Soyabean flour 15 g, Bengal Gram flour 15 g, Pearl Millet flour 10 g, Finger millet flour 10g and Sorghum flour 10 g) along with herbal powder (Basil and Curry leaves in different ratio) and Bengal gram powder as base flour. The optimized product with highest overall acceptability contained Bengal gram flour 70 g Multigrain Flour 30 g Basil leaves powder 40 g, and Curry leaves powder 40 g.
Pearl millet (*Pennisetum glaucum*) is an important coarse cereal crop in western India (Gujarat, Rajasthan and Haryana). Pearl millet was effective in improving the sensory attributes, *in vitro* protein digestibility, *in-vitro* starch digestibility. Khan Rukhsar *et al.*

(2019) [5] reported development of multi nutrient Laddu employing pearl millet, rava, groundnut and coconut with Jaggery as sweetener.

Bengal gram also called chickpea or gram (*Cicer arietinum* Linn), is a major pulse crop in India, and accounts for nearly 40% of the total pulse production. Dried chickpeas contain about 20% protein. The bulk of the seed is made up of carbohydrates (61%) and 5% fat.

Ragi provide high amount of amino acid methionine, calcium, vitamins and fiber. Almond is a rich source of vitamin E, Fibre (12% Dietary Fiber), Protein, B vitamins. It contains phytosterol associated with cholesterol lowering properties.

Laddu or *Ladoo* are sphere-shaped sweets from the Indian subcontinent. They are made with either singly or in combination of grains flour along with ghee/oil/butter and sugar, with other optional / functional ingredients that vary by recipes. Milk solids are optionally added in different types of *Ladoo* and/or grain based burfi.

The fast paced life in the present era leads the people to eat highly processed and unhealthy fast foods, which can leads to progression of many life style diseases. Celiac disease, a serious autoimmune disorder triggered by gluten, affects approximately between 0.7 to 2.9 % of the global population and many of the people are undiagnosed regarding these conditions. Hence development of nutritious functional multi grain *Ladoo* is the necessity of the society and the food industry to cater the need of the people. Present study was carried out to assess the suitability and feasibility of processing methods and manufacture of gluten free multi grain *Ladoo.*

Material and Methods

- **Grains**: Grains *viz*. pearl millet, chick pea and ragi for making flours development of multigrain *Ladoo* were obtained from the Department of Agronomy, Anand Agricultural University, Anand. Multi grains *viz*. Pearl Millet (Bajra, *Pennisetum glaucum*) variety GHB 558, Chick pea (Gram, *Cicer arietinum*) variety GG 1 and Finger Millet (Ragi, *Eleusine coracana*) variety Gujarat Nagli 4 was employed in the study.
- ***Khoa***: The raw milk (mixed – cow and buffalo) used for preparing *Khoa* was procured from Vidya Dairy, Anand. Milk was standardised to 4.5 per cent fat / 8.5 per cent SNF and was converted to *Khoa* (having ~ 55% total solids) by traditional open pan method and was used for manufacture of multigrain *Ladoo*.
- ***Ghee***: The cream used for preparation of *Ghee* was obtained from Department of Dairy Processing and Operations, SMC College of Dairy Science, AAU, Anand. Direct creamery method was used for manufacture of *Ghee* at the laboratory of Dairy Technology Department.
- **Sugar**: Good quality granulated (crystal) sugar (Madhur brand, refined, non-sulphated) procured from local market of Anand was grinded using mixer grinder and was used as sweetening ingredient for manufacture of multigrain *Ladoo*.
- **Condiments**: Fresh and good quality condiments *viz*. cardamom and nutmeg (green cardamom and nutmeg of Granary brand from local market) were used as flavouring for manufacture of multigrain *Ladoo*. Dry fruits *viz*. Almonds, Cashew and Raisins were purchased from local market Granary brand.
- **Analysis:** Moisture (925.10), protein (974.24), fat (992.16), FFA (969.22) and ash (65.17) contents of the *Ladoo* were determined according to standard AOAC (2000) [1]. Carbohydrate content was estimated by difference. The water activity of the sample was measured using the water activity probe (Hygrolab 3, Rotronic Measurement Solutions AG, and Switzerland). Crude protein content was calculated by multiplying Kjeldahl nitrogen by a factor of 6.25. For hardness measurement each experimental *Ladoo* were subjected to uniaxial compression to 80 per cent of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England (Plate III), fitted with a 50 kg load cell. The force-distance curve was obtained for a two-bite deformation cycle employing a crosshead speed of 50 mm/min, trigger force of 10 gf, and 70 per cent compression of the samples to determine various textural attributes. Sensory evaluation of the product was carried out by the selected panel of 10 judges on 9 point hedonic scale (Meilgaard *et al.* 1999) [7]. Flow diagram for the manufacture of multigrain *Ladoo* is depicted in Figure 1.

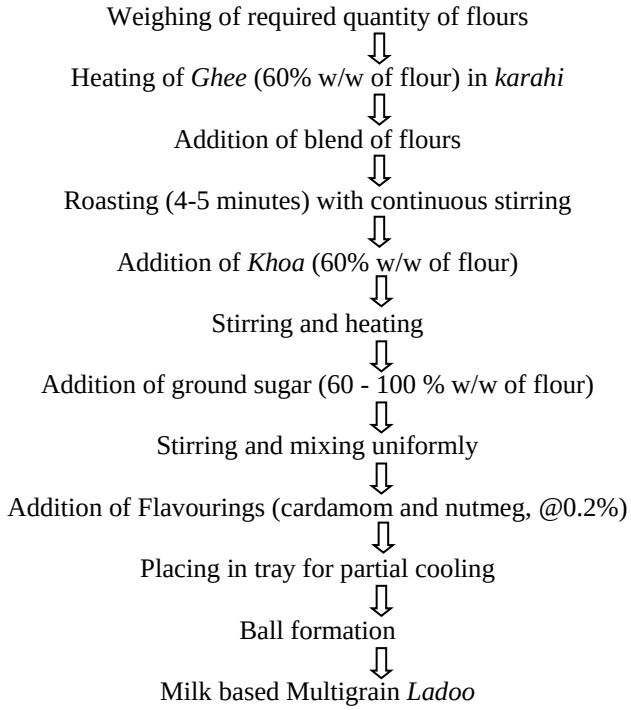


Fig 1: Flow Chart for the method of Manufacture of Multigrain *Ladoo*

Results and Discussion

Optimization of roasting process

The product was prepared as per the flow diagram delineated in figure 1. In the preliminary trials, flours were processed (sieving) and roasting process was optimized using open pan method as well as in microwave oven. Roasting in open pan was carried out for approximately 8 – 10 min., while in microwave oven roasting was carried out at 170°C for 12 – 14 min. It was observed that microwave roasting was more time consuming to achieve similar roasted flavour and lightness in the roasted product compared to open pan method. The prepared products were given to sensory panel for judging. The multigrain (MGL) *Ladoo* prepared by open pan roasting was significantly

(p<0.05) superior to those made by microwave roasting in all sensory parameters except sweetness which had non-significant variation in the score (Table 1). After selection of the roasting process for flour the study was further conducted to optimize the level of different flours in the blend along with level of sugar for manufacture of multigrain *Ladoo*.

Table 1: Sensory evaluation of *Multigrain Ladoo* made by microwave and open pan roasting methods

Attributes (9 point hedonic scale)	Roasting methods		SEM	CD (0.05)	CV%
	Microwave	*Open pan*			
Colour & Appearance	7.65±0.38	8.14±0.11	0.11	0.33	3.54
Body & Texture	7.76±0.27	8.25±0.17	0.09	0.26	2.83
Flavour	6.8±0.44	8.29±0.26	0.14	0.42	4.75
Sweetness	8.0±0.16	8.2±0.18	0.07	NS	2.13
Overall Acceptability	6.62±0.44	8.32±0.20	0.13	0.40	4.58

Optimization of level of flour (Finger millet, Pearl millet and Chickpea) and Sugar

Multi grain *Ladoo* were prepared employing three types of grains *viz*. Pearl millet, Chick pea and Finger millet. For manufacture of milk base multigrain *Ladoo* three variable were selected *viz* : level of finger millet flour addition (10-20 per cent), rate of pearl millet flour (40-60 per cent), and sugar addition (60-100 per cent w/w of flour). Chick pea flour was added by difference to make the total flour quantity 100 (Table 2). Khoa and ghee were kept constant i.e. sixty per cent of the weight of flour (Figure 1).

Influence of proportion of Ragi, Pearl millet and Chickpea flours and sugar levels on sensory scores of Multigrain *Ladoo*

The sensory parameters chosen to assess the quality of multigrain *Ladoo* were colour and appearance, body and texture, flavour, sweetness and overall acceptability score. The sensory score of multigrain *Ladoo* prepared using different combinations of levels of three types of flour *viz*. Ragi (A), Pearl millet (B) and chickpea (by % flour difference = 100 – ragi - pearl millet) and sugar levels (C, added on total flour basis w/w) as determined by an advanced statistical software programme named RSM Design Expert 13.0.1.0 was employed. In similar manner the hardness value and protein content of multigrain *Ladoo* prepared using different combinations of levels of three types of flour *viz*. Ragi (A), Pearl millet (B) and chickpea (by difference) and sugar levels (C) as determined by RSM Design Expert 13.0.1.0 along with formulations as per their run order is shown in Table 2. The scores of colour and appearance, body and texture, flavour, sweetness and overall acceptability score as well as Hardness and protein content values were well fitted in quadratic model. Regression analysis resulted in quadratic models for each parameter, with coefficients of determination (R^2) 0.804, 0.861, 0.885, 0.900, 0.844, 0.984 and 0.858 for colour and appearance, body and texture, flavour, sweetness, overall acceptability, hardness and protein content respectively, indicating approximately 80 to 98% of the variability, accompanied by a highly significant model F-value of responses from 4.56, 6.93, 8.52, 10.04, 6.02, 68.94 and 6.71 respectively, showing good model fit for predicting consistent optimization levels of variables (Table 3). Similarly an adequate precision (APV) of responses varying from 7.67, 9.40, 11.08, 10.04, 8.17, 27.64 and 9.64 respectively, which are well above the critical value of 4 (Table 3) confirming a robust predictive ability of the model

Table 2: Experimental design matrix for sensory scores (on 9 point hedonic scale), Hardness (N) and Protein (%) content of Multigrain *Ladoo*

Run	A: Ragi (%)	B: Pearl Millet (%)	C: Sugar (% by wt. of flour)	Colour & App.	Body & Texture	Flavour score	Sweetness	Overall Acceptability	Hardness	Protein
1	15.00	50.00	80.00	8.17	8.25	8.17	8.08	8.33	32.2	7.15
2	15.00	30.00	80.00	7.94	8.17	7.80	7.65	7.83	34.0	9.56
3	15.00	50.00	80.00	8.42	8.33	8.17	8.33	8.25	31.8	7.05
4	15.00	50.00	80.00	8.42	8.33	8.17	8.33	8.17	31.6	7.18
5	15.00	50.00	80.00	8.42	8.33	8.17	8.33	8.25	32.0	7.00
6	10.00	60.00	60.00	8.08	7.83	7.75	7.25	7.25	30.5	7.16
7	15.00	50.00	80.00	8.42	8.33	8.17	8.33	7.83	32.5	7.50
8	20.00	60.00	100.00	7.67	7.83	7.75	6.84	7.46	25.4	6.95
9	25.00	50.00	80.00	7.67	7.5	6.86	6.75	6.70	26.5	6.85
10	15.00	50.00	80.00	8.17	8.33	8.17	8.25	8.33	31.9	7.20
11	15.00	50.00	40.00	8.18	8.08	7.92	6.83	7.50	32.5	7.48
12	20.00	60.00	60.00	7.67	7.83	7.75	7.42	7.46	26.1	6.76
13	10.00	40.00	60.00	7.77	7.83	7.75	7.25	7.25	33.0	8.40
14	10.00	60.00	100.00	8.32	8.17	8.17	8.08	7.83	31.4	7.80
15	10.00	40.00	100.00	8.08	8.17	8.46	7.83	8.00	33.2	8.24
16	20.00	40.00	100.00	8.08	7.53	6.87	7.16	6.67	34.0	7.05
17	15.00	50.00	120.00	8.5	8.5	8.17	7.83	8.25	32.0	7.43
18	20.00	40.00	60.00	7.67	7.83	7.3	7.42	7.46	33.8	7.15
19	15.00	70.00	80.00	8.08	7.92	8.17	7.67	7.92	22.3	6.60
20	5.00	50.00	80.00	8.19	7.42	8.25	7.58	7.17	32.9	7.90

Effect on Colour & Appearance Scores: The colour and appearance scores of multi grain laddu, ranged from 7.67 to 8.42 (Table 2). The formulation with 15.0% ragi flour, 50.0% pearl millet flour and 80.0% sucrose received the highest score, while the one with 20.0% ragi flour, 60.0% pearl millet flour and 60.0% sucrose scored the lowest. The colour and appearance of the product were negatively influenced by ragi flour (A) (p<0.05) at linear level and it had a non-significant positive influence by pearl millet flour (B) and sucrose (C). The interactive effect of ragi flour and pearl millet flour (AB) had significantly negative impact, while ragi flour and sucrose (AC) had non-significant

positive and pearl millet flour and sucrose had non-significant negative impact on this response. At quadratic level, ragi flour (A^2) and sugar (C^2) had non-significant negative impact and pearl millet flour (B^2) had significant negative impact on colour and appearance score. Similar effect was found in following studies. Ashwini and Anil (2024) [21] reported the opposite trend of decreasing colour and appearance score when ragi flour was increased in the blend.

Effect on Body and Texture scores: The body and texture scores of MGL *Ladoo* ranged from 7.5 to 8.33 (Table 2). The formulation with 15.0% ragi flour, 50.0% pearl millet flour and 80.0% sucrose received the highest score, while the formulation with 25.0% ragi flour, 50.0% pearl millet flour and 80.0% sucrose scored the lowest. The body and texture score of the product were negatively influenced by ragi flour (A) and pearl millet flour, however, sugar had non-significant ($p<0.05$) positive effect. In the interactive effect of ragi flour and sugar (AC) was negatively affected, however, ragi and pearl millet (AB); pearl millet and sugar (BC) had non-significant positive effect on body and texture. It signifies the impact of ragi flour being more hygroscopic of all the flours in study. At quadratic level, ragi flour (A^2) and pearl millet flour (B^2) had a significant negative impact on body and texture score, while sugar (C2) had non-significant ($p<0.05$) negative impact. The results found in the present study is well correlated with the reports of Swati *et al.* (2020) who prepared *Pinni* with varying proportions of kidney beans.

Table 3: Partial co-efficient of regression equations of suggested model for sensory scores (on 9 point hedonic scale), Hardness (N) and Protein content (%) of Multigrain *Ladoo*

Terms	Colour & App	Body & Texture	Flavour	Sweetness	Overall Accep	Hardness (N)	Protein (%)
Intercept	8.24	8.29	8.12	8.22	8.13	32.07	7.16
A: Ragi	-0.187*	-0.053	-0.292*	-0.196*	-0.132	-1.350*	-0.3618*
B: Pearl Millet	0.047	-0.011	0.114#	-0.007	0.050	-2.750*	-0.5056*
C: Sugar	0.079	0.074	0.072	0.092	0.127	-0.025	0.029
AB	-0.162#	0.041	0.207#	-0.082	0.120	-1.500*	0.148
AC	0.025	-0.126	-0.200#	-0.292*	-0.26#	-0.200	-0.048
BC	-0.102	0.041	0.022	-0.020	0.077	-0.025	0.136
A^2	-0.077	-0.228*	-0.139*	-0.292*	-0.336*	-0.539*	0.041
B^2	-0.086#	-0.082#	-0.069	-0.180	0.107*	-0.926*	0.217#
C^2	-0.004	-0.021	-0.054	-0.200	0.107*	0.099	0.061
R^2	0.804	0.861	0.885	0.900	0.844	0.984	0.858
Model F-value	4.56	6.93	8.52	10.4	6.02	68.94	6.71
Adeq Precision	7.67	9.40	11.08	10.4	8.17	27.64	9.64
Suggested Model	QUADRATIC						
Significant *At 1% level of significance, Significant #At 5% level of significance							

Effect on Flavour score: The flavour score of the product, which is an important attribute in sensory evaluation ranged from 6.86 to 8.46. The lowest score was obtained for the formulation having ragi flour 25 %, pearl millet 50% and sugar 80 % of the flour weight. The formulation having 10 % ragi flour, 40 % pearl millet flour and 100 % sugar on the basis of total flour weight, received the highest score. As ragi flour is known to have earthy and slightly bitter taste and have sandy or gritty texture that could have affected the flavour score at higher proportion of ragi flour in the blend. At linear level the flavour score of the product were significantly negatively influenced by ragi flour (A), however, pearl millet flour had significant ($p<0.05$) positive impact and sugar had non-significant ($p<0.05$) positive effect. At interaction level, ragi and sugar (AC) had significant negative influence on flavour, while ragi and pearl millet had significant positive impact; pearl millet and sugar had non-significant positive impact on flavour. At quadratic term ragi had significant ($p<0.05$) negative impact while pearl millet and sugar both had non-significant negative impact on flavour score. A similar decreasing trend in flavour score is reported by Swati *et al.* (2020) for a different product (*Pinni*) when the content of Kidney Beans increased in the blend.

Effect on Sweetness score: The sweetness score of the multi grain *Ladoo* ranged from 6.75 to 8.33. The lowest score obtained for the formulation having ragi 25.0%, pearl millet 50% and sugar 80%. The highest score was recorded for the formulation having 15.0% ragi, 50.0% pearl millet, 35.0% chickpea flour (Chickpea = 100 – ragi - pearl millet) and 80.0% sugar. At linear level ragi flour had significantly ($p<0.05$) negative influence while pearl millet had non-significant negative and sugar had positive effect on sweetness. Interaction of variables *viz*. ragi (A), pearl millet (B) and sugar (C) had negative effect on sweetness score. Ragi and sugar (AC) resulted in significantly ($p<0.05$) negative influence and other two (AB & BC) remained non-significantly ($p<0.05$) negative. Similarly at quadratic level ragi flour depicted significantly negative influence and pearl millet and sugar had non-significant negative impact on sweetness.

Effect on Overall Acceptability score: The scores for overall acceptability parameter ranged from lowest 6.67 (Formulation: 20% ragi: 40% pearl millet:100% sugar) to highest 8.33 (formulation: 15% ragi:50% pearl millet:80% sugar). At linear level ragi had negative while pearl millet and sugar had positive impact on overall acceptability of multigrain *Ladoo* Interaction effect of variables showed significantly ($p<0.05$) negative influence for ragi and sugar (AC) while ragi and pearl millet (AB); pearl millet and sugar (BC) resulted in non-significant positive effect. At quadratic level ragi flour depicted significantly negative influence, however, pearl millet and sugar had significant positive impact on overall acceptability of multi grain *Ladoo*. The effects of variables on overall acceptability response are presented in Figure 2. It can be seen from the figure that ragi and sugar level had dipped the liking for the

product and pearl millet and sugar levels have positive effect.

Effect on instrumental Hardness: Instrumental hardness varied from 22.3N (Formulations containing 15% ragi, 70% pearl millet, 15% chickpea and 80% sugar, formulations containing lowest amount of chickpea flour) to 34.0 N (Formulations containing 15% ragi, 30% pearl millet, 55% chickpea flour and 80% sugar, formulation containing highest amount of chickpea flour). This was obvious as chickpea flour contains more than the double amount of protein compared to other two flours in the study. At linear level, ragi and pearl millet showed significantly negative impact on hardness while sugar showed non-significant negative impact. Interaction of pearl millet and ragi flour (AB) depicted significant negative, however, ragi and sugar (AC) and pearl millet and sugar (BC) had non-significant negative impact on instrumental hardness. At quadratic level ragi and pearl millet flour had significantly ($p<0.05$) negative impact while sugar had non-significant positive effect on hardness.

Effect on Protein content (%): The protein content of multigrain *Ladoo* varied from 6.60 % (being lowest and having formulations of ragi 15%, 70% pearl millet, 15% chickpea and 80% sugar) to highest protein content of 9.56 % in formulations containing 15% ragi, 30% pearl millet, 55% chickpea and 80% sugar). This was obvious as proportion of chickpea flour increased in the blend of multigrain *Ladoo*. At linear level, ragi and pearl millet flour showed significantly ($p<0.05$) negative impact on protein content. Interaction effect resulted in non-significant effect and ragi and sugar (AC) showed negative, while ragi and pearl millet (AB) and pearl millet and sugar (BC) was positive on protein content. At quadratic level only pearl millet depicted significantly positive effect, while ragi and sugar had non-significant positive effect. The protein content observed in present study was in line with the data reported by Yuvarani and Anitha (2016) [12] for multigrain *Ladoo* containing different proportions of finger and foxtail mill*et al.*ong with wheat flour (50 g each) and sprouted green and horse gram (25 g each), jiggery (150 g) and ghee (30 g).

Table 4: The multiple regression equation generated to predict the sensory scores, hardness and protein (%) as affected by ragi flour (A) pearl millet flour (B) & sucrose (C)

Property	Equation
Colour & Appearence	8.24-0.19A+ 0.047B+0.079C-0.16AB+0.025AC-0.10BC-0.078A^2-0.086B^2-3.977E-003C^2
Body & Texture	8.29-0.053A-0.011B+0.074C+0.041AB-0.13AC+0.041BC-0.23A2-0.082B2-0.021C^2
Flavour	8.12-0.29*A+0.11* B+0.072* C+0.21* AB-0.20* AC+0.023* BC-0.14* A^2-0.070* B^2-0.055* C^2
Sweetness	8.22-0.20*A-7.500E-003* B+0.092* C-0.082* AB-0.29* AC-0.020* BC-0.29* A^2-0.18* B^2-0.20* C^2
Overall Acceptability	8.14-0.13*A+0.050* B+0.13* C+0.12* AB-0.26* AC+0.078* BC-0.34* A^2-0.11* B^2-0.11* C^2
Hardness (N)	32.07-1.35*A-2.75* B-0.025* C-1.50* AB-0.20* AC-0.025* BC-0.54* A^2-0.93* B^2+0.099* C^2
Protein (%)	7.16-0.36*A-0.51* B+0.029* C+0.15* AB+0.049* AC+0.14* BC-0.041* A^2-0.22* B^2+0.061* C^2

The data were analysed in Design Expert Package 13.0.1.0. Considering the parameters and their limits, the RSM suggested the one most suited solution for multigrain *Ladoo* was 15% ragi, 54.76% pearl millet, (30.24% chickpea flour) on weight by weight basis and 80% sugar by weight of flour with desirability of 0.896. The level of importance of flavour and overall acceptability scores were kept higher during optimization as these characteristics are having higher importance in the development of traditional products in terms of sensory values.

The predicted and actual response values (obtained after making the product using the optimum level of ingredients have been presented in Table 5. Comparison of actual and predicted values, based on response surface modeling solution, using paired T-test suggests non-significant difference between them suggesting a robust and definite predictivity of the model. Hence it was concluded that the given solution for standardized recipe to manufacture Multigrain *Ladoo* (MGL) is adequate.

Table 6: Comparison of predicted v/s actual values of responses used for optimization of flour and sugar levels for multigrain *Ladoo*

Response	P Value	Predicted Value *	Actual Value @	Cal. t-Value#	Significance
Colour and Appearance (Out of 9)	0.2128	8.24	8.28	1.3939	NS
Body & texture (Out of 9)	0.1676	8.26	8.29	1.5694	NS
Flavour (Out of 45)	0.0528	8.16	8.24	2.4069	NS
Sweetness (Out of 9)	0.0767	8.18	8.24	2.1350	NS
Overall acceptability (Out of 9)	0.0599	8.14	8.18	2.3147	NS
Hardness (N)	0.0676	30.55	29.62	2.2262	NS
Protein (%)	0.2769	27.67	27.30	1.1957	NS

*Predicted values of Design Expert 8.0.3 package
@ Actual values are average of seven trials for optimized product
# t-values found non-significant at 5 per cent level of significance
NS = Non Significant; Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

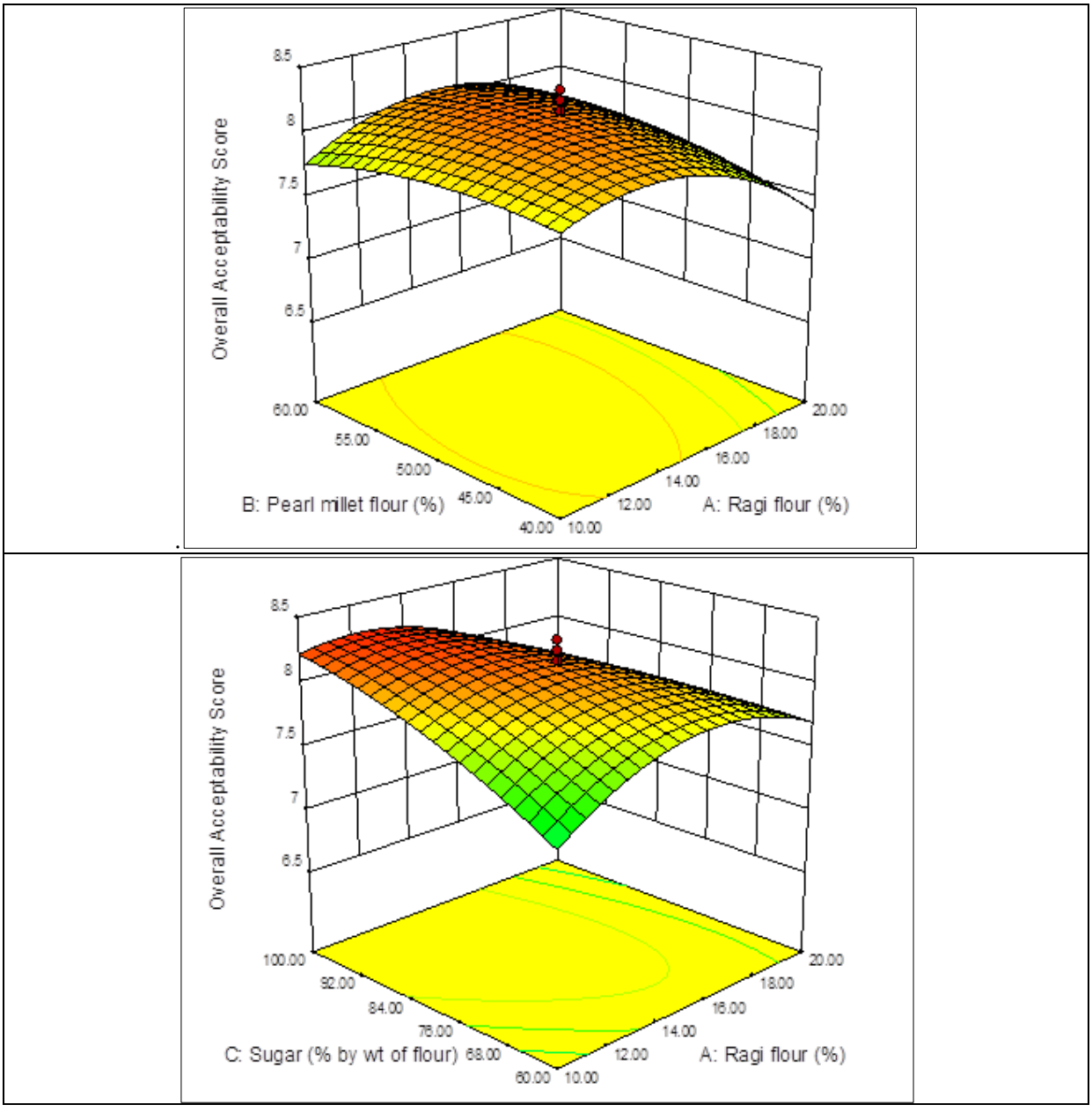
The developed multigrain *Ladoo* was analyzed for its proximate composition along with its physico-chemical and sensory properties. The obtained data is presented in Table 6. It could be observed from the data that moisture content was sufficiently controlled below 5.00 % and water activity to less than 0.360 signifying better shelf life of the product.

Table 6: Proximate composition, physico-chemical and sensory analysis of developed multigrain gluten free *Ladoo*.

Composition	
Moisture (%)	4.64±0.06
Fat (%)	30.51±0.10
Protein (%)	7.08±0.07
Ash (%)	2.16±0.05
Total Carbohydrate (%)	55.60±0.16
Physico-chemical properties	
Free Fatty Acids **(µ eq/g)**	0.065±0.01
Water activity (a_w)	0.358±0.02
Hardness (N)	30.77±0.27
Sensory Scores	
Colour and Appearence	7.68±0.18
Flavour	8.36±0.13
Body and Texture	8.62±0.16
Sweetness	8.20±0.04
Overall Acceptability	8.21±0.05

Each observation is mean ± SD of Five replications.

The developed multigrain *Ladoo* was also analysed for gluten (03.014) content and crude fiber (03.018) content (FSSAI, 2023). It was found that the developed product was gluten free since the analysis result for the multigrain flour was not having any gluten. Crude fiber content of the multigrain *Ladoo* was 3.43±0.21. The calculated calorific values of multigrain *Ladoo* obtained 527.7 kcal/ respectively.



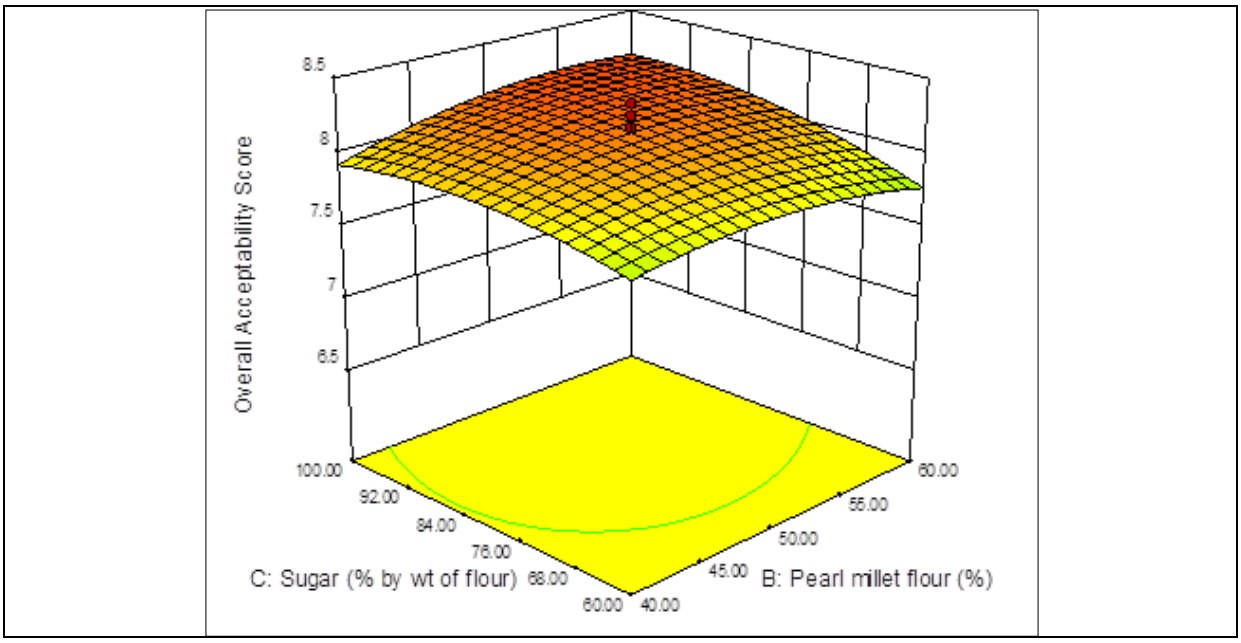


Fig 2: Influence of rate of pearl millet flour (B) (%, w/w), ragi flour (A) and sugar (C) (%, w/w of flour) addition on overall acceptability score (out of 9)

Conclusion

Open pan roasting method resulted into khoa based multigrain *Ladoo* having better sensory scores in terms of colour and appearance, body and texture, flavour as well as overall acceptability. The level of multigrain flour was optimized to Ragi flour 15%, Pearl millet flour 54.76% and 30.24% Chickpea flour. Sugar level was optimized at 80.00% of the flour weight. Khoa was added at fixed rate at 60.00% of the flour weight. Cardamom and Nutmeg was added as flavouring spice @ 0.2%. As envisaged the developed product did not have any gluten content and crude fiber content was approximately 3.43%. The developed product has excellent sensory properties and acceptability score was more than 8.00.

References

1. AOAC International. Official methods of analysis. 17th ed. Gaithersburg, MD (USA): Association of Official Analytical Chemists; 2000. Methods 925.10, 65.17, 974.24, 992.16.
2. Ashwini N, Anil B. Development and evaluation of nutrient-rich mixed seed laddu. Int J Curr Sci Res Rev. 2024;7(8):6405–6411. doi:10.47191/ijcsrr/V7-i8-53
3. Food Safety and Standards Authority of India (FSSAI). Manual of methods of analysis of foods: Cereal and cereal products. New Delhi: Ministry of Health and Family Welfare, Government of India; 2023.
4. Kaur S, Singh N, Sodhi NS, Rana JC. Diversity in properties of seed and flour of kidney bean germplasm. Food Chem. 2009;117(2):282–289. doi:10.1016/j.foodchem.2009.04.002
5. Khan RA, Adsul DS, Shekhar A. Multinutrient laddu. Int J Food Nutr Sci. 2019;8(1):4–9.
6. Sharma L, Goyal K. To study the organoleptic properties of ladoos made from variations of flax seeds and multigrain flour. Int J Food Sci Nutr. 2017;2(2):23–26. Available from: https://www.researchgate.net/publication/330847351
7. Meilgaard MC, Carr BT, Civille GV. Sensory evaluation techniques. 4th ed. Boca Raton (FL): CRC Press; 1999. doi:10.1201/9781003040729
8. Naidu BG, Shirke KJ, Shekhar A. A study of a galactogogue and protein-rich multigrain ladoo. Int J Food Nutr Sci. 2013;2(2):91–94.
9. Gatti S, Rubio-Tapia A, Makharia G, Catassi C. Patient and community health global burden in a world with more celiac disease. Gastroenterology. 2024;167(1):23–33. doi:10.1053/j.gastro.2024.01.035
10. Singh S, Paul V. Sensory evaluation of value-added laddu prepared from multigrain flour and herbal powder. Pharma Innov J. 2023;12(5):2540–2543.
11. Kimothi S, Dhaliwal YS, Modgil R. Nutritional and organoleptic evaluation of pinni prepared from different varieties of kidney bean flour of Himachal Pradesh. Asian J Sci Technol. 2020;11(11):11368–11375. Available from: https://www.researchgate.net/publication/361648896
12. Uvarani S, Anitha V. A study on the consumer acceptance, nutritive value and antioxidant activity of multigrain ladoo. Int J Home Sci. 2016;2(3):227–232.