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Development, Nutritional and Storage Analysis of Pearl Millet Value-added Traditional Snacks (*Namakpara*, *Mathri*) Enriched with *Jamun* Seed Powder

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ABSTRACT

Background: Pearl millet and *jamun* seed powder were combined to develop snacks that utilize the nutritional value of pearl millet and *jamun* seeds as antioxidants for innovative, health-conscious options. This aligns with the demand for sustainable, nutrient-rich snacks blending traditional flavors with modern health considerations.

Methods: Different formulations incorporated *jamun* seed powder at 20% levels. The study utilized a 9-point hedonic scale for sensory evaluation and standard procedures for nutritional analysis, including proximate, minerals, *in vitro* digestibility and storage fat quality assessments.

Result: *Jamun* seed powder influenced the sensory scores, with 10% incorporation maintaining acceptability. Nutrient profiles were impacted, altering protein, fat, ash, crude fiber, calcium, phosphorus, zinc, phytic acid and polyphenols. *In-vitro* protein digestibility decreased, while starch digestibility remained unaffected. During storage, *jamun* seed products retained sensory attributes better than controls. Type I samples exhibits potential antioxidant and anti-rancidity properties, evident in reduced fat acidity and peroxide value after 90 days (143.40 to 137.25 KOH/100 gm and 14.33 to 13.42 meq/1000 g of fat). This study enhances nutritious and sustainable snack development, offering consumers gluten free indulgence in traditional flavors with added health benefits.

Key words: *Jamun* seed, *Mathri*, *Namakpara*, Pearl millets, Significance.

INTRODUCTION

Namakpara and *Mathri* are popular traditional Indian snacks known for their savory taste and crunchy texture joyed during festive occasions, tea-time, or as accompaniments to meals and prepared using refined flour as the main ingredient. However, the increasing awareness about the health implications of consuming refined flour-based products has prompted researchers and food manufacturers to explore alternative and healthier ingredient options. Pearl millet, also known as Bajra in Hindi, is one of the major millet crops grown in India. Pearl millet (*Pennisetum glaucum*) is a nutritious and drought-resistant (Singh, 2003) cereal grain that has gained attention for its health benefits. Pearl millet is rich in dietary fiber, vitamins, minerals and bioactive compounds (Vaijapurkar *et al*., 2015; Kaushik and Grewal, 2017) which contribute to its antioxidant and anti-inflammatory properties. As a gluten-free grain, pearl millet is suitable for individuals with gluten sensitivity or celiac disease (Veena *et al*., 2004), making it an ideal choice for developing gluten-free snacks.

Jamun seeds (*Syzygium cumini*), are traditionally used for their medicinal properties (Sidana *et al*., 2017) and are known for their anti-diabetic, anti-inflammatory and antioxidant effects. The seeds contain chemical constituents (Raza *et al*., 2015) *e.g.* phenolic compounds (Banu and Jyothi, 2016), flavonoids and other bioactive that contribute to their therapeutic potential. *Jamun*, also known as the Indian Blackberry fruit, is native to India. In recent years, there has been increasing interest in utilizing pearl millet and *jamun* seeds for their nutritional and health benefits. Overall, the ample production of pearl millet and *jamun* seeds in India is promising in ensuring food security, providing nutrition, enhanced health benefits and promoting sustainable agricultural practices.

In this research study, we explore the potential of pearl millet-based *Namakpara* and *Mathri* snacks incorporated with *jamun* seeds to assess their potential as healthier alternatives. We aim to enrich these traditional snacks with essential nutrients, enhance their sensory attributes and improve their overall profile. We evaluate the changes in proximate compositions, sensory characteristics and oxidative stability during storage to understand the effects of these additions on snack quality and shelf life.

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MATERIALS AND METHODS

The Department of Genetics and Plant Breeding at CCS, HAU, Hisar provided the Pearl millet variety (HC 10). Fresh *Jamun* fruits from a nearby market were cleaned, the seeds removed and air-dried for 24 hours at 55°C. The dried seeds were sieved, crushed and kept in hygienic storage.

Ingredients for *namakpara*

Carom seeds (1 g), Salt (1 g), Sodium bicarbonate (1 g), Ghee (20 g), Water (60 ml), Oil for frying.

Ingredients for *mathri*

Black pepper powder (0.5 g), Salt (2 g), Dried fenugreek leaves (0.5 g), Sodium bicarbonate (1 g), Ghee (30 g), Water (50 ml), Oil for frying.

Types for *namakpara* and *mathri*

Control = Pearl millet flour (50 g), Refined flour (50 g).

Type I= Pearl millet flour (45 g), Refined flour (45 g), *jamun* seed powder (10 g).

Type II= Pearl millet flour (42.5 g), Refined flour (42.5 g), *jamun* seed powder (15 g).

Type III= Pearl millet flour (40 g), Refined flour (40 g), *jamun* seed powder (20 g).

Method to develop *namakpara and mathri*

To properly combine all the ingredients mentioned for *mathri* and *namakpara*, sieved pearl millet flour, refined flour and *jamun* seed powder. Ghee was added and the flour mixture was carefully stirred with both hands to make a stiff dough with warm water. The dough was divided into two equal pieces and the balls were rolled each one into a thin sheet using a rolling pin. With the help of a knife, cut the sheet into shapes and deep-fried in hot oil till golden brown over low heat (Plate 1 and 2).

Sensory assessment

A semi-trained panel of 10 judges evaluated the snacks' sensory quality using a 9-point hedonic scale (Peryam *et al*., 1957).

Nutritional evaluation

The products were dried at 60°C for analytical analysis. The standard analysis procedures were used to calculate the moisture, protein, fat, crude fiber and ash contents (AOAC, 2000). According to Lindsay and Norwell's (1969) approach, the total mineral content was calculated. We used the modified approach to determine *in vitro* protein digestibility (Mertz *et al*., 1983) and starch digestibility was evaluated using Singh *et al.* (1982) methodology. Phytic acid in samples was measured using Davies and Reid's method from 1979 and Singh and Jambunathan's method from 1981 was used to extract the polyphenols. The shelf-life of 90 days was assessed by sensory characteristics, fat acidity and lipid oxidation (AOAC, 2000).

Statistic evaluation

According to the accepted methodology, the statistical analysis of the quality evaluation data included mean, standard deviation and ANOVA with three replications (Sheoran and Pannu, 1999) and a T-test was performed for nutritional analysis.

Hypothesis

The question is whether using *jamun* seed powder for pearl millet flour in snack compositions will impact the products' nutritional value and sensory qualities. The sensory and nutritional qualities of the snacks will be the same in this scenario, H0, = 0. Another possibility is Ha: 0 and > 0 (one-tailed test); the snacks' sensory and nutritional characteristics will be better or worse than the control. The sensory and nutritional qualities of the snacks will differ from the control, according to a two-tailed test result of 0.

RESULTS AND DISCUSSION

Sensory analysis

The organoleptic (Table 1) assessment of *Namakpara* and *Mathri*, incorporating *jamun* seeds, power highlighted their sensitivity to seed levels. Lower *jamun* seed amounts preserved sensory acceptability, but higher levels negatively impacted color, appearance, texture, taste and overall acceptability. Control *Namakpara,* made with pearl millet and refined flour, scored 7.90 for color and appearance, 7.60 for aroma, 7.70 for texture, 7.70 for taste and 7.76

Plate 1: *Namakpara.*

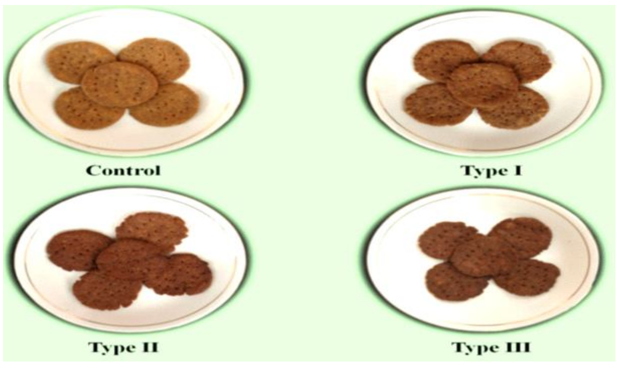

Plate 2: *Mathri.*

overall. Type I *Namakpara* with *jamun* seeds was 'liked moderately,' while Type II and III were 'liked slightly.' *Mathri* remained organoleptically acceptable up to 10% *jamun* seed incorporation, with Type III falling into the "Neither like nor dislike" category. Control *mathri* scored 7.80 for color and appearance, 7.40 for taste, 7.70 for texture, 7.90 for taste and 7.72 overall, placing them in the 'liked moderately" group. The study emphasizes the delicate balance in incorporating *jamun* seeds for optimal sensory appeal in these snacks. The sensory results are supported by Yadav and Yadav (2020) who developed *namakapara, sev, mathri* with a gluten-free flour mix. Tripathi *et al.* (2017) stated that malted nutria flour and leaf powder mix could be used up to 20% without affecting the sensory score. Developed *mathri* with cress garden seed up to 15% was rated desirable for color, appearance, flavor, texture, taste and overall acceptability (Rana and Kaur 2016). Savita *et al.* (2023) found similar sensory results in biscuits, *chapati, dalia and upma* developed with a 20% incorporation of pearl millet and *jamun* seed powder and pearl millets flour. Similar sensory score results were reported by Savita *et al.* (2024) that the incorporation of *jamun* seed powder decreased the sensory score in pasta and noodles. The added *Jamun* seed powder to pearl millet-based snacks may deepen the color due to its polyphenolic content, potentially influencing sensory traits.

Nutritional analysis

The nutrient profile (Table 2) of the snacks was influenced by the *jamun* seed power incorporation, leading to changes in protein (8.84 to 7.34%), fat (28.63 to 23.01%), ash (2.12 to 2.77%), crude fiber (1.07 to 1.51%), calcium (28.82 to 47.47 mg/100 gm), phosphorus (132.43 to 152.53 mg/100 gm), zinc (1.95 to 2.60 mg/100gm), phytic acid (382.23 to 405.23 mg/100 gm) and polyphenols (258.13 to 272.55 mg/100 gm) content. The decrease in crude protein (7.95%, 7.34%) and fat (23.10%, 26.21%) content in Type I samples may be attributed to the substitution effect of *jamun* seeds, which have a lower protein (8.84%, 8.52%) and fat (25.10%, 28.63%) content compared to the control *namakpara* and *mathri* respectively. Conversely, the increase in ash (2.48%, 2.77%) and crude fiber (1.51%, 1.45%) content in Type I samples (*namakpara* and *mathri*) could be due to the mineral and fiber-rich nature of *jamun* seeds. The significant increase in calcium (44.36 and 47.47 mg/100 gm) and zinc (2.53 and 2.60 mg/100 gm) content in Type I samples (*namakpara* and *mathri*) highlights the potential of *jamun* seeds as a source of essential minerals in traditional snacks. However, the decrease in phosphorus (152.53 to 132.43 m g/100 gm) content warrants investigation to further understand the interplay of ingredients affecting phosphorus availability. The *in-vitro* studies indicated that *jamun* seed incorporation led to a reduction in protein digestibility (65.74 to 51.47%) and starch digestibility (29.30 to 31.50 mg maltose released/gm) was not affected by *jamun* seed powder incorporations. The phytic acid (405.23 to 382.23 mg/100 gm) content decreased in formulated products which is a desirable outcome as phytic acid can interfere with mineral absorption. The increase in polyphenols (258.13 to 272.55 mg/100gm) content suggests the potential for *jamun* seeds to contribute to the antioxidant content of the snacks. Results align with Singh (2003) on moisture in *sev* and *matar.* Type I treatments showed significantly lower protein than controls. Fat in control was slightly lower, the ash content in *sev* matched and crude fiber values were lower than Singh's for *sev* and *matar.* Calcium content was quite similar and higher phosphorus in Singh's study could stem from pearl millet variations. *Namakpara* starch digestibility was lower and *sev in-vitro* protein digestibility matched Singh's values (2003). Present results supported by Rana and Kaur (2016) that *mathri* developed with garden cress seeds (15%level) decrease protein, fat and moisture content. Mehra and Singh (2017) reported that pearl millet incorporation in

Table 1: Mean scores for organoleptic acceptability of pearl millet based *jamun* seeds incorporated traditional snacks.

Product	Color	Appearance	Aroma	Texture	Taste	Overall acceptability
			Mean score			
			Namakpara			
Control	7.90±0.18	7.90±0.18	7.60±0.22	7.70±0.26	7.70±0.15	7.76±0.17
Type I	7.70±0.26	7.70±0.26	7.60±0.27	8.00±0.21	7.80±0.25	7.76±0.24
Type II	6.90±0.35	7.00±0.39	7.20±0.20	7.00±0.15	6.75±0.43	6.97±0.27
Type III	6.20±0.29	6.40±0.34	6.80±0.20	6.60±0.16	6.30±0.52	6.46±0.27
C.D. ($P \leq 0.05$)	0.80	0.88	0.64	0.58	1.06	0.69
			Mathri			
Control	7.80±0.20	7.80±0.20	7.40±0.16	7.70±0.21	7.90±0.18	7.72±0.14
Type I	7.05±0.15	7.05±0.15	7.15±0.18	7.05±0.15	6.75±0.27	7.01±0.11
Type II	6.75±0.17	6.65±0.15	6.80±0.20	7.05±0.21	6.60±0.14	6.77±0.15
Type III	6.10±0.23	6.10±0.23	5.70±0.21	5.80±0.24	5.75±0.20	5.89±0.20
C.D. ($P \leq 0.05$)	0.55	0.54	0.55	0.61	0.58	0.45

Values are mean ± SE of ten independent determinations.

mathri increases the nutrient content than cereal-based *mathri.* Kadbhane *et al.* (2019) experiment shows that tandulaja leaf powder (7 gm) in *mathri* increases nutrient content such as protein (11.5gm), fat (24.45%) and ash (2.5 gm). Savita *et al.* (2023) developed biscuits and Indian breakfast items (chapati, dalia, upma) with *jamun* seed powder, assessing their nutritional profile. Nutritional composition such as crude fiber, calcium, iron, zinc and polyphenols content increased while protein, fat, phosphorus and phytic acid content significantly decreased when 10% *jamun* seed powder was added. The incorporation of *Jamun* seed powder into pasta and noodles significantly enhanced their nutritional profile by increasing protein, ash, calcium, iron, zinc, phytic acids and polyphenols, without affecting moisture, fat, fiber, magnesium, protein, or starch digestibility (Savita *et al.,* 2024). This suggests *Jamun* seed powder can be a valuable ingredient for improving the nutritional value of these food products. Control products exhibited similar or better results compared to other samples in terms of moisture, fat, fiber, magnesium, protein and starch digestibility. However, the incorporation of *Jamun* seed powder in snacks made from pearl millets offers the additional advantage of enriching the product with essential minerals, antioxidants and bioactive compounds like phytic acids and polyphenols, thereby potentially enhancing its nutritional value and health benefits. Some recommend limiting phytate intake to 100-400 mg/day, especially if you have digestive issues, mineral deficiencies, or body pain. To minimize micronutrient loss, it is advised to consume less than 25 mg of phytic acid per 100 g of food, as it can inhibit mineral absorption. Typical Western diets contain 250-800 mg of phytate daily, with vegetarian and Mediterranean diets potentially reaching up to 1 gram, while some European/American diets may provide up to 2 grams. (Buades Fuster *et al*., 2017). Additionally, *Jamun* seed powder could introduce a unique flavor profile and contribute to the diversification of snack options, catering to consumer preferences for healthier and more nutrient-dense choices.

Storage study

Table 3 highlights the diverse impacts of incorporating pearl millet-based *jamun* seed powder on the organoleptic scores of Namakpara and Mathri during storage. Type I samples exhibited better retention of sensory attributes than controls, particularly in color, appearance, texture, taste and overall acceptability. Enhanced scores suggest *jamun* seed incorporation improves the snacks' long-term sensory appear. Aroma, however, showed minimal changes during storage. Overall acceptability scores of Type I samples remained comparable to controls initially, but after 30 days, *Mathri* control scores decreased while Type I scores held steady. At 60 and 90 days, both *Namakpara* and *Mathri* control scores dropped further, with Type I samples retaining better scores, notably significant for *Mathri* at 60 and 90 days. Table 4 highlights the impact of *jamun* seed incorporation on lipid quality and oxidative stability during storage. Type I samples showed a significant decrease in fat acidity and peroxide value, indicating potential antioxidant properties, mitigating lipid oxidation and improving snack shelf life and quality. Notably, Singh (2003) reported a significant reduction in overall acceptability scores of *matar*

Table 2: Nutrients of pearl millet based *jamun* seeds incorporated traditional snacks.

	Namakpara			*Mathri*		
Nutrients	Control	Type I	t value	Control	Type I	t value
Proximate compositions (% dry matter basis)						
Moisture*	5.94±0.11	6.13±0.11	2.04 NS	5.95±0.08	6.42±0.49	1.60 NS
Crude protein	8.84±0.13	7.95±0.04	11.12**	8.52±0.37	7.34±0.29	4.26**
Fat	25.10±0.55	23.10±0.50	4.58**	28.63±0.40	26.21±0.70	5.14**
Ash	2.12±0.07	2.48±0.08	5.86**	2.76±0.09	2.77±0.07	0.04 NS
Crude fiber	1.12±0.06	1.51±0.07	7.43**	1.07±0.07	1.45±0.08	6.11**
Total minerals (mg/100 gm on dry matter basis)						
Calcium	28.82±1.12	44.36±0.92	18.51**	31.83±0.25	47.47±0.37	60.20**
Phosphorus	152.53±6.54	137.18±2.05	3.87*	149.23±0.65	132.43±0.24	41.85**
Iron	4.16±0.45	4.47±0.09	1.16 NS	3.88±0.11	4.24±0.13	3.56*
Zinc	1.95±0.11	2.53±0.05	7.58**	2.03±0.06	2.60±0.09	8.96**
Magnesium	98.30±0.75	98.63±0.95	0.46 NS	101.53±3.72	101.74±1.10	0.09 NS
***In vitro* studies**						
Protein digestibility (%)	65.74±2.64	60.65±1.20	3.03 NS	54.83±2.27	51.47±0.59	2.47 NS
Starch digestibility	29.30±1.90	30.44±1.48	0.82 NS	30.56±1.25	31.50±0.75	1. 10 NS
Phytic acid (mg/100 gm)	405.23±2.43	386.51±3.40	7.74**	403.16±6.56	382.23±3.87	4.75**
Polyphenols (mg/100 gm)	258.13±2.15	268.11±3.60	4.11*	262.83±5.02	272.55±2.85	2.91*

Note: *-Significant (P<0.05), **- Significant (P<0.01), NS- Non significant, Values are mean ± SE of three independent determinations, starch digestibility expressed as (mg maltose released/gm).

during storage, emphasizing the importance of ingredient ratios in maintaining acceptability over time. Ahlawat and Jood (2011) stated that the increase in fat acidity could be attributed to the hydrolysis of triglycerides resulting in the formation of free fatty acids with an increased storage period. Possibly, the increment was due to the oxidation of polyunsaturated fatty acids which lead to rancidity and off-flavor development. Savita *et al.* (2023) stated that the incorporation of *jamun* seed powder in pearl millet for the development of biscuits increased the shelf life of stored products. Savita *et al.* (2024) reported that incorporating *Jamun* seed powder into pasta and noodles increases

Table 3: Changes in organoleptic scores of pearl millet based *jamun* seeds incorporated traditional snacks during storage.

Days	Variable	*Namakpara*			*Mathri*		
		Control	Type I	t-value	Control	Type I	t-value
0	Color	7.90±0.56^{a}	7.70±0.82^{a}	0.63^{NS}	7.80±0.63^{a}	7.05±0.49^{a}	2.94**
30		7.80±0.78^{a}	7.40±0.96^{a}	1.01^{NS}	7.65±0.57^{ab}	7.00±0.66^{a}	2.32*
60		7.20±0.48^{b}	7.10±0.51^{a}	0.44^{NS}	7.30±0.48^{b}	6.80±0.42^{a}	2.46*
90		7.00±0.66^{b}	7.05±0.59^{a}	0.17^{NS}	7.30±0.48^{b}	6.80±0.42^{a}	2.46*
0	Appearance	7.90±0.56^{a}	7.70±0.82^{a}	0.63^{NS}	7.80±0.63^{a}	7.05±0.49^{a}	2.94**
30		7.50±0.70^{ab}	7.10±0.73^{ab}	1.23^{NS}	7.65±0.74^{a}	7.00±0.66^{a}	2.05*
60		7.20±0.48^{b}	6.70±0.48^{b}	2.31*	7.35±0.47^{a}	6.95±0.36^{a}	2.10*
90		7.00±0.66^{b}	6.65±0.66 ^{b}	1.17^{NS}	7.30±0.42^{a}	6.90±0.51^{a}	1.89^{NS}
0	Aroma	7.60±0.69^{a}	7.60±0.84^{a}	0.00^{NS}	7.40±0.51^{a}	7.15±0.57^{a}	1.01^{NS}
30		7.30±0.82^{a}	7.00±0.66^{a}	0.89^{NS}	7.35±0.57^{a}	7.10±0.56^{a}	0.97^{NS}
60		6.10±0.84^{b}	6.00±0.66^{b}	0.29^{NS}	5.50±0.70^{b}	5.35±0.57^{b}	0.51^{NS}
90		5.85±0.74^{b}	5.75±0.63^{b}	0.32^{NS}	5.40±0.51^{b}	5.05±1.01^{b}	0.97^{NS}
0	Texture	7.70±0.82^{a}	8.00±0.66^{a}	0.89^{NS}	7.70±0.67^{a}	7.05±0.49^{ab}	2.45*
30		7.40±0.69^{a}	7.20±0.78^{b}	0.60^{NS}	7.25±0.54^{ab}	7.10±0.56^{a}	0.60^{NS}
60		6.80±0.34^{b}	6.60±0.51^{c}	1.01^{NS}	7.00±0.40^{b}	6.75±0.35ab	1.46^{NS}
90		6.70±0.48^{b}	6.50±0.52^{c}	0.88^{NS}	6.90±0.39^{b}	6.65±0.41^{b}	1.38 ^{NS}
0	Taste	7.70±0.48^{a}	7.80±0.78^{a}	0.34^{NS}	7.90±0.56^{a}	6.75±0.85^{ab}	3.53**
30		7.40±0.69^{a}	7.10±0.73^{b}	0.93^{NS}	7.65±0.57^{a}	7.30±0.67^{a}	1.24^{NS}
60		6.70±0.34^{b}	5.90±0.56^{c}	3.79**	6.50±0.52^{b}	6.30±0.42^{bc}	0.93^{NS}
90		6.50±0.52^{b}	5.55±0.83^{c}	3.05**	6.40±0.51^{b}	5.95±0.49^{c}	1.98^{NS}
0	Overall	7.76±0.52 a	7.76±0.74^{a}	0.00^{NS}	7.72±0.44^{a}	7.01±0.36^{ab}	3.89**
30	acceptability	7.48±0.68^{a}	7.16±0.69^{b}	1.03 ^{NS}	7.51±0.49^{a}	7.10±0.51^{a}	1.80^{NS}
60		6.80±0.25^{b}	6.46±0.29^{c}	2.74**	6.73±0.44^{b}	6.43±0.29^{b}	1.77^{NS}
90		6.61±0.23^{b}	6.30±0.40^{c}	2.09*	6.66±0.24^{b}	6.27±0.23^{b}	3.65**

Values are mean ± SE of ten independent determinations, Note I: The t-value indicates the difference between control and Type I treatment at different intervals, Note II: *- Significant (P<0.05), **- Significant (P<0.01), NS- Non significant, Note III: Means varying different superscripts in a row differs significantly (p<0.05).

Table 4: pearl millet based *jamun* seeds incorporated traditional snacks (dry matter basis) during storage.

Days	Variable	*Namakpara*			*Mathri*		
		Control	Type I	t-value	Control	Type I	t-value
0	Fat acidity (mg	37.06±0.03^{d}	35.74±2.43^{d}	0.93^{NS}	35.08±0.03^{d}	30.35±0.39^{d}	20.92**
30	KOH/100 g)	72.15±0.15^{c}	69.54±0.24^{c}	15.85**	77.33±0.37^{c}	72.72±0.15^{c}	19.73**
60		115.40±0.36^{b}	112.09±0.09^{b}	15.32**	121.03±0.25^{b}	116.39±2.32^{b}	3.43**
90		143.40±3.40^{a}	141.28±1.66^{a}	0.96^{NS}	142.77±0.66^{a}	137.25±0.56^{a}	10.95**
0	Peroxide value	4.25±0.04^{d}	4.13±0.05^{d}	2.91*	4.45±0.01^{d}	4.22±0.02^{d}	16.75**
30	(meq/1000 g of	7.61±0.01^{c}	7.43±0.02^{c}	13.00**	7.72±0.01^{c}	7.57±0.03^{c}	7.77**
60	fat)	10.50±0.01^{b}	10.39±0.02^{b}	6.47**	11.47±0.03^{b}	11.32±0.02^{b}	7.27**
90		13.86±0.05^{a}	13.42±0.04^{a}	10.71*	15.36±0.02^{a}	14.33±0.08^{a}	20.35**

Values are mean ± SE of three independent determinations, Note I: The t-value indicates the difference between control and Type I treatment at different intervals, Note II: *- Significant (P<0.05), **- Significant (P<0.01), NS- Non significant, Note III: Means varying different superscripts in a row differs significantly (p<0.05).

their shelf life during storage periods (90 days). Pearl millet, while rich in nutrients, poses challenges due to its anti-nutrient content, which lowers nutrient bioavailability and necessitates strategies to manage bitterness and rancidity (Nantanga *et al*., 2008). Enzymatic breakdown during storage can lead to an increase in product fatty acids and peroxide value over time (Chaiyasit *et al*., 2007; Yadav *et al*., 2014). Moreover, light exposure accelerates oxidation while fat acidity, influenced by moisture and lipolysis, tends to rise during storage and is associated with bitterness (Nantanga *et al*., 2008). Overall, the findings from this study demonstrate the potential of pearl millet-based *jamun* seed incorporation in improving the lipid quality and oxidative stability of traditional snacks during storage.

CONCLUSION

The present study revealed that incorporating up to 10% *jamun* seed powder optimally enhances the nutritional profile without significantly affecting sensory scores. This enrichment increased protein, ash, calcium, iron, zinc, phytic acids and polyphenols while maintaining moisture, fat, fiber, magnesium, protein and starch digestibility. Storage studies indicated that *jamun* seed powder incorporation also extended the shelf life of these products. Leveraging *jamun* seeds' nutritional potential allows the food industry to promote healthier snacking options and meet the growing demand for nutritious and palatable foods. Overall, the findings from this study offer valuable information for snack manufacturers and food technologists in developing healthier and more nutritious snacks without compromising on sensory quality. However, finding the right balance between nutritional enhancements and maintaining sensory is essential for successful product development.

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