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Evaluating the Nutritional and Sensory Properties of Baked Goods Utilizing Bio-fortified Pearl Millet and Underutilized Carrot Leaf Powder

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ABSTRACT: The traditional bakery industry, integral to the food processing sector, faces the challenge of meeting the demands of a growing global population for fresh, convenient, and nutritious products. Addressing malnutrition, particularly prevalent in developing nations, requires innovative strategies such as bio-fortification. This research explores the impact of incorporating bio-fortified pearl millet and carrot leaf powders (CLP) as nutritional additives in bun formulations. Powdered carrot leaves (CLP) were incorporated into pearl millet in distinct proportions of 5%, 10%, 15%, and 20%, denoted as T_1, T_2, T_3, and T_4, respectively. The results of the evaluation revealed that all of the developed buns were considered acceptable by the judges, except for T_4 buns, which were categorized as falling within the range of "neither like nor dislike". The nutritional assessment revealed that buns with 20% CLP exhibited significantly higher nutritional content, followed by T_3, T_2, and T_1. These findings underscore the transformative potential of leaf powders in fortifying bakery products, offering a promising avenue to enhance food security and nutrition on a global scale.

Keywords: Pearl Millet, Bun, Carrot Leaf Powder (CLP), Bakery, Sensory and Nutritional Evaluation.

INTRODUCTION

India leads the global charge in millet production, particularly focusing on pearl millet (*Pennisetum glaucum*), esteemed for its nutritional richness and robustness (Elyas *et al*., 2002). Pearl millet serves as a dietary cornerstone in regions with limited food diversity, contributing significantly to food security in arid areas due to its remarkable drought resistance. Functioning as a staple crop, it sustains millions, and its culinary adaptability, soil enhancement properties, and significance in livestock underscore its worldwide importance (Dykes and Roony 2006). The nutritional profile of pearl millet grains not only matches but surpasses major cereal grains in terms of protein, energy, vitamins, and minerals (Anitha *et al.*, 2023). Beyond these fundamental attributes, pearl millet stands out as an abundant source of dietary fibre, phytochemicals, micronutrients, and nutraceuticals. Its high energy content, comprising around 8-10% protein, lower starch levels, and substantial insoluble fibre, sets it apart. Remarkably, its α-amylase activity surpasses that of wheat by 8-15 times. Additionally, pearl millet boasts a low glycemic index of 55 and is naturally devoid of gluten. Collectively, these exceptional qualities position pearl millet as an invaluable and highly nutritious grain on the global stage (Nambiar *et al.*, 2011).

In the context of global food processing, the bakery sector is an esteemed and pivotal tradition. In India, the bakery industry holds promising growth potential, setting itself apart among various other segments in the food processing sector (Patel and Venkateswara Rao 1996). Bakery products, cherished for their substantial nutritional value and cost-effectiveness, enjoy widespread consumption. Baking, a culinary technique involving sealed oven cooking with dry heat and steaming, facilitates the creation of diverse food items, surrounding bread, cakes, biscuits, and cookies. Due to the continued significance of bread as a staple food in various regions globally, considerable endeavours have been dedicated to enhancing its nutritional value. The optimization of bread production can involve the incorporation of specific elements containing beneficial bioactive compounds, nutraceuticals, and functional properties. This approach aims to create bread formulations that are appealing and well-received by consumers (Dziki *et al.*, 2014).

Carrot leaves also hold a significant importance in the realm of nutrition and sustainability. Carrot leaves are often-relinquish leafy greens that are rich sources of essential nutrients, including vitamins such as vitamin K, vitamin C, and various B vitamins, along with minerals like calcium and iron (Pereira *et al.,* 2003; Leite *et al.,* 2011). Incorporating carrot leaves into cooking preparations not only enhances the flavour and texture of products but also diversifies nutrient intake (Calviello *et al.,* 2007). Moreover, utilizing carrot leaves in cooking aligns with sustainable consumption practices, reducing food waste by harnessing the full potential of these plants. Their cost-effectiveness, diverse cooking applications, and ability to complement various recipes make them invaluable ingredients in promoting both personal health and environmental sustainability while supporting the ethos of reducing waste and embracing holistic food consumption (Goneim *et al*., 2011). The present study was planned to develop buns made from bio-fortified pearl millet along with the addition of carrot leaf powder (CLP) and to evaluate its sensory and nutritional characteristics. The development of value-added food products utilizing these less commonly used greens and millets represents an optimal approach to enhancing the nutritional value of people's daily diets across all age groups, fostering their overall health and well-being.

MATERIALS AND METHOD

The bio-fortified pearl millet (HHB-299) was obtained from the *Bajra* section of the Genetics and Plant Breeding Department at CCS Haryana Agricultural University, Hisar. Meanwhile, the carrot leaves and other ingredients were sourced from the local market during the winter season. To extend the shelf life of leaves, blanching was performed before the drying process. Subsequently, the fresh carrot leaves were detached from their stalks, washed thoroughly under running water, and then subjected to blanching in boiling water for 60 seconds and then immersed in chilled water immediately drying in a cabinet dryer until they attained the desired level of dryness.

For the buns' preparation, the control bun was developed using a combination of pearl millet flour and refined flour in equal parts, with a ratio of 50:50. In the trial group, carrot leaves powder (CLP) was added in four separate variations at 5%, 10%, 15%, and 20%, categorized as T_1, T_2, T_3, and T_4, respectively. The process of bun preparations is shown in Fig. 2.

Sensory evaluation of buns: The sensory quality attributes of the buns were evaluated by a panel of ten semi-trained judges using a nine-point hedonic scale. Panelists were presented with samples of the buns and asked to rate the acceptability of the product on a scale of 1 to 9, where 9 indicated "extremely like" and 1 indicated "extremely dislike."

Nutritional evaluation of buns: The proximate composition analysis of the developed buns was carried out in accordance with the guidelines outlined by the AOAC (2000). The moisture content was determined using the Hot Air Oven method. The analysis of ash, fat, and crude fibre content followed the standard procedures set by AOAC (2000). For the determination of crude protein, the KEL PLUS Automatic Nitrogen Estimation System was employed, with a conversion factor of 6.25 applied to convert the nitrogen values into crude protein content. Crude fat content was estimated using the Automatic SOCS plus Solvent Extraction System. The analysis of minerals such as Calcium, Iron, and Zinc was conducted by the Atomic Spectrophotometer method as per the guidelines of Lindsey and Norwell (1980). The β-carotene content was determined following the protocols specified by AOAC (2000).

Statistical Analysis: The collected data from both the nutritional analysis and sensory evaluation of developed buns were statistically analyzed using parameters such as mean and standard error. The ANOVA (analysis of variance) technique was employed for the statistical analysis, following the standard method outlined by Sheoran and Pannu (1999).

RESULTS AND DISCUSSION

Moisture content. The developed buns incorporated with carrot leaf powder are shown in Fig. 1. As outlined in Table 1, the buns' moisture content experienced a noteworthy ($p \leq 0.05$) decrease with the addition of CLP. The control bun registered the highest moisture content at 30.65%, whereas the T_4 buns, enriched with 20% carrot leaves powder, displayed the lowest moisture content at 26.67%. The reduction in moisture content to 26.67% across all CLP-supplemented buns, except for the control bun, can be attributed to the infusion of CLP's high fibre content (Salazar *et al.,* 2021; Singh *et al.,* 2016). This decrease in moisture is crucial for extending the shelf life of food products by impeding the proliferation of spoilage microorganisms (Tukassar *et al.,* 2023).

Crude protein. The initial bun, under standard conditions, displayed a crude protein content of 10.11%. However, this content witnessed a significant ($p \leq 0.05$) upswing with the introduction of carrot leaves powder, reaching a peak at the 20% level. Among the experimental buns, T_4 stood out with the highest protein content at 14.87%, followed by T_3, T_2, and T_1, with values of 13.41%, 12.42%, and 11.07%, respectively. The heightened crude protein levels can be attributed to the protein-rich nature of carrot leaves powder. When integrated into pearl millet flour, it elevates the protein content of the resultant buns. These outcomes align with the findings of Tukassar *et al.* (2023), suggesting the potential utilization of cauliflower by-products as an additional plant protein source. Their study demonstrated that a 30% supplementation of cauliflower by-products yielded the highest protein content at 9.7%, whereas the control muffins contained only 7.53%. In a parallel study by Padamshree *et al.* (2013), a protein content of 10.49% was achieved. This heightened protein content was attributed to the inclusion of pearl millet, amaranth, and roasted Bengal gram in the formulation of the bar, as indicated in their research findings.

Crude fat. The fat content of the standard bun was quantified at 10.05%, while the inclusion of CLP up to 20% led to a range of 9.35% to 8.03% in the corresponding buns. Tukassar *et al.*,(2023) demonstrated a fat content variation from 6.44% in the control group to 6.82% in CBP30 (cauliflower by-products@30%).

Ash. The total ash content for CLP-supplemented buns at 5%, 10%, 15%, and 20% levels were 1.76%, 1.86%, 2.13%, and 2.27%, respectively. In contrast, the control bun, without the addition of carrot leaves powder, exhibited an ash content of 1.63%. Tumuhimbise *et al.* (2019) observed a significant rise in ash content in Orange Flesh Sweet Potato (OFSP)-based composite flours, from 2.7% to 5.3%, with the incorporation of skimmed milk and amaranth leaf powder into bread, according to their research.

Crude fibre. The analysis indicated a significant ($p \leq 0.05$) elevation in the crude fibre content in the developed buns compared to the control bun. Specifically, T_4 bun exhibited a crude fibre content that was 2.5 times higher than that of the control bun (Table 1). The study observed a notable increase in dietary fibre content, escalating from 0.73% in the control to 3.74% with 30% supplementation of cauliflower by-product (CBP). This surge in dietary fibre, attributed to the substantial quantity of dietary fibre in CBP powder, resulted in increased density and a reduced number of air pockets in the muffins, as observed in the studies of (Heo *et al.*,2019; Mirani and Goli, 2021).

MINERAL CONTENT

Calcium, Iron and Zinc content: The calcium, iron, and zinc content in control buns were determined to be 69.04, 4.07, and 3.99 mg, respectively. As the supplementation of carrot leaves powder (CLP) in the developed buns reached 20%, the mineral content values exhibited a marked increase compared to levels at 5%, 10%, and 15% supplementation (Table 2). Tukassar *et al.*, (2023) emphasized an elevation in calcium content in cauliflower by-product at 30% (CBP30) muffins, from 171.47 mg in the control group to 244.56 mg in the CBP30 samples. Furthermore, the CBP30 group displayed the highest iron content, reaching 6.56 mg, likely attributed to the heightened presence of CBP.

Calcium and zinc content in supplemented buns ranged from 156.22 to 368.50 and 3.71 to 3.75 mg/100g, respectively. The iron content for T_1, T_2, T_3, and T_4 =buns, supplemented with carrot leaves powder (CLP), was recorded as 4.80, 5.51, 6.68, and 7.37 mg/100g, respectively (Table 2). These findings align with the results presented by Abul-Fadl (2012), who observed that the addition of CBP powder at various levels resulted in mineral contents in the developed products approaching the recommended dietary allowance (RDA) values.

β-carotene content: Control buns from pearl millet had a *β*-carotene content of 15.97 µg/100g, while buns enriched with carrot leaves powder exhibited significantly ($p \leq 0.05$) higher *β*-carotene content, ranging from 268.31 to 881.76 µg/100g. At the maximum supplementation level of 20% carrot leaves powder (CLP) in T_4 , the *β*- carotene content exhibited a significantly higher value compared to the control buns, with a statistically significant difference ($p \leq 0.05$) (Table 2). Buns of all types supplemented with carrot leaves powder (CLP) displayed *β*-carotene concentrations ranging from 15 to 50 times higher than those observed in the control buns.

Sensory evaluation of buns: The sensory evaluation of buns, supplemented with carrot leaves powder (CLP) alongside the control, is outlined in Table 3. Panellists concluded that both the control and supplemented buns were organoleptically acceptable. The control bun received elevated mean scores in colour, aroma, texture, and overall acceptability, placing it in the "Liked very much" category. For buns supplemented with 5% carrot leaves powder (CLP), mean scores for aroma, appearance, taste, and overall acceptability were 7.60, 7.60, 7.30, and 7.56, respectively. However, as the supplementation level increased up to 20% (T_4), the sensory scores decreased, falling into the "neither like nor dislike" category. The sensory scores of developed muffins at 20% and 30% levels of cauliflower by-products subsequently decreased in various characteristics such as appearance, taste, aroma, texture, softness, palatability, colour, and overall acceptability. The lower sensory scores for CBP20 and CBP30 could be attributed to elevated hardness values and increased batter viscosity resulting from the inclusion of cauliflower by-product (CBP), as reported by Tukassar *et al.*, (2023).

Buns enriched with carrot leaves powder (CLP) at T_2 and T_3 received scores indicating a range from "liked slightly" to "liked moderately" in terms of colour, appearance, aroma, texture, taste, and overall acceptability. The overall acceptability scores for T_1, T_2, and T_3 were 7.56, 7.02, and 6.18, respectively, suggesting that CLP-supplemented buns fell within the range of "liked moderately to slightly." It was observed that as the CLP level increased, the scores for colour, taste, and texture of T_2, T_3, and T_4 buns fluctuated between 5.6 to 7.10, 5.70 to 7.10, and 5.80 to 7.00, respectively. In contrast to the current findings, previous studies conducted by Wani *et al.* (2013); Wani and Sood (2014) demonstrated the preparation of noodles using CBP up to 10% with comparable eating qualities to the control group. The overall sensory characteristics of muffins enriched with CBP appear to be influenced by the extent of incorporation, subsequently impacting the total dietary fibre content of the muffins and altering their acceptability among consumers.

Fig. 1. CLP incorporated buns.

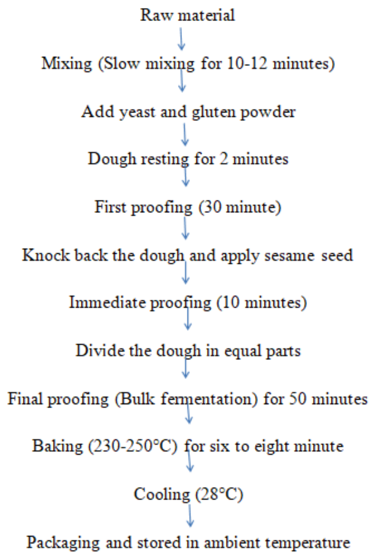

Fig. 2. Process flowchart for bun preparation.

Table 1: Proximate composition of CLP incorporated bun (g/100g, on dry matter basis).

Treatments	Moisture*	Crude Protein	Crude Fat	Ash	Crude Fibre
Control	30.65±0.24	10.11±0.05	10.05±0.14	1.63±0.14	0.97±0.12
T_1	29.77±0.38	11.07±0.06	9.35±0.24	1.76±0.18	1.59±0.06
T_2	28.72±0.63	12.42±0.02	9.00±0.02	1.86±0.09	1.66±0.08
T_3	28.12±1.58	13.41±0.05	8.51±0.05	2.13±0.12	1.76±0.08
T_4	26.67±0.88	14.87±0.04	8.03±0.03	2.27±0.08	2.00±0.15
CD($P \leq 0.05$)	2.75	0.24	0.86	0.36	0.24

Values are mean ± SD of three independent determinations
Control buns : 50:50 pearl millet flour and refined flour; T_1: CLP@5%,: T_2: CLP@10%,: T_3: CLP@15%,: T_4: CLP@20%
*Moisture was analysed on fresh weight basis

Table 2: Mineral and β-carotene content of CLP incorporated bun (g/100g, on dry matter basis).

Treatments	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	β-carotene (μg/100g)
Control	69.04±0.54	4.07±0.03	3.99±0.06	15.97±0.57
T_1	156.22±0.39	4.80±0.09	3.75±0.08	268.31±0.84
T_2	227.32±0.33	5.51±0.24	3.74±0.02	496.41±0.10
T_3	299.34±0.66	6.68±0.16	3.73±0.10	664.07±7.07
T_4	368.50±1.00	7.37±0.31	3.71±.0.13	881.76±1.15
CD($P \leq 0.05$)	1.69	0.44	0.32	10.91

Values are mean ± SD of three independent determinations
Control buns : 50:50 pearl millet flour and refined flour; T_1: CLP@5%,: T_2: CLP@10%,: T_3: CLP@15%,: T_4: CLP@20%

Table 3: Mean acceptability scores of CLP incorporated buns.

Treatments	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Control	8.80±0.13	8.50±0.22	8.50±0.22	8.40±0.22	8.40±0.16	8.52±0.16
T_1	7.80±0.20	7.60±0.22	7.60±0.22	7.50±0.22	7.30±0.21	7.56±0.19
T_2	7.10±0.23	7.00±0.21	6.90±0.20	7.00±0.23	7.10±0.18	7.02±0.15
T_3	6.30±0.23	6.10±0.27	6.30±0.21	6.20±0.24	6.10±0.23	6.18±0.19
T_4	5.60±0.22	5.50±0.22	5.80±0.24	5.80±0.24	5.70±0.23	5.68±0.18

Values are expressed as Mean±SE of ten observations;
Control buns: 50:50 pearl millet flour and refined flour; T_1: CLP@5%, T_2: CLP@10%, T_3: CLP@15%, T_4: CLP@20%

CONCLUSIONS

In accordance with research findings, carrot leaves, akin to their roots, possess a substantial nutrient profile. When integrated with bio-fortified pearl millet, they augment the nutritional value of the final product. However, the sensory evaluation of the buns revealed a notable decrease in acceptability with the inclusion of carrot leaves powder, particularly evident in T_4 buns fortified at a 20 percent level. Upon scrutinizing the nutritional composition, buns supplemented with 20 percent carrot leaves powder displayed the highest nutrient contents compared to the control bun. Conversely, T_1 buns exhibited the minimum levels of both crude protein and crude fibre content when compared to T_4 buns. Given the abundant presence of calcium (Ca), zinc (Zn), iron (Fe), and β-carotene in carrot leaves powder, it emerges as a promising option for fortifying various bakery products. Nevertheless, further studies are imperative to assess the bioavailability of these minerals in bakery products for future considerations.

FUTURE SCOPE

The integration of carrot leaves powder into bakery products, especially in bio-fortified pearl millet-based formulations, holds promise for enhancing nutritional content, marked by elevated levels of calcium, zinc, iron, and β-carotene. Future research should focus on evaluating the bioavailability of these enriched minerals in bakery items, paving the way for innovative and nutritionally superior baked goods in the market.

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Conflict of Interest. None.

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