



Gluten-Free *Laddoo* of Raw and Popped Amaranth Grains with Attractive Sensory and Nutritional Qualities

Akanksha Singh^{1,*}, Shashank Singh²

¹Department of Food Science and Nutrition, College of Home Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

²Kamla Nehru Institute of Physical and Social Sciences, Sultanpur, India

Email address:

akanksha513510@gmail.com (A. Singh)

*Corresponding author

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Abstract: *Background:* Gluten-free bakery foodstuffs are a challenge for technologists and nutritionists since alternative ingredients used in their formulations have poor functional and nutritional properties. *Objective:* To prepare gluten-free *Laddoo* using raw and popped amaranth, a grain with high quality nutrients and promising good sensory qualities and formulate the best combinations. *Method:* Amaranth grains were washed, spread over filter paper sheet and dried completely. After drying, the grains were ground in an electric grinder to fine powder and supplemented at 50 and 100 per cent level in the preparation of *Laddoos*. The *Laddoos* prepared by using Bengal gram flour served as control. *Result:* The best formulation for *Laddoo* included 100% popped amaranth grains and 30–40% raw amaranth flour which produced good sensory quality and higher in nutrients like protein and minerals than with control *laddoo*. The best *Laddoo* recipe had 20% of raw amaranth flour and 100% of whole-grain popped amaranth. The results of the study indicated that with the increase in incorporation level of amaranth flour in *Laddoo* the amount of total dietary fibre, insoluble and soluble dietary fibre increased significantly. *Conclusion:* This study concluded that content of macro-nutrients of the amaranth based products has advantages over the conventional gluten-free ones, offering real gluten-free foodstuffs.

Keywords: Amaranth, Gluten-free, Nutrients, *Laddoo*, Sensory

1. Introduction

Celiac disease (CD) is an inflammatory disease of the small intestine triggered by gluten proteins from wheat, barley and rye. Its prevalence is 1:100–1:200 in any population over the world [21] and CD patients must adhere to a lifelong gluten-free diet. Therefore, gluten-free products commercialization has grown at an annual rate of 28% in the last years [12]. Gluten-free breads and cookies are principally based on flour from rice or maize with low content and poor-quality proteins plus additives to improve their viscoelastic properties for baking.

Frequently CD patients, especially children in a strict gluten-free diet, are undernourished because of the reduced intake of energy which is largely taken from wheat-based foodstuffs in a current western diet [28]. Additionally, they suffer from calcium and other minerals deficiency because of

the previous malabsorption in active CD, as well as the actual low content of micronutrients into the alternative flours used in gluten-free formulations [1]. Therefore, it is very important to develop gluten-free food stuffs with high nutritional quality ingredients. The best good news is that amaranth is not taxonomically related to wheat, it is a naturally gluten-free source for formulations directed to CD patients [14].

Amaranthus belonging to the family *Amaranthaceae*, comprises a series of wild, weedy and cultivated species and found worldwide in almost all agricultural environments. Amaranthus species have different centers of domestication and origin, being widely distributed in North America, Central America, and the South American Andes, where the greatest genetic diversity is found [25]. Among all the species, *Amaranthus caudatus*, *Amaranthus hypochondriacus* and *Amaranthus cruentus* are mainly cultivated for their seeds [7] and are considered as pseudocereals, with a high seed protein

content and a high lysine content [4, 13]. These *Amaranthus* species are cultivated in different regions of South and Central America, India, and Nepal [27, 22]. In India, *Amaranthus* is chiefly grown in Himalayas from Kashmir to Bhutan and some extent in the states of Gujarat, Maharashtra, Karnataka and eastern parts of Uttar Pradesh and used as an important ingredient in food [8, 9].

The amaranth grains can be toasted, popped, extruded or milled into flour and can therefore be consumed as such or included in other cereal products such as bread, cakes, muffins, pancakes, cookies, dumplings, noodles and crackers.[24]. The optimal nutritive composition of this seed has made its use attractive as a blending food source to improve the nutritional value of some cereal by-products. In Mexico, the popped amaranth confection, 'alegria' is a popular favorite among locals and tourists [15]. The flour or flaked forms are combined with wheat or other flours to make bread, cookies and other baked goods. Amaranth is used to make up only 10-20% of the flour blend, but it can be blended at 50-75% levels and still maintain functional properties and flavour [28]. Coarsely ground amaranth is used to make a tasty and nutritious porridge cooked by itself or mixed with other grains and pseudo cereals such as oats, wheat, milled flax seed. Thus, in this study, preparation of Gluten-Free *Laddoo* by using raw and popped Amaranth grains and their Sensory and Nutritional Qualities evaluation.

2. Materials and Method

2.1. Method for Preparation of Laddoo

Amaranth grains were procured in a single lot from the Medicinal Aromatic and Underutilized Plants Section, Department of Genetics and Plant Breeding, College of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Commercially available whole wheat flour and other ingredients used in *Laddoo* making was purchased from the local supermarket. All the chemicals used in this study are of analytical grade.

For cleaning, amaranth grains were washed, Sun dried for one day and manually cleaned to remove stones, grit, chaff

and other impurities (Figure 1). After drying the grains were oven dried at 60°C for 3 hours. The oven dried grains were then milled in milling machine (Atta master). Number 2 sieve (give slightly coarser flour) was used to obtain flour for *Laddoo* development. The flour made was then sieved out manually and some amount of fiber was lost in the sieved-out material, there after the prepared sample was packed in air tight containers and stored at room temperature until used in *Laddoo* preparation.

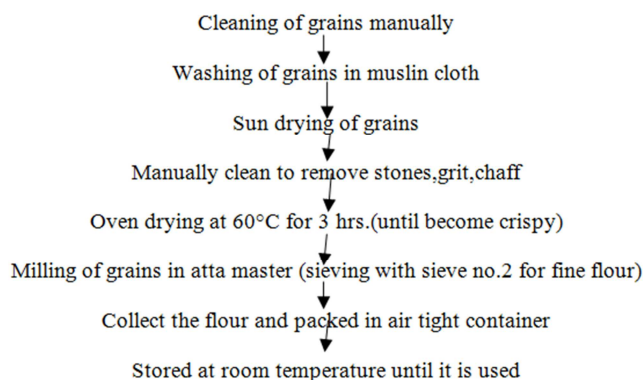


Figure 1. Flow diagram for preparation of amaranth flour.

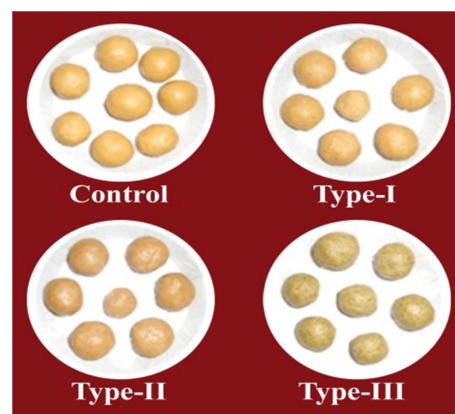


Figure 2. Amaranth flour laddoo.

Table 1. The proportion of ingredients used for preparation of *Laddoo*.

S. No.	Ingredients	Control	Type - I	Type --II	Type - III
1.	Wheat flour (g)	50	40	35	30
2.	Bemgal gram flour (g)	50	40	35	30
3.	Amaranth flour (g)	0	20	30	40
4.	Ground sugar (g)	40	40	40	40
5.	Ghee (g)	50	50	50	50

2.1.1. Amaranth Seed Flour Laddoo

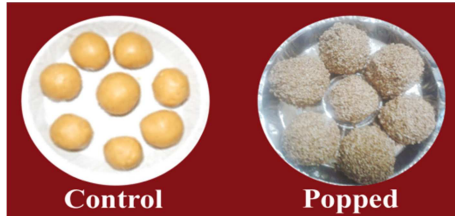
Amaranth flour, wheat flour and Bengal gram flour were sieved separately. The flours were roasted separately till light brown. Roasted flours were mixed together and fried in ghee for 2-3 minutes. Removed from fire and allowed to cool. Ground sugar was added and mixed well. *Laddoo* were made of even size (Figure 2).

2.1.2. Popped Amaranth Laddoo

Amaranth grains were popped. Water was brought to boil in the vessel and jaggery was added and mixed by stirring. Jaggery syrup of two thread consistency was made. When the solution thickened after boiling, popped amaranth were mixed in the jaggery syrup (Figure 3).

Table 2. The proportion of ingredients used for preparation of Popped Laddoo.

S. No.	Ingredients	Amount
1	Popped amaranth (g)	100
2	Jaggery (g)	150
3	Water (ml)	100

**Figure 3.** Popped Amaranth Laddoo.

2.2. Sensory Evaluation of Developed Laddoo

All types of *Laddoo* with their controls were organoleptically evaluated by a panel of ten semi-trained judges from I. C College of Home Science, CCS Haryana Agricultural University employing 9-Point Hedonic Scale [2]. Averages of scores for all sensory characteristics, viz., colour, appearance, flavour, texture, taste were expressed in terms of overall acceptability.

2.3. Nutritional Characteristics of Value Added Laddoo

All three types of *Laddoos* along with control *chapatti*, were oven dried to a constant weight at 60°C, ground to a fine powder in an electrical grinder and analyzed for various nutrients. Proximate composition including moisture, protein, fat, ash and crude fibre was determined by standard methods

[3]. Total, soluble and insoluble dietary fibre constituents were determined by the enzymatic method [11]. Total minerals were determined [17].

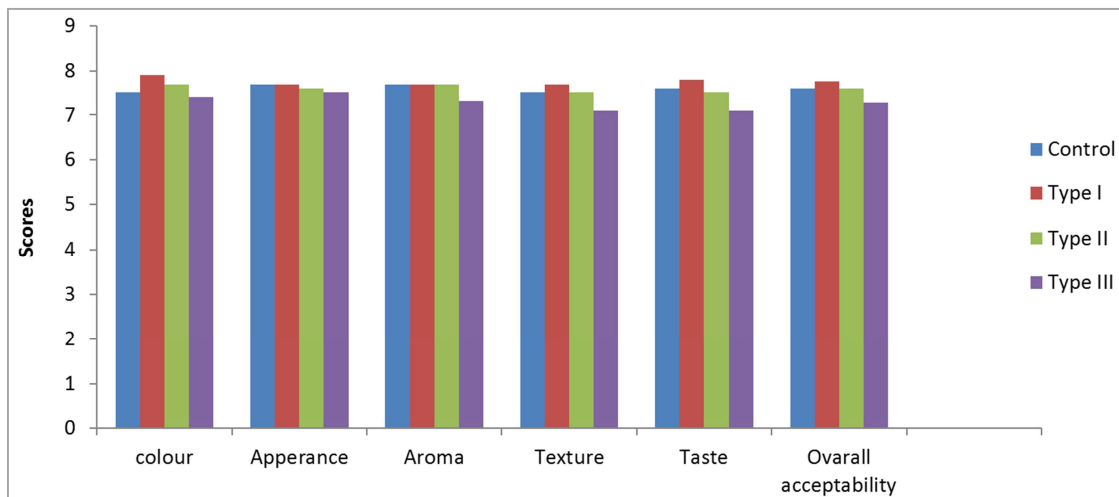
2.4. Statistical Analysis

The data were statistically analysed in complete randomized design for analysis of variance, mean, standards deviation and critical difference according to the standard method [23].

3. Results

3.1. Sensory Characteristics of Developed Amaranth Flour Laddoo

In the figure 4 showed that sensory scores of *Laddoo* prepared without the use of amaranth flour (control) were 7.50, 7.70, 7.70, 7.50, 7.60 and 7.60 for colour, appearance, aroma, texture, taste, and overall acceptability, respectively, which were in the category of 'liked very much'. The scores for sensory characteristics like colour, appearance, aroma, texture, taste, and overall acceptability of *Laddoo* prepared from 20% amaranth flour (Type-I) were 7.90, 7.70, 7.70, 7.70, 7.80 and 7.76, respectively. In Type II *Laddoo* the scores for colour and aroma, appearance and overall acceptability, texture and taste were similar i.e 7.70, 7.60 and 7.50, respectively. Type I and Type II *Laddoo* were 'liked very much' by the panel of judges. The scores of sensory characteristics of Type-III *Laddoo* prepared from 40% amaranth flour showed that they fell in the category of 'liked moderately'.

**Figure 4.** Mean scores of sensory characteristics of Laddoo.

3.2. Sensory Characteristics of Developed Popped Amaranth Laddoo

Figure 5 indicated that control *Laddoo* and popped *Laddoo* were organoleptically acceptable in terms of all the sensory characteristics and fell in the category of 'liked very much'. In control *Laddoo* the mean scores of sensory characteristics

for appearance and aroma were same i.e. 7.70 for taste and overall acceptability were 7.60 and for colour and texture were 7.50. The scores of sensory characteristics i.e. colour, appearance, aroma, texture, taste and overall acceptability were 7.70, 7.60, 7.50, 7.50, 7.50 and 7.86 respectively, in popped *Laddoo*. It was observed that sensory scores of control as well as popped *Laddoo* fell in the category of

‘liked very much’.

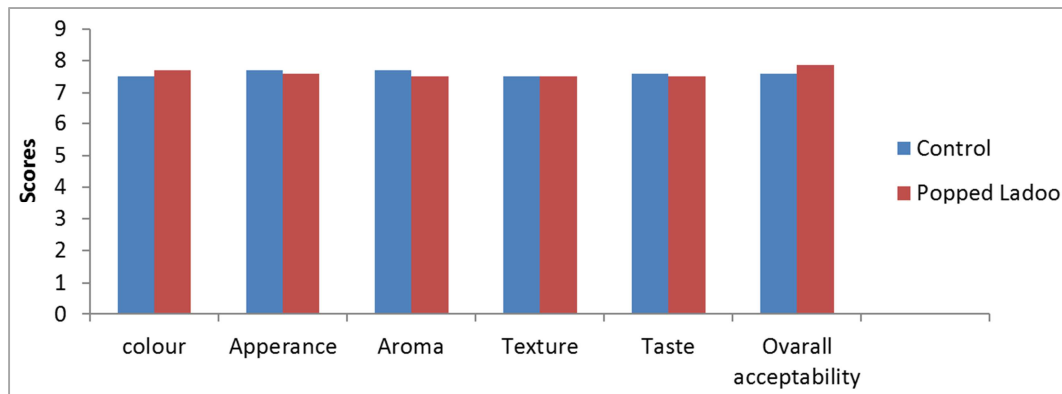


Figure 5. Mean scores of sensory characteristics of Popped Laddoo.

3.3. Nutritional Evaluation of Developed Value Added Amaranth Flour Laddoo

3.3.1. Proximate Composition

The moisture content of Type I, Type II and Type III as well as control Laddoo was almost similar i.e. 2.00, 1.92, 1.80 and 1.90, respectively. The protein content in control Laddoo was 17.76 per cent which significantly decreased to 16.86%, 14.30% and 13.20% in Type I, Type II and Type III Laddoo, respectively. This difference might be attributed

to less amount of protein in amaranth as compared to bengal gram flour. The fat content of control Laddoo was 27.50% whereas the fat content of Laddoo incorporated with 20%, 30% and 40% amaranth flour was 31.46, 32.80 and 35.46%. The crude fibre contents in control Laddoo was 1.30% which significantly increased to 2.13, 2.86 and 3.96% in Type I, Type II and Type III Laddoo, respectively. The control Laddoo contained 2.07% ash whereas Type-I Laddoo contained 2.27%, Type-II Laddoo 2.48% and Type-III Laddoo 2.78% (table 3).

Table 3. Proximate composition of Laddoo (% dry weight basis).

Types of Laddoo	Moisture	Crude protein	Fat	Crude fibre	Ash
Control (WF:BGF::50:50)	1.90±0.31	17.76±0.36	27.50±0.17	1.30±0.11	2.07±0.07
Type I (WF:BGF: AF::40:40:20)	2.00±0.18	16.86±0.17	31.46±0.17	2.13±0.08	2.27±0.06
Type II (WF:BGF: AF::35:35:30)	1.92±0.13	14.30±0.05	32.80±0.11	2.86±0.08	2.48±0.05
Type III (WF:BGF: AF::30:30:40)	1.80±0.86	13.20±0.05	35.46±0.17	3.96±0.08	2.78±0.04
CD (P=0.05)	0.75	0.66	0.50	0.35	0.17

Values are mean±SE of three independent determinations

WF=Wheat Flour BGF=Bengal Gram Flour

3.3.2. Dietary Fibre

Total dietary fibre content of control Laddoo was 12.56% and that of Type I, II and III Laddoo were 19.45, 24.41 and 26.86%, respectively. The total dietary fibre content of all three types of Laddoos differed significantly from each other as well as from control Laddoo. Similar trend was observed in insoluble and soluble dietary fibre content of control and amaranth flour incorporated Laddoo. With the increase of

incorporation level of amaranth flour in Laddoo, the amount of total dietary fibre, insoluble and soluble dietary fibre increased significantly. The insoluble and soluble dietary fibre contents of control Laddoo were 8.79% and 3.76%, respectively, which increased to 15.03% and 11.83%, respectively, with the incorporation of 40% amaranth flour (table 4).

Table 4. Dietary fibre content of Laddoo (% dry weight basis).

Product	Dietary fibre		
Types of Laddoo	Total dietary fibre	Insoluble dietary fibre	Soluble dietary fibre
Control (WF:BGF::50:50)	12.56±0.16	8.79±0.02	3.76±0.14
Type I (WF:BGF: AF::40:40:20)	19.45±0.63	13.58±0.54	5.86±0.12
Type II (WF:BGF: AF::35:35:30)	24.41±0.15	14.61±0.01	9.80±0.17
Type III (WF:BGF: AF::30:30:40)	26.86±0.19	15.03±0.00	11.83±0.20
CD (P=0.05)	1.16	0.89	0.54

Values are mean±SE of three independent determinations

WF=Wheat Flour BGF=Bengal Gram Flour AF=Amaranth Flour

3.3.3. Total and Available Minerals

The results on mineral content of *Laddoo* are presented in Table 5. Total calcium content of control *Laddoo* was 157.79 mg/100g and that of Type-I, II, and Type-III *Laddoo* were 189.10, 203.47 and 217.48 mg/100g, respectively. The zinc content of control *Laddoo* was 2.43mg/100g. A significant increase in zinc content to 2.85, 3.04 and 3.18 mg/100g in Type I, Type II and Type III *Laddoo* was observed, respectively, after incorporation of amaranth flour to wheat flour and bengal gram flour *Laddoo*.

The iron content of control *Laddoo* was 7.75 mg/100g

which increased to 7.95mg/100g after 20% incorporation of amaranth flour, to 8.20mg/100 after 30% incorporation and 9.64 mg/100g after 40% incorporation of amaranth flour. All the three types of *Laddoo* differed significantly among themselves as well as from control *Laddoo* for their iron content. The potassium content of wheat flour and bengal gram flour *Laddoo* (control) was 356.08 mg/100g which subsequently increased to 410.16, 445.33 and 481.00 mg/100g after incorporation of 20%, 30% and 40% amaranth flour, respectively.

Table 5. Total mineral content of *Laddoo* (mg/100g, dry weight basis).

Products	Total minerals			
<i>Laddoo</i>	Calcium	Zinc	Iron	Potassium
Control (WF:BGF::50:50)	157.79±2.67	2.43±0.01	7.75±0.04	356.08±7.33
Type I (WF:BGF: AF::40:40:20)	189.10±1.6	2.85±0.02	7.95±0.01	410.16±4.98
Type II (WF:BGF: AF::35:35:30)	203.47±1.97	3.04±0.02	8.20±0.01	445.33±5.12
Type III (WF:BGF: AF::30:30:40)	217.48±2.73	3.18±0.01	9.64±0.04	481.00±5.55
CD (P=0.05)	7.09	0.04	0.15	18.09

Values are mean±SE of three independent determinations

WF=Wheat Flour AF=Amaranth Flour BGF=Bengal Gram Flour.

Table 6. Available calcium and iron content of *Laddoo* (mg/100g, dry weight basis).

Product	Available mineral	
<i>Laddoo</i>	Available calcium	Available iron
Control (WF:BGF::50:50)	37.64±0.49	1.22±0.11
Type I (WF:BGF: AF::40:40:20)	47.35±0.28	1.28±0.03
Type II (WF:BGF: AF::35:35:30)	49.50±0.57	1.29±0.04
Type III (WF:BGF: AF::30:30:40)	53.39±0.41	1.41±0.02
CD (P=0.05)	1.46	0.16

Values are mean±SE of three independent determinations

WF=Wheat Flour AF=Amaranth Flour BGF=Bengal Gram Flour

Table 7. Nutritional composition of Popped *Laddoo*.

Parameter	Mean±SE
Proximate composition (%)	
Moisture	6.20±0.35
Crude Protein	18.42±0.20
Fat	2.70±0.05
Ash	2.08±0.03
Crude Fibre	5.50±0.15
Dietary fibre (%)	
Total dietary fibre	17.85±0.05
Soluble dietary fibre	8.05±0.05
Insoluble dietary fibre	9.80±0.11
Total minerals (mg/100g)	
Calcium	255.81±1.84
Zinc	5.88±0.01
Iron	14.34±0.08
Potassium	392.83±4.98
Available minerals (mg/100g)	
Calcium	68.56±0.48
Iron	5.28±0.02

Values are mean ± SE of three independent determinations.

3.3.4. Nutritional Evaluation of Developed Amaranth Popped *Laddoo*

The available calcium content in control *Laddoo* was 37.64 mg/100g (Table 6). A significant increase in available calcium content to 47.35, 49.50 and 53.39 mg/100g in Type I, Type II and Type III *Laddoo* was observed, respectively, after incorporation of 20%, 30% and 40% amaranth flour to wheat flour and bengal gram flour. The available iron content of control *Laddoo* was 1.22mg/100g, which increased up to 1.41 mg/100g with incorporation of 40% amaranth flour (Type III). Type I and Type II *Laddoo* contained 1.28 and 1.29 mg/100g of available iron, respectively.

The results on proximate composition of popped *laddoo* are presented in Table 7. Moisture content of popped *Laddoo* was 6.20 per cent. The results revealed that the crude protein, fat, ash and crude fibre were 18.42, 2.70, 2.08 and 5.50%, respectively. Total insoluble and soluble dietary fibre content in popped *Laddoo* were 17.85, 8.05 and 9.80%, respectively. Data on total calcium, zinc, iron and potassium content of popped *Laddoo* are also depicted in Table 7. The values of these minerals were 255.81, 5.88, 14.34 and 392.83 mg/100g respectively. In popped *Laddoo* the available calcium and iron were 68.56 and 5.28 mg/100g, respectively.

4. Discussion

In present study *Laddoo* were prepared by incorporating either popped amaranth grain or amaranth flour at various acceptable levels. On the basis of sensory characteristics, it was observed that *Laddoo* prepared from 20% and 30% amaranth flour were 'liked very much' by the judges whereas *Laddoo* prepared from 40% amaranth flour were 'liked moderately'. *Laddoo* prepared with incorporation level of 20% amaranth seeds and 10% watermelon seeds

scored highest (on nine point Hedonic Scale) with regard to colour and appearance, body and texture, taste and flavour and overall acceptability.

With the addition of amaranth flour at 20, 30 and 40% level to control *Laddoo* the content of crude protein decreased significantly (16.86, 14.30 and 13.20%), respectively which may be ascribed to less amount of protein present in amaranth flour as compared to bengal gram flour. Jain and Grewal (2015) found that value added ready to eat snacks prepared with incorporation of amaranth flour (raw and roasted) contained significantly higher protein, fat, ash and fibre content as compared to control. It was due to higher nutritional composition of amaranth. Jagreuzi *et al.* (2010) reported that amaranth snacks contained higher protein, fat and fibre content than maize snacks. Sudha and Leelavati, (2012) showed that protein content of pasta improved from 9.56 to 16.57% by using 10% amaranth seed flour. The protein content of amaranth products was two to three times higher than those of other products formulated with rice and/or maize flours and other starch sources (Zohu *et al.* 2002). Blending of amaranth grain flours to cereal flours improved the protein quality of the product (Hansen *et al.* 2005). The use of 40% whole amaranth flour in the formulation of bread provided significant higher amounts of dietary fibre, proteins [26] and lipids showing increases of 2.1, 2.0 and 1.1 g/100 g d.m., respectively [20].

The results of the study indicated that with the increase in incorporation level of amaranth flour in various products the amount of total dietary fibre, insoluble and soluble dietary fibre increased significantly. The insoluble and soluble dietary fibre contents of control *Laddoo* were 8.79% and 3.76%, which increased to 15.03% and 11.83%, respectively, with the incorporation of 40% amaranth flour. Substitution of bread wheat flour for whole meal amaranth flour up to a level of 30% significantly improved protein and dietary fibre contents, reaching an increase of 23 and 50% with regard to control sample, respectively [18]. Incorporation of 10% amaranth resulted in an increase of 18 times the amount of dietary fibre compared to the control [16]. Amaranth flour cookies had higher amount of total dietary fibre, followed by wheat flour cookies and raw amaranth flour cookies, respectively [8]. This was due to the higher total dietary fibre content in germinated amaranth flour.

Other minerals like iron, zinc and potassium also increased significantly in all products after incorporation of amaranth flour/grains. Significant improvement in available calcium and available iron content were also observed with the incorporation of amaranth flour/grains. The iron content of amaranth and Montina breads was 45% and 26% higher, respectively, than the iron content in the commercial product [6]. Whole amaranth flour used in bread formulation increased the mineral content, particularly that of iron content in bread samples up to 1.6- (29.94 µg/g) and 2.3- (43.88 µg/g) fold when using 20% and 40% whole amaranth flour, respectively, compared to controls. These results indicate that incorporation of amaranth flour during bread making could be a useful strategy improving their nutritional

value [20]. By substituting the wheat or maize flour with amaranth, the protein content and quality as well as the iron, zinc and calcium content of the snacks were improved [19]. The incorporation of 10% amaranth in formulation of cheese bread increased triple the amount of iron compared to the control [16]. It was established that zinc, calcium and iron contents of bread increased as amount of amaranth substitution increased [10]. The multigrain cookies fortified with the amaranth grains indicated very good nutritional properties and mineral content and hence can be considered healthy for consumption [5].

5. Conclusion

The nutritional composition of *Laddoos* revealed that the crude protein content was 17.76% in control *Laddoo*. With the addition of amaranth flour at 20, 30 and 40% level to control *Laddoo* the content of crude protein decreased significantly (16.86, 14.30 and 13.20%), respectively. The fat content of control *Laddoo* was 35.46%. After incorporation of amaranth flour upto 40% to control *Laddoo*, the fat content decreased from 32.80% (control) to 27.50%. The ash content of *Laddoos* increased from 2.07% (control) to 2.78% (40% incorporation of amaranth). Total dietary fibre insoluble dietary fibre and soluble dietary fibre content increased significantly after incorporation of amaranth flour to control *Laddoo*. Calcium, zinc, iron and potassium contents increased significantly in all the amaranth flour incorporated *Laddoos* as compared to their respective controls. Type I *Laddoo* had 189.10mgCa/100g, 2.85mgZn/100g, 7.95mgFe/100g and 410.15 mgK/100g. Type II *Laddoo* had calcium 203.47 mg/100g, zinc 3.04mg/100g, iron 8.20 mg/100 and potassium 445.33mg/100g. Type III *Laddoo* contained calcium 217.48mg/100g, zinc 3.18mg/100g, iron 9.64mg/100g and potassium 410.15 mg/100g. Available calcium and iron contents also increased in all the *Laddoo* (Type I 47.35 and 1.28; Type II 49.50 and 1.29; Type III 53.39 and 1.41mg/100g, respectively) as compared to their respective controls (37.64 and 1.22mg/100g). Results of nutrient evaluation of popped *Laddoo* revealed 6.25% moisture, 18.42% crude protein, 2.70% fat, 2.08% ash and 5.50% crude fibre. Popped *Laddoo* had 17.85% total dietary fibre, 255.81 mg/100g calcium, 5.88 mg/100g zinc, 14.34 mg/100g iron and 392.83 mg/100g potassium content. In popped *Laddoo* available calcium and iron contents were 68.56 and 5.28 mg/100g. Sensory evaluation of products showed that amaranth could be incorporated up to 40% in *Laddoo*. From the present study it is concluded that that amaranth can be utilized in preparation of various traditional and snack products to enhance their nutritive value. The study demonstrated that grain amaranth has potential to contribute to the alleviation of dietary nutritional deficiencies. The development and utilization of the *gluten free* on one hand will promote value addition of the products and on the other hand will provide low cost nutritious alternatives specially in poor developing

countries for combating malnutrition among children and vulnerable sections of the society. The content of macro-nutrients of the amaranth based products has advantages over the conventional gluten-free ones, offering real gluten-free foodstuffs.

6. Recommendation

In this study we were found value added *Laddoo* showed increased in nutrient content so in future this types value added *Laddoo* contributed nutrient rich snack items.

Author Contribution

Akanksha Singh developed the value-added product, performed the analytic calculations and performed the numerical simulations. Both Akanksha Singh and Shashank Singh contributed to the final version of the manuscript. Darshan Punia supervised the project

Conflict of Interest

The authors have no conflict of interest in this paper.

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References

- [1] Thompson T, Dennis M, Higgins LA, Lee AR, Sharret MK (2005). Gluten-free diet survey: are Americans with celiac disease consuming recommended amounts of fibre, iron, calcium and grain foods? *J Hum Nutr Dietetics* 18: 173–179.
- [2] Amerine, M. A.; Pangborn, R. M. and Roseller, E. B. (1965). Principles of sensory evaluation of foods. Academic Press, New York, p 265.
- [3] AOAC. 2000. Official Methods of Analysis. 17th Ed. Washington: Association of Official Analytical Chemists.
- [4] Barba de la Rosa, A. P., O. Paredes-Lopez and J. Gueguen. (1992). Globulins fraction from amaranth: Studies on subunit composition by ultracentrifugation and chromatography. *Journal of Agriculture and Food Chemistry*, 40, 937-940.
- [5] Bhat, A., Satpathy, G. and Gupta, R. K. (2015). Evaluation of Nutraceutical properties of *Amaranthus hypochondriacus* L. grains and formulation of value added cookies. *Journal of Pharmacognosy and Phytochemistry*, 3 (5), 51-54.
- [6] Breshears, k. L. and Crowe, K. M. (2013). Sensory and Textural Evaluation of Gluten-Free Bread Substituted With Amaranth and Montinaa Flour. *Journal of Food Research*, 2 (4), 1-10.
- [7] Bressani, R. (2003). Amaranth. In: Caballero, B., (ed)., *Encyclopedia of Food Sciences and Nutrition*, Academic Press, Oxford. pp. 166-173.
- [8] Chauhan, A., and Singh, S., (2013). Influence of Germination on Physico – chemical Properties of Amaranth (*Amaranthus Spp.*) Flour. *International Journal of Agriculture and Food Science Technology*, 4 (3), 215-220.
- [9] Chauhan, A., Saxena, D. C. and Singg, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Food Science and Technology*, 2: 1-8.
- [10] Emire, S. D. and Arega, M. (2012). Value added product development and quality characterization of amaranth (*Amaranthus caudatus* L.) grown in East Africa. *African Journal of Food Science and Technology*, 3 (6), 129-141.
- [11] Furda, I. (1981). Simultaneous analysis of soluble dietary fibre. The analysis of dietary fibre in Food. W. P. T. James and O. Theander (Eds.) Marcel Dekkar, New York. 163-172.
- [12] Glover, K (2009). Companies expand gluten free offerings. <http://industry.bnet.com/food/1000549/companies-expand-gluten-freofferings/>.
- [13] Gorinstein, S., E. Delgado-Licon, E. Pawelzik, H. Heriyati Permandy, M. Weisz & S. Trakhtenberg. (2001). Characterization of soluble amaranth and soybean protein based on fluorescence, hydrophobicity, electrophoresis, amino acid analysis, circular dichroism, and differential scanning calorimetry measurements. *Journal of Agriculture Food and Chemistry*, 49, 5595-5601.
- [14] Jain, A. and Grewal, R. B. (2015). Development and quality evaluation of value added extruded snacks by supplementing Amaranth and Guar gum in mixed cereal flour formulation constituting maize, rice and wheat. *International Journal of Recent Scientific Research*, 6 (9), 6221-6227.
- [15] Jauregui, R. N., Silva, M. E. P. Areas, J. A. G. (2000). Extrusion cooking process for amaranth (*Amaranthus caudatus* L.). *Journal of Food Science*, 65 (6), 1009–1015.
- [16] Lemos, A. D. R., Capriles, V. D., Silva, M. E. M. P. S., and Areas, J. A. G., (2012). Effect of incorporation of amaranth on the physical properties and nutritional value of cheese bread. *Ciênc. Tecnology Aliment*, 32 (3), 427-43.
- [17] Lindsey, W. L. and Norwell, M. A. (1969). A new DPTA-TEA Soil test for zinc and iron. *Agronomy. Abstract*. 61, 84-89.
- [18] Martinez, C. S., Ribotta, P. D., Leon, A. E., & Añón, M. C. (2016). Effect of amaranth flour (*Amaranthus mantegazzianus*) on the technological and sensory quality of bread wheat pasta. *Food Science and Technology International*, 127–135.
- [19] Muyonga, J. H., Nabakabya, D., Dorothy, N., Nakimbugwe, L. and Masinde, D. (2008). Efforts to promote amaranth production and consumption in uganda to fight malnutrition. *International Union of Food Science and Technology*, 5, 1–10.
- [20] Sanz-Penella JM, Laparra JM, Sanz Y. and Haros M. (2012). Bread supplemented with Amaranth (*Amaranthus cruentus*): Effect of Phytates on In Vitro Iron Absorption. *Plant Foods Humen Nutrition*, 67: 50–60.
- [21] Schuppan D, Junker, Y. and Barisani D (2009). Celiac disease: from pathogenesis to novel therapies. *Gastroenterology* 137: 1912–1933.
- [22] Segura, B. M. Esther. and R. Bressani. (2002). Distribution of protein physical fractions of milling and sieving of grain amaranth. *Arch. Latinoameric. Nutrition*. 52, 167-171.

- [23] Sheoran, O. P. and Pannu, R. S. (1999). Statistical Package for agricultural workers. "O. P. Stat" College of Agriculture, Kaul, CCS Haryana Agricultural University, Hisar. India.
- [24] Sudha, M. L. and Leelavati, K. (2012). Effect of blends of dehydrated green pea flour and amaranth seed flour on the rheological, microstructure and pasta making quality. *Journal of Food Science and Technology*, 49 (6), 713–720.
- [25] Sun, M, H. Chen and F. C. Leung. (1999). Low-Cot DNA sequences for fingerprinting analysis of germplasm diversity and relationships in *Amaranthus*. *Theoretical Application of Genetics*, 99, 464–472.
- [26] Virginia P, Ruchi and Ajit P. (2014). Development of nutritious snacks by incorporation of amaranth seeds, watermelon seeds and their flour. *Indian Journal of Community Health*, 26, 93-94.
- [27] Zheleznov, A. V., L. P. Solonenko and N. B. Zheleznova. (1997). Seed proteins of the wild and the cultivated *Amaranthus* species. *Euphytica*, 97, 177-182.
- [28] Zohu Z, Robards K, Helliwell S, Blanchard C (2002). Composition & functional properties of rice. *International Journal of Food Science Technology*, 37, 849–868.