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Utilization of Buckwheat, Proso Millet, and Amaranth for A Gluten-Free Cereal Bar

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***Abstract*—Four formulations of cereal bar were prepared using common buckwheat (55 parts), proso millet (15-30 parts), white amaranth (25-40 parts), walnut (27.5 parts), and jaggery (50 parts), by varying the proportions of proso millet and white amaranth in the ratio of 15:40, 20:35, 25:30 and 30:25. Roasted cereals and walnut pieces were mixed with jaggery syrup of 73.7° Bx and baked at 120° C for 20 minutes. The bars' proximate composition, mineral content (Ca, Fe and P) were evaluated and compared with the bar available in the market. The textural analysis and sensory profile of the bar were also evaluated. The crude fiber, calcium, and iron were significantly higher (p<0.05) in formulated bars compared to the market sample while energy and fat content were significantly higher (p<0.05) in the market sample. The formulated bars provided 440.31- 489.81kcal energy per 100 g, which qualified the product as a good energy-dense snack. From the textural analysis and sensory evaluation, Formulation C (common buckwheat-55, proso millet-25, white amaranth-30, walnut-27.5, and jaggery-50) was harder and preferred the most based on taste and overall acceptability. The research concludes the good potentiality of underutilized crops for cereal bar production.**

***Keywords*— Hardness; Pseudo cereals; Texture; Walnut**

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I. INTRODUCTION

The ready-to-eat snack food is made from mixing processed cereals with a variety of ingredients including oilseeds, nuts, sugar, chocolate, etc. [1]. Busy lifestyles and preferences for healthy foods have developed an interest in the development of snack bars with less refined sugar and cereals with more fiber. The cereal bar market is increasing and has become the preferred snack among consumers [2][3]. Sharma et al. [4] revealed that nowadays a combination of cereals, nuts, and other ingredients for making cereal bars depends upon their health benefits, natural, and sensory attributes. As reviewed by Ojha et al. [4], common buckwheat, proso millet, and amaranth are some of the major crops which are grown in high hill and mountainous regions of Nepal, however, these crops are not explored commercially despite being healthy. The consumption is limited to the household. Though neglected and underutilized food crops (NUFC) are highly nutritious and considered future-smart crops due to low input requirement and environment resilient properties [6]; farmers, policymakers, industry, and consumers considered NUFC as low priority crops, resulting in a decline in production of these crops. NUFC has a high potential to upgrade the country's economy if these crops are utilized as industrial raw materials.

The major raw material for cereal bars is wheat, so the cereal bars may not be suitable for gluten-sensitive people. Malabsorption due to damage of finger-like villi of the small intestine is associated with celiac disease after consuming gluten. The only prevailing treatment for celiac patients is a gluten-free diet [7].

The main purpose of this research is to prepare a nutritious gluten-free cereal bar, which is convenient to consume and store by using NUFC like buckwheat, amaranth, and proso millet. These cereals are also called pseudo-cereals. The research also aims to utilized non-refined sugar (molasses) as a binder, and walnut for flavor enhancers. Walnut is a good source of Omega 3 fatty acid, arachidonic acid, vitamin E, and phytochemical substances [8]. Compared to refined sugar, jaggery is a good source of minerals [9]. Numerous formulations of cereal bars have been developed and marketed worldwide with improved features like high antioxidant, high fiber, and probiotics [4], however in Nepal utilization of NUFC for cereal bar development has not been studied yet. To make NUFC a profitable cash crop, it is necessary to support local food chains and design NUFC as industrial raw material, which will ultimately increase the local demand of NUFC. This will ultimately encourage farmers to cultivate the crops more, which will help strengthen the rural economy. Recently, cereal bars are becoming popular as a healthy snack in the market, however, local resources are not being explored for its production. On the other hand, consumers will benefit from the bar's nutrition.

II. MATERIALS AND METHODS

A. Material

Common buckwheat, white amaranth, and proso millet were procured from High hill Crops Research Program (HCRP), NARC, *Dolakha*, and walnut from the farmers' field of *Jumla*. Solid jaggery and mold of dimension 20×20 cm were bought at a local shop from *Asan*, Kathmandu. The cereal bar (local company) was procured from the near market of Kathmandu for comparing physicochemical properties and textural profile.

B. Methods of cereal bar preparation

The cereal bar was prepared by hot/oven process as reviewed by Sharma et al. [4]. Cereals (common buckwheat, white amaranth, and proso millet) were subjected to dry cleaning followed by wet cleaning. They were dried in a cabinet dryer at 70°C for about 2 hours until it is completely dried. Common buckwheat and proso millet were roasted with hull for 5 min at a medium-high temperature in *karai* (black utensils used in the kitchen for cooking), 15-20 g at a time, while white amaranth was puffed in a medium-high temperature, 2-3 g at a time. After roasting, common buckwheat and proso millet were dehulled in Satake rice sheller, hulls are separated from grits by winnowing. The jaggery syrup was prepared by cutting small pieces of solid jaggery from the big cube using a sharp knife and pouring 20 ml of hot water per 100g of jaggery, and the prepared syrup was filtered through a muslin cloth. Walnut shells were broken using a wooden hammer and thus obtained walnuts were cutinto small pieces using a knife.

All the ingredients i.e. grits of common buckwheat and proso millet, puffed white amaranth, walnut pieces, and jaggery syrup were added to a large bowl according to the formulation given in **Table 1** below, and uniformly mixed using a spoon. After mixing the ingredients, it was poured into the mold of dimension 20×20 cm over the butter paper and pressed evenly. Then using a knife, the bars were cut into dimensions approximately 10×4 cm. Then, it was subjected to baking in a baking oven at 120° C for 20 min. The baked cereal bars were packed in aluminum foil after cooling, then packed in a plastic pouch (LDPE) of 75 µm, and stored at refrigerated temperature for further analysis.

Table 1: Formulation of the cereal bar

F	CB (Parts)	PM (Parts)	A (Parts)	W (Parts)	J (Parts)
A	55	15	40	27.5	50
B	55	20	35	27.5	50
C	55	25	30	27.5	50
D	55	30	25	27.5	50

F=Formulation, CB=Common buckwheat, PM=Proso millet, A=Amaranth, W=Walnut, J=Jaggery

C. Physiochemical analysis of cereal bar

Moisture (%), protein (%), crude fat (%), crude fiber (%), total ash (%), calcium (mg/100g), iron (mg/100g), and phosphorous (mg/100g) of the cereal bars were determined by the method as described by [10]. The moisture was determined by using a hot air oven until the constant weight was obtained. Crude protein of the cereal bars was determined using micro-Kjeldahl apparatus for nitrogen estimation, and multiplying the nitrogen percentage by the factor 6.25. The crude fat of the cereal bars was determined using an automatic Soxhlet apparatus and petroleum ether as a hot solvent. The crude fiber of the cereal bars was determined by recovering ash-free residue. The total ash content of the cereal bars was determined by incinerating all the organic matter of the sample at 550°C in a muffle furnace. The iron content of the cereal bars was determined by converting iron to red ferric thiocyanate and measuring absorbance at 480 nm in a UV-vis spectrophotometer (Cary UV-Vis spectrophotometer, Agilent, USA). The calcium content of the cereal bars was determined by titrating dissolved calcium oxalate in hot sulphuric acid with standard potassium permanganate. The phosphorus content of the cereal bars was measured by measuring the absorbance of complex molybdenum blue (reduced phospomolybdate) at 650 nm in a UV-vis spectrophotometer (Cary UV-Vis spectrophotometer, Agilent, USA). The TSS of jaggery was determined by using the 'Abbemat 3200' refractometer.

The energy of cereal bars was calculated using a bomb calorimeter (Parr 6400 Calorimeter, Parr Instrument Company, USA). The calorimeter was first standardized by using a pellet of 1 g benzoic acid. The principle for calculation of energy is the amount of heat produced after burning of food sample.

D. Textural analysis of cereal bar

The cereal bars were subjected to textural analysis using 'TA.XT plus' Texture Analyser (Stable Micro Systems Ltd., UK). The bar was cut into 2×2 cm. A cylindrical aluminum probe of 75 mm diameter was used and operated at a speed of 1 mm/S. The time difference between the two compressions was set at 5 s. The sample was compressed to 50% of its original size. The hardness, cohesiveness, springiness, and

Parameters	A	B	C	D	MB
Moisture	4.20 ± 0.05^{ab}	4.58 ± 0.04^{b}	3.78 ± 0.12^{a}	3.96 ± 0.11^{a}	6.69 ± 0.22^{c}
Protein	11.51 ± 0.28^{a}	10.77 ± 0.23^{ab}	10.7 ± 0.31^{ab}	11.18 ± 0.39^{ab}	9.82 ± 0.28^{b}
Fat	14.45 ± 0.29^{a}	13.67 ± 0.21^{ab}	12.83 ± 0.31^{b}	12.83 ± 0.38^{b}	23.84 ± 0.16^{c}
Crude fiber	6.33 ± 0.89^{a}	7.05 ± 0.63^{a}	5.45 ± 0.13^{ab}	7.11 ± 0.21^{a}	3.92 ± 0.23^{b}
Total ash	1.92 ± 0.09^{ab}	1.97 ± 0.06^{ab}	2.09 ± 0.07^{bc}	2.29 ± 0.07^{c}	1.72 ± 0.05^{a}
Calcium (mg/100 g)	177.58 ± 5.13^{a}	175.58 ± 11.61^{a}	114.56 ± 4.47^{b}	104.17 ± 4.6^{b}	101.59 ± 3.13^{b}
Iron (mg/100 g)	6.53 ± 0.56^{a}	6.64 ± 0.75^{a}	15.68 ± 1.83^{b}	19.24 ± 0.46^{b}	5.16 ± 0.11^{a}
Phosphorus (mg/100 g)	189.86 ± 2.00^{a}	177.55 ± 7.91^{a}	202.29 ± 6.41^{a}	201.17 ± 5.81^{a}	234.59 ± 2.33^{b}
Energy (kcal/100 g)	489.81 ± 1.53^{c}	450.12 ± 1.27^{ab}	440.31 ± 0.48^{a}	455.54 ± 5.35^{b}	525.71 ± 3.46^{d}

chewiness parameters were obtained as described by Kaur et al. [11] from the peak.

E. Sensory evaluation

Sensory evaluation was carried out using the rank test as described by [10]. Different sensory attributes like texture, taste, appearance and overall acceptance were evaluated by 20 panelists.

F. Research design and data analysis

The research design was completely randomized design with four treatments and triplicate analysis is carried out for each parameter. The lot of 1 kg was prepared at a time, and three lot was prepared. The data of physicochemical analysis and textural analysis were analyzed by one-way Analysis of variance (ANOVA) using SPSS at a 5% level of significance. The significant differences between them were studied by using Tukey HSD at a 5% level of significance. The data of sensory evaluation was analyzed by using box-plot and tabulated value reproduced from Kramer's rank-sum test (shown in **Table 2**) as described in Ranganna [10].

Table 2: The tabulated value of upper pair and lower pair for 4 treatments and 20 panelists.

	At a 5% level of significance
Upper pair	39-61
Lower pair	42-58

III. RESULTS AND DISCUSSION

A. Physiochemical analysis of cereal bars

Physiochemical analysis of cereal bars and bar from a market was carried out and tabulated in **Table 3**.

The MC ranged from 3.78 to 4.58 % in formulated cereal bar whereas Mountain bar has significantly higher MC with 6.69%. The formulated cereal bars were not significantly different regarding protein content. However, the protein content in formulation A was significantly higher ($p<0.05$) than in a market sample. The crude fiber of formulated cereal bars was not significantly different ($P<0.05$). The ash content of formulations D (with the highest proso millet among formulations) was significantly higher ($P<0.05$) than all other formulations and market sample. The calcium and iron of formulation C and D were significantly higher ($P<0.05$) than another bar, while phosphorous content and energy value were significantly higher ($P<0.05$) in the market sample.

Table 3: Physiochemical analysis of cereal bars

Note: Values are the mean ± standard error of mean obtained from the triplicate data, Different alphabet in the same row indicates significant difference ($p<0.05$), A, B, C, D represent different formulations of cereal bar, whereas MB represents reference sample bought from the market. All the data are on a dry basis except moisture and energy.

The lower moisture content prevents microbial growth and extends the shelf life of the product, hence is an important factor in food preservation [11]. The protein content in the gluten-free cereal bar developed by Kaur et al. [11] 10.5%, while Agbaje et al. [12] reported 3.38-4.04% who in their work used glutinous rice flakes and dried sunnah foods to prepare cereal bar. Similarly, Covino et al. [13] reported protein (%) in the range of 6.05-6.41 in the cereal bar prepared from brazil nut, rice flakes, soy lecithin, invert sugar, vegetable fat and flaxseed as major ingredients.

Kaur et al. [11] reported 2.89 % fat in their study of gluten-free cereal bars, which was lower than the value obtained in this study for formulated cereal bars. Subedi and Upadhyaya [14] reported 0.71 to 2.43 % crude fiber in flaxseed incorporated oat bar, which was lower than the value obtained in this study. However, Covino et al [13] revealed fiber (%) in the range of 18.74-21.35, which was greater than the value obtained in this research. The amount of ash present in a food product plays a significant role while determining the levels of essential minerals. Kaur et al. [11] reported 1.34% ash in quinoa-based cereal bars, while Covino et al. [13] found 1.57-1.71 in cereal bar.

Agbaje et al. [12] reported 18.65-48.29 mg calcium/100g and 3.36-4.15 mg iron/100 g in cereal bar prepared from glutinous rice, dates, figs, raisins, black cumin, glucose syrup, and honey, while Subedi and Upadhyaya [14] reported 55.26-81.45 mg calcium/100g, 5.79-7.55 mg iron/100g, and 188.19-242.72 mg phosphorous/100 g in flaxseed incorporated oat bar. Covino et al. [13] reported iron (mg/100g) content 14.64-15.76 in cereal bar. Agbaje *et al.*, [12] reported energy values to range from 322.06-379.8 Kcal/100 g in glutinous rice flakes cereal bars. Samakradhamrongthai et al. [15] reported energy value in the range of 481.35-679.87 Kcal/100 g in the cereal bar prepared from cereals, bars, and sweeteners. The nutrients and nutritional values in cereal bars are never the same and vary greatly, and are determined by the type and amount of ingredients used for the preparation of the bar [16].

B. Textural analysis of cereal bar

The hardness, cohesiveness, springiness, and chewiness of cereal bars and market sample were determined and shown in **Fig. 1a**, **Fig. 1b**, **Fig. 1c**, and **Fig. 1d** respectively.

The hardness of cereal bars ranges from 154.15 to 441.62 N, while that of the market sample was found to be 372.09 N. The formulation C, D, and the market sample was found to be significantly higher ($P<0.05$) than formulation A and B. The cohesiveness and springiness of all the formulated bars and market sample were found to be similar ($P<0.05$), and the values range from 0.17-0.37, and 0.99 respectively. The chewiness increased with an increase in the percentage of proso millet in the formulations and ranged from 27.62-130.52 respectively. The value for formulation A was significantly lower ($P<0.05$) than other formulations and market sample.

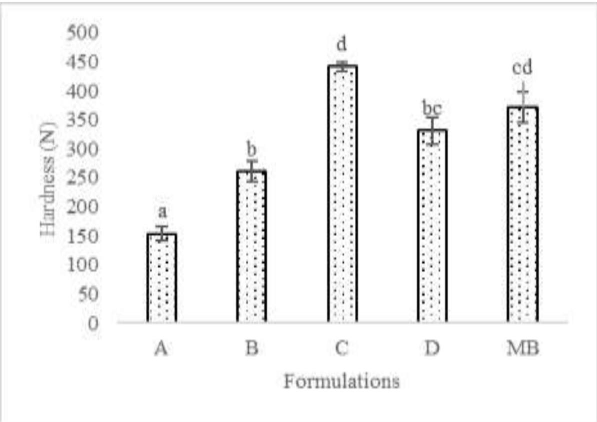

Figure 1a: Hardness of cereal bar and market sample

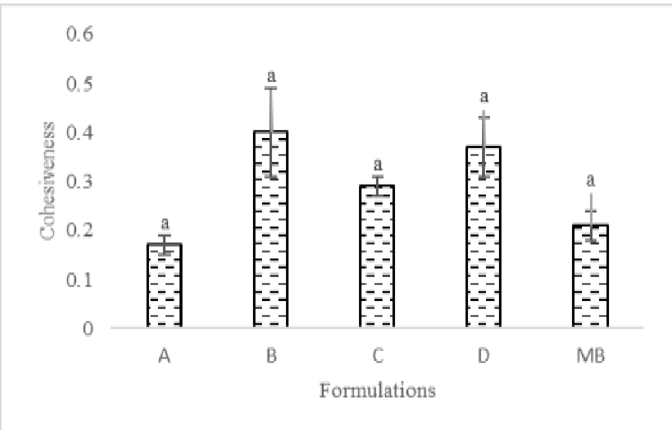

Figure 1b: Cohesiveness of cereal bar and market sample

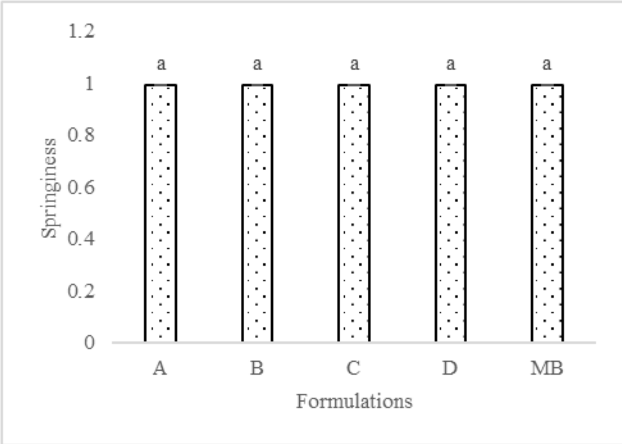

Figure 1c: Springiness of cereal bar and market sample

The difference in the proportions of proso millet and amaranth affect the hardness of the cereal bars; however poor correlations were observed due to heterogeneity in textural properties of different ingredients used. Mridula *et al.*, [17] revealed that flaxseed proportions variation did not affect the hardness of the bar, but found a negative correlation with the level of sweeteners. Kaur et al. [11] reported the mean values of hardness, cohesiveness, springiness, and chewiness of quinoa-based gluten-free cereal bar to be 27.73N, 0.249, 0.359, and 2.48 respectively, which was different from than author’s reported value. The difference may be due to the use of different types and amounts of binding agents. Kaur et al. [11] used honey as a binding agent at level 50% whereas jaggery syrup was used in our study at level 35%. The findings are supported by the study of Mridula et al. [17], who reported that sweeteners affected the hardness, cohesiveness, springiness, and chewiness in energy bars. Different researchers have found that cereal bar formulations variation affect the texture profile of bar [18][19].

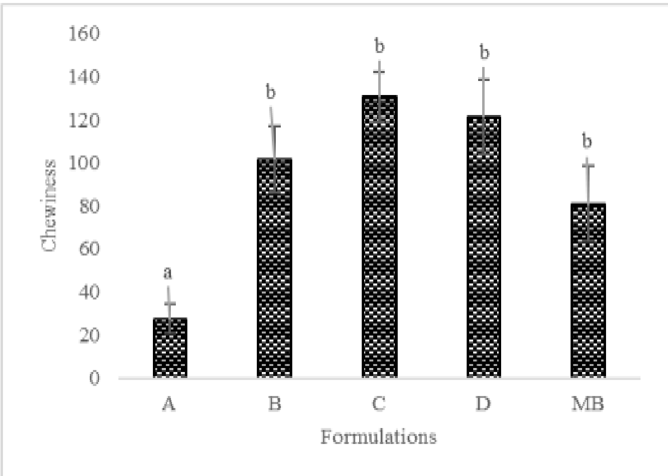

Figure 1d: Chewiness of cereal bar and market sample

C. Sensory evaluation of cereal bar

The sensory evaluation (Texture, Taste, and Overall acceptability) of formulated cereal bar was carried out excluding the market sample (Difference in look and size) and is represented in **Fig. 2a**, **Fig. 2b**, and **Fig. 2c** respectively.

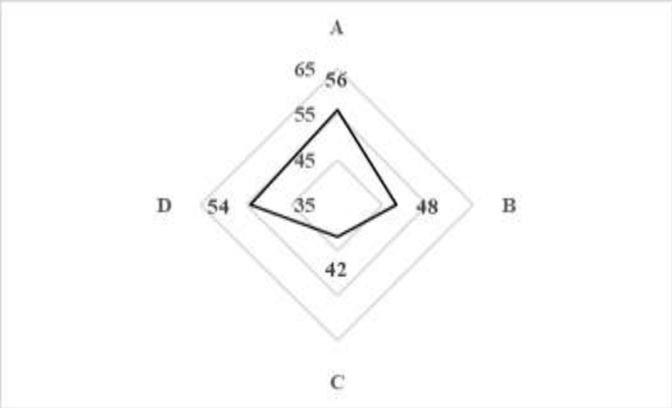

Figure 2a: Cumulative sensory score for the texture of formulated cereal bars

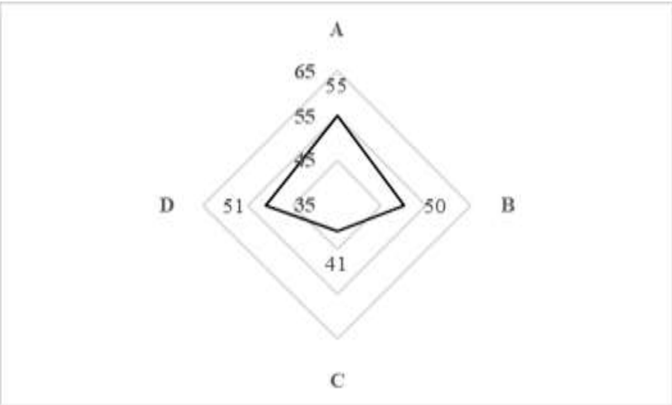

Figure 2b: Cumulative sensory score for a taste of formulated cereal bars

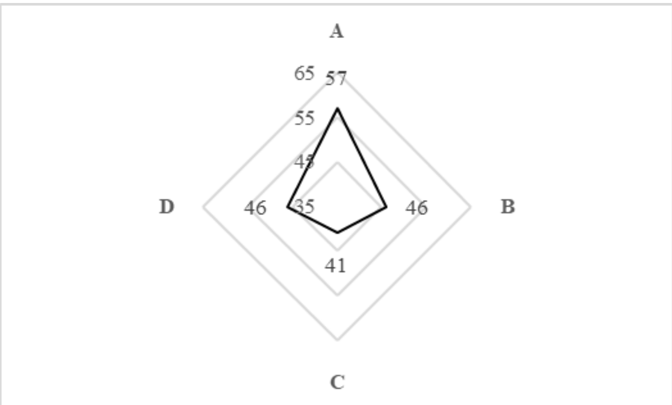

Figure 2c: Cumulative sensory score for overall acceptability of formulated cereal bars

From the graph, it is seen that the rank sum of all the samples falls within the upper pair limit for all sensory attributes (table 2). Hence, the samples are not significantly different (P>0.05). The lower pair of entries are then considered for comparison. It is seen that the rank sum of formulation C is lower than 42 for taste and overall acceptability. Hence, formulation C is superior to the rest of the samples at a 5% level regarding taste and overall acceptability.

The sensory score of cereal bars is affected by the source of cereals, oilseeds, preliminary processing of cereals, nuts, fruit, binder, etc. [11][15][20].

IV. CONCLUSIONS

The protein, crude fiber, iron, and calcium content of formulated cereal bars were higher than the market sample, while fat, phosphorus content, and energy of formulated cereal bars were less than the market sample. The research concludes that NUFC can be utilized for cereal bar making with good nutritional quality and textural properties. Cereal bars prepared from formulation B (buckwheat 55 parts, proso millet 25 parts, amaranth 30 parts, walnut 27.5 parts, and jaggery 50 parts) were found to be best among the other formulations. Further research can be carried out to study the effect of roasting time and temperature on the textural properties of cereal bars.

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