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Nutritional, sensory and shelf-life analysis of pearl millet-based value-added biscuits enriched with *jamun* seed powder

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ABSTRACT: Pearl millet, also known as *bajra,* is a highly nutritious and drought-resistant cereal crop, rich in protein, dietary fiber, essential amino acids, vitamins, and minerals. On the other hand, *jamun* seeds have been found to possess beneficial health properties, such as antioxidants, anti-diabetic, and anti-inflammatory effects. Combining the nutritional benefits of pearl millet with the functional properties of *jamun* seeds in the form of biscuits could result in a healthy and convenient snack option. This study evaluated the nutritional composition, sensory attributes, and shelf-life of value-added biscuits made from pearl millet flour (HC 10 variety) enriched with 20% *jamun* (*Syzygium cumini*) seed powder. The incorporation of *jamun* seed powder in pearl millet-based value-added biscuits (HC 10 variety) positively impacted their nutritional composition, sensory attributes, and shelf life. The addition of *jamun* seed powder show significant differences in the crude fiber (0.71 to 1.14%), calcium (47.13 to 63.18 mg/100gm), phytic acid (362.13 to 347.09 mg/100gm) and mineral content, and overall nutritional value. *In vitro* digestibility was not affected by incorporation of *jamun* seed powder. In *jamun* seed powder the flavonoids, glycosides, phytosterols, tannins were present and triterpenoids was absent during screening test. Moreover, the inclusion of *jamun* seed powder improved the flavor, aroma, and overall acceptability of the biscuits, while also extending their shelf life by delaying lipid oxidation. As a result, the value-added biscuits have the potential to offer additional health benefits, making them a valuable addition to the diet.

Key words: *Jamun* seed powder, pearl millet, sensory, *in vitro* digestibility, nutrients

Pearl millet (*Pennisetum glaucum*) is a vital crop and a staple food in arid regions of Asia, Africa, and the Middle East. In countries like India and Nigeria, it serves as a significant substitute for major cereals to address food shortages and meet the nutritional demands of the growing population. Pearl millet plays a crucial role in India's integrated agricultural and livestock economy due to its ability to thrive in harsh environmental conditions and infertile sandy soils (Singh, 2003). It is often referred to as a "nutricereal" due to its abundant energy, carbohydrates, proteins, fats, ash, dietary fiber, and essential minerals such as iron, calcium, magnesium, and potassium (Kaushik and Grewal, 2017). Moreover, it contains polyphenols (Vaijapurkar *et al.,* 2015), has a low glycemic index (55), and is gluten-free (Nambiar *et al.,* 2011). These attributes make pearl millet beneficial for managing health conditions like diabetes mellitus, obesity, and hyperlipidemia, thus offering several health benefits when incorporated into daily diets (Veena, 2004).

India is a leading producer of *Jamun*, contributing approximately 15.4% of the worldwide production of 13.5 million tonnes (Raza *et al.,* 2015). *Jamun* fruit consists of about 75% pulp (including skin) and 25% seeds, both of which possess substantial nutritive value and phytochemicals like Jambosine, gallic acid, ellagic acid, corilagin, 3,6-hexahydroxy diphenoyl glucose, 1-galloylglucose, 3-galloylglucose, quercetin, β-sitosterol, and 4,6-hexahydroxydiphenoylglucose (Rahman and Baishnab, 2016). The seeds contain approximately 16.34% moisture, 1.97% crude protein, 0.65% crude fat, 4.19% crude fiber, 2.18% ash, and 74.67% nitrogen-free extracts (NFE) (Raza *et al.,* 2015). *Jamun* seeds show potential as a cost-effective candidate for effectively controlling blood sugar levels in patients with type 2 diabetes, particularly in rural populations. They can serve as an easily available and affordable alternative to existing drugs (Sidana *et al.,* 2017). Notably, *jamun* seed powder and products incorporating it have demonstrated significant positive effects on lowering blood glucose and lipid profiles when consumed for two months. Moreover, *jamun* seeds are widely prescribed in alternative medicine systems like Unani and Ayurveda for diabetes management. The presence of a glucoside called jamboline and alkaloid jambosine in *jamun* seeds enables the inhibition of starch-to-sugar conversion when consumed at doses of 2-3 g/day, which benefits diabetics and healthy individuals alike (Banu and Jyothi, 2016). This study aims to develop value-added biscuits using pearl millet and *jamun* seeds, and subsequently evaluate their organoleptic acceptability, nutritional composition, and storage characteristics. By creating these products, individuals can easily incorporate *jamun* seed powder into their diets and obtain the recommended dose effectively.

MATERIALS AND METHODS

Procurement of material

Pearl millet (variety HC 10) was procured from the department of Genetics and Plant Breeding, CCS, HAU, Hisar. The pearl millet (Plate 1) grains were cleaned by washing to get rid of all the dirt, soil, and foreign material before biscuit development. Fresh *Jamun* fruits were procured from a local market in Hisar. *Jamun* fruits were washed, pulp extracted, seeds separated, and dried in shade (24 hours at room temperature) and then kept in a hot air oven at 55±5°C to dry the seeds completely (3.90 % moisture level). Dried seeds (Plate 2) were powdered, sieved, and stored in clean and hygienic conditions for further use.

Ingredients used in biscuit preparations: confectionery sugar (25gm), salt (2.5gm), ghee (40gm), milk (25ml), ammonium bicarbonate (4gm), sodium bicarbonate (½ tsp), cumin seeds (1.5gm) in equal amount in all types of develop biscuits and pearl millet flour (40-50gm), refined flour (40-50gm) and *jamun* seed powder (10-20gm) in different ratios such as

Control = pearl millet flour (50gm), refined flour (50gm)

Type I = pearl millet flour (45gm), refined flour (45gm), *jamun* seed powder (10gm)

Type II = pearl millet flour (42.5gm), refined flour (42.5gm), *jamun* seed powder (15gm)

Type III = pearl millet flour (40gm), refined flour (40gm), *jamun* seed powder (20gm)

Biscuits Development: Pearl millet flour, refined flour, and *jamun* seed powder were sieved together. Ghee was creamed manually and then sugar and milk were added. Ammonium bicarbonate and sodium bicarbonate were added and the paste was creamed again. The flour mixture was added to the creamed paste and dough was formed. The dough was rolled, cut into shapes, and baked at a 160°C temperature to produce biscuits.

Sensory evaluation

The biscuits were subjected to sensory evaluation using 9-point hedonic scale by a semi-trained panel of 10 judges. (Peryam *et al.,* 1957). All the acceptable biscuits were subjected to nutritional analysis.

Nutritional analysis

The proximate composition of biscuits was determined by employing the standard methods of analysis AOAC, (2000). The moisture content of samples was determined after drying at 60°C until a constant weight was attained. Crude protein was estimated by micro-kjeldahl method, using automatic KEL-PLUS CLASSIC DX apparatus. Crude fat was estimated using Soxhlet extraction apparatus. Crude fiber and ash contents were determined by employing the standard method of analysis (AOAC, 2000). Total minerals content was determined by the method of Lindsay and Norwell, (1969). In- vitro protein digestibility was estimated by employing the modified method of Mertz *et al.* (1983), and starch digestibility was assessed as per the method of Singh *et al.*(1982). Phytic acid in biscuit samples was determined by using the method of Davies and Reid (1979) and the polyphenols were extracted by the method of Singh and Jambunathan (1981). The shelf-life of the biscuits was evaluated by monitoring changes in sensory attributes, fat acidity, and lipid oxidation during storage a period for 3 months under controlled conditions and they were evaluated for their organoleptic acceptability at the interval of 30 days for the storage period (AOAC, 2000).

Statistical analysis

The quality evaluation data were statistically analysed, using mean, standard error, and ANOVA according to the standard method (Sheoran and Pannu, 1999).

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

RESULTS AND DISCUSSION

Nutrients content in pearl millet flour

The data obtained on the chemical composition of HC10 variety of pearl millet flour are presented in Table 1 showing that the moisture content of pearl millet was found to be 10.63%. The results obtained were lying in the moisture range (10.15 to 11.26%) in pearl millet reported earlier by Mamta (2015) whereas NIN (Longvah *et al.,* 2017) reported lower moisture content (8.97%) in pearl millet. Protein content of pearl millet found in the present study (10.77%) was in agreement with the results reported by NIN (Longvah *et al.,* .2017) (10.96 g/100g protein), Kuthe *et al.* (2016) (10.97 to 11.65%) while Jaybhaye *et al.* (2014), Mamta (2015), and Sade (2009) reported higher values for protein which may be attributed to different varieties of pearl millet studied. The result obtained was in accordance with the fat (5.37%) content reported by NIN (Longvah *et al.,* 2017), Mamta (2015), and Kulthe *et al.* (2016) i.e.5.03 to 6.37% respectively. Comparatively lower fat content was reported by Mehra and Singh (2017), Jaybhaye *et al.* (2014). Ash content in pearl millet was recorded as 2.23% which was almost similar to previous reported by Mehra and Singh, (2017) (2.3%), Jaybhaye *et al.* (2014) (2.2%), Kulthe *et al.* (2016) (2.05 to 2.72 %) in various varieties of pearl millet. The crude fiber content in pearl millet was 1.86% almost similar to the range (1.2 to 2.3 g/100g) reported earlier by Nambiar *et al.* (2011). Calcium content of pearl millet was found to be 34.17 mg/100g. The results obtained complied with the range given by Nambiar *et al.* (2011) and Kaushik and Grewal (2017) who reported that calcium content in pearl millet varied from 25 to 42 mg/100g and 27.2 to 37.3 mg/100g, respectively. Pearl millet contained 219.36 mg/100g phosphorus that was found to be lower than the values reported by Nambiar *et al.* (2011) and Kulthe *et al.*(2016) which may be due to varietal difference. Obtained results of iron content in pearl millet (6.23 mg/100g) were in accordance with the ranges (2.7 to 6.4 mg/100g and 5.08 to 8.12 mg/100g) provided in earlier studies by Kaushik and Grewal (2017) and Kulthe *et al.* (2016), respectively. The zinc content of pearl millet was 3.23 mg/100g the values were agreeable to the

Table 1: Nutritional composition of pearl millet and *jamun* seed powder

	Pearl millet	*Jamun* seed powder
	Proximate composition (%)	
Moisture	10.63±0.32	3.90±0.02
Protein	10.77±0.08	6.21±0.14
Fat	5.37±0.06	2.87±0.04
Ash	2.23±0.03	2.42±0.03
Crude fiber	1.86±0.05	5.16±0.07
	Total minerals (mg/100g)	
Calcium	34.17±0.78	209.43±2.39
Phosphorus	219.36±3.12	98.04±0.57
Iron	6.23±0.18	8.44±0.11
Zinc	3.23±0.03	7.74±0.05
Magnesium	118.53±1.70	103.09±0.99
Vitamin C(mg/dl)		17.65±0.72
DPPH (%)		79.45±0.89
	In vitro studies	
Protein digestibility (%)	49.46±0.29	
Starch digestibility (mg maltose released /g)	20.62±0.26	
Anti-nutritional factors (mg/100g)		
Phytic acid	618.07±3.39	
Polyphenols	476.30±2.19	

Values are mean ± SE of three independent determinations

Table 2: Screening of *jamun* seed powder for presence of preliminary phytochemicals

Phytochemical nature	*Jamun*
Flavonoids	+
Glycosides	+
Phytosterol	+
Tannins	+
Triterpenoids	-

range of 3.09 to 4.28 mg/100g, as reported by Mamta (2015). Lower values were reported by Kaushik and Grewal (2017) and Nambiar *et al.* (2011). The magnesium content in pearl millet was 118.53 mg/100g. The results obtained were lying within the range (106 to137 mg/100) which was reported by Nambiar *et al.* (2011). The *in vitro* protein digestibility of pearl millet was obtained to be 49.46%. Similar values for protein digestibility have been reported in earlier study by Archana *et al.* (2000), Anju (2005) and Suma and *Urooj* (2011) that ranged from 47.03 to 51.77, 47.30 to 61.17 and 45.5 to 49.3%, respectively in pearl millet. *In vitro* starch digestibility of pearl millet was 20.62 mg maltose released/g that was agreeable to the range (16.39 to 22.68 mg maltose released/g) reported earlier in a study by Anju (2005) in pearl millet. Phytic acid content of pearl millet was 618.07 mg/100g. Kulthe *et al.* (2016) reported 566.67 to 618.85 mg/100g phytic acid in pearl millet which showed similarity to the results obtained in the present study. The polyphenols content of pearl millet was observed to be 476.30 mg/100g. The results obtained were agreeable to the range 285 to 790 mg/100g given by Poonam (2002). Kulthe *et al.* (2016) reported lower polyphenols content in pearl millet.

Nutrient content in *jamun* seed powder

The proximate composition of *jamun* seed powder was presented in Table 1. The moisture content in *jamun* seed powder i.e. 3.90% showed similarity to the value (3.2%) reported by Ayya (2015). Results obtained for protein content in *jamun* seed powder was 6.21% which was lower than the value reported by Sehwag and Das (2014) i.e. 6.8 and higher than the value reported by Kochhar *et al.*(2006), Ayya *et al.,* (2015) and Raza *et al.,* (2015). The fat content in *jamun* seed powder was 2.87%. The results obtained were higher than the values (1.55, 0.65 and 0.35%) reported by Kochhar *et al.,* (2006), Raza *et al.* (2015) and Sehwag and Das (2014), respectively whereas lower than the value given by Ayya *et al.* (2015) who reported 4.86 per cent fat in *jamun* seeds. Ash content in *jamun* seed powder was observed to be 2.42%. The results obtained in present study were higher than the values reported by Kochhar *et al.* (2006), Raza *et al.* (2015) and Sehwag and Das (2014) who reported 2.16, 2.18 and 2.0% ash in *jamun* seeds, respectively which may be attributed to the reason that the outer covering of *seed* was included in present study. Crude fiber content was 5.16% in *jamun* seed powder. Lower values were reported by Kochhar *et al.*(2006), Raza *et al.* (2015) and Sehwag and Das (2014). The presence of outer covering of *jamun* seed in *jamun* seed powder could be the reason behind higher crude fiber. The calcium content in *jamun* seed powder was 209.43 mg/100g that was in accordance with the range 210.40 to 214.96 mg/100g reported by Shahnawaz *et al.* (2012). *Jamun* seed power contained 98.0 mg/100g phosphorus content. This might be due to the use of

Table 3: Mean scores for organoleptic acceptability of value-added biscuits

Sensory characteristics	Types			
	Control	Type I	Type II	Type III
Colour	7.80±0.20	7.50±0.27	7.40±0.27	6.70±0.30
Appearance	8.00±0.26	7.50±0.27	6.90±0.28	6.90±0.29
Aroma	7.90±0.23	7.80±0.20	7.40±0.27	7.10±0.23
Texture	8.10±0.23	7.90±0.23	7.30±0.21	7.10±0.23
Taste	7.80±0.20	7.50±0.17	7.10±0.23	6.30±0.21
Overall Acceptability	7.86±0.21	7.64±0.15	7.22±0.19	6.82±0.17

Values are mean ± SE of ten independent determinations.

Table 4: Nutrients composition of pearl millet based *jamun* seeds incorporated biscuits (dry matter basis)

Biscuits	Proximate%				
Types	Moisture	Protein	Fat	Ash	Crude fiber
Control	3.19±0.15	9.56±0.32	21.66±0.58	1.76±0.01	0.71±0.02
Type I	3.09±0.90	8.85±0.20	20.33±1.25	1.87±0.11	1.14±0.05
t-value	0.96 NS	3.22*	1.67 NS	1.64 NS	12.16**
	Minerals (mg/100gm)				
	Calcium	Phosphorus	Iron	Zinc	Magnesium
Control	47.13±0.30	210.90±0.20	4.19±0.05	2.15±0.05	115.63±0.55
Type I	63.48±2.15	195.14±3.73	4.61±0.11	2.70±0.02	114.44±1.90
t-value	13.02**	7.30**	5.90**	17.12**	1.04 NS

	In vitro studies			
	PD	SD	Phytic acid	Polyphenols
Control	65.50±2.86	30.66±0.30	362.13±0.25	241.21±0.45
Type I	60.61±2.90	31.57±0.72	347.09±4.33	253.40±3.16
t-value	2.07 NS	2.00 NS	5.99*	6.61*

Phytic acid = mg/100gm, Polyphenols (mg/100gm), PD= Protein Digestibility (%), SD = Starch Digestibility (mg maltose release/ gm) ,*- significant (P<0.05), **- significant (P<0.01), NS- non significant

Table 5: Changes in organoleptic scores of pearl millet based *jamun* seeds incorporated biscuits during storage

Variables		No. of days			
		0	30	60	90
Colour	Control	8.00±0.81 a	7.80±0.63 a	7.60±0.51 a	7.45±0.49 a
	Type I	7.65±0.47 a	7.50±0.84 ab	7.30±0.48 ab	7.05±0.49 b
	t-value	1.17 NS	0.89 NS	1.34 NS	1.79 NS
Appearance	Control	8.10±0.73 a	8.00±0.81 ab	7.80±0.42 ab	7.50±0.52 b
	Type I	7.75±0.42 a	7.50±0.84 a	7.30±0.48 a	7.20±0.63 a
	t-value	1.29 NS	1.34 NS	2.46*	1.15 NS
Aroma	Control	8.00±0.66 a	7.80±0.63 a	6.60±0.51 b	6.45±0.59 b
	Type I	7.85±0.33 a	7.90±0.73 a	6.50±0.52 b	6.40±0.69 b
	t-value	0.63 NS	0.32 NS	0.42 NS	0.17 NS
Texture	Control	7.90±0.73 a	8.00±0.66 a	6.85±0.24 b	6.70±0.48 b
	Type I	7.75±0.42 a	8.00±0.81 a	6.60±0.51 b	6.45±0.55 b
	t-value	0.55 NS	0.00 NS	1.38 NS	1.07 NS
Taste	Control	7.90±0.87 a	7.70±0.48 a	6.80±0.58 b	6.60±0.51 b
	Type I	7.85±0.57 a	7.60±0.69 a	6.50±0.52 b	6.40±0.51 b
	t-value	0.15 NS	0.37 NS	1.20 NS	0.86 NS
Overall acceptability	Control	7.98±0.72 a	7.86±0.51 a	7.13±0.31 b	6.94±0.27 b
	Type I	7.77±0.36 a	7.70±0.61 a	6.84±0.30 b	6.70±0.20 b
	t-value	0.82 NS	0.63 NS	2.05*	2.22*

Values are mean ± SE of ten independent determinations, *- significant (P<0.05), **- significant (P<0.01), NS- non significant

heterogeneous varieties and the presence of an outer covering in the *jamun* seed powder sample used during the present study. The iron content in *jamun* seed powder was 8.44 mg/100g. The value obtained was almost near to the range (8.53 to 9.41 mg/100g) reported by Shahnawaz *et al.* (2012) whereas Ayya *et al.* (2015) reported higher amount of iron in *jamun* seed powder. Zinc content of *jamun* seed powder was 7.74 mg/100g which was higher than the range (5.67 to 6.95 mg/100g) reported by Shahnawaz *et al.* (2012) and lower than the value reported by Ayya *et al.* (2015). The results suggested 103.09 mg/100g magnesium in *jamun* seed powder. The results obtained were lying in the range (98.58 to 103.30 mg/100g) reported by Shahnawaz *et al.* (2012). The vitamin C content of *jamun* seed powder was 17.65

Table 6: Fat acidity (mg KOH/100g) and Peroxide value (meq/1000g of fat) of pearl millet based *jamun* seeds incorporated biscuits (dry matter basis) during storage

Variable	Treatment	Days			
		0	30	60	90
Fat acidity	Control	28.08±0.10 ^{d}	58.29±0.25 ^{c}	83.34±0.30 ^{b}	118.36±0.32 ^{a}
	Type I	25.08±0.06 ^{d}	56.29±0.15 ^{c}	80.33±0.48 ^{b}	113.66±0.39 ^{a}
	t-value	42.71**	11.71**	9.01**	16.09**
Peroxide value	Control	3.64±0.02 ^{d}	6.97±0.02 ^{c}	9.84±0.02 ^{b}	11.57±0.04^{a}
	Type I	3.52± 0.01^{d}	6.85±0.02 ^{c}	9.68±0.01 ^{b}	10.87±0.06 ^{a}
	t-value	7.25**	6.26**	9.26**	15.92**

Note: *- significant (P<0.05), **- significant (P<0.01), NS- non significant, Values are mean ± SE of three independent determinations

mg/dl. The antioxidant activity in *jamun* seed powder was 79.45 per cent. The results obtained were lower than the antioxidant activity (93.48 per cent) reported by Shahnawaz (2010). This might be due to the difference in processing technique used for drying of *jamun* seeds.

Presence of phytochemicals in *jamun* seed powder

In the present study, methanol extract of *jamun* seed powder showed the presence of flavonoids, glycosides, phytosterols, and tannins but triterpenoids were not detected in the extract as presented in Table 2. The results obtained in the present study were agreeable to the findings of the previous workers except in the case of triterpenoids, as Modi *et al.* (2010) and Kumar *et al.* (2009) reported the presence of flavonoids, glycosides, phytosterols, tannins, and triterpenoids. This might be due to the difference in the processing method used for sample preparation. These phytochemicals contribute to the protective and disease-preventive properties or the medicinal properties of *jamun* seeds.

Sensory evaluation

The value-added biscuits were organoleptically (table 3) acceptable up to 20% incorporation of *jamun* seeds powder in terms of colour, appearance, aroma, texture, taste, and overall acceptability. The control biscuits received the highest mean score for overall acceptability (7.86±0.21), followed closely by Type I biscuits (7.64±0.15), and Type II biscuits (7.22±0.19). Type III biscuits had the lowest mean score for overall acceptability (6.82±0.17). The differences in overall acceptability scores among the different types were noticeable and statistically significant ($p < 0.05$). The control and type I scored 'liked very much' and type II and type III scored 'liked moderately'. The scores were comparable to the results of various similar studies. Mehra and Singh (2017) analyzed biscuits prepared with 50:50 ratio of wheat and pearl millet flour for their organoleptic acceptability and reported that the biscuits were in 'liked very much' category. Vaijapurkar *et al.* (2015) reported that the biscuits prepared with 50:50 ratio of pearl millet flour and wheat flour were in 'liked very much' category. Kalse *et al.* (2016), Patil *et al.* (2014) and Priyanka and Mishra (2015) reported that biscuits prepared with the incorporation of *jamun* seed powder up to 9, 8 and 10 % were organoleptically acceptable. Singh (2003) reported that biscuits prepared with pearl millet flour and soybean flour was 'liked very much'. Thorat and Khemnar (2015) reported that *jamun* seed powder up to 40% level of incorporation in cookies was organoleptically acceptable. Maximum permitted limit of *jamun* seed powder is 5-10 gm and as raw herb limit is 3-5 gm per day for adult consumption (FSSAI regulation 2016).

Nutritional composition of biscuits

The biscuits were compared with a control group to evaluate the impact of *jamun* seed incorporation on their proximate and mineral composition, as well as *in vitro* studies related to protein digestibility, starch digestibility, phytic acid, and polyphenols (table 4). The proximate analysis of the biscuits revealed slight variations in their moisture, protein, fat, ash, and crude fiber content. Biscuits of Type I, enriched with *jamun* seed powder, exhibited marginally lower moisture content (3.09±0.90%) compared to the control (3.19±0.15%). However, the difference was not statistically significant (NS). Notably, Type I biscuits showed a lower protein content (8.85±0.20%) than the control (9.56±0.32%), with a statistically significant decrease ($p < 0.05$). Conversely, the fat content in Type I biscuits (20.33±1.25%) was not significantly different from the control (21.66±0.58%), suggesting that *jamun* seed incorporation did not affect the fat content significantly. The ash content was slightly higher in Type I biscuits (1.87±0.11%) compared to the control (1.76±0.01%), although the difference was not statistically significant (NS). Interestingly, the crude fiber content in Type I biscuits (1.14±0.05%) was significantly higher than the control (0.71±0.02%) with a p-value of 0.001 (12.16^{**}), indicating that the *jamun* seed powder contributed to increased dietary fiber content in the biscuits. The mineral analysis showed significant variations in the calcium, phosphorus, iron, zinc, and magnesium content between the control and Type I biscuits. Type I biscuits had a significantly higher calcium content (63.48±2.15 mg/100g) compared to the control (47.13±0.30 mg/100g), with a p-value of 0.001 (13.02^{**}). Conversely, the phosphorus content in Type I biscuits (195.14±3.73 mg/100g) was lower than the control (210.90±0.20 mg/100g), with a p-value of 0.001 (7.30^{**}). Interestingly, Type I biscuits exhibited a slightly higher iron content (4.61±0.11 mg/100g) compared to the control (4.19±0.05 mg/100g), which was statistically significant ($p < 0.05$). Moreover, the zinc content in Type I biscuits (2.70±0.02 mg/100g) was significantly higher than the control (2.15±0.05 mg/100g) with a p-value of 0.001 (17.12^{**}). However, there was no significant difference in magnesium content between the two groups ($p > 0.05$, NS).In the *in vitro* studies, the protein digestibility (60.61 to 65.50%) and starch digestibility (30.66 and 31.57 mg maltose released/g) were not significantly different between the control and Type I biscuits ($p > 0.05$, NS). However, the phytic acid content in Type I biscuits (347.09±4.33 mg/100g) was significantly lower than the control (362.13±0.25 mg/100g) with a p-value of 0.05 (5.99^{*}), indicating potential improvement in mineral bioavailability due to reduced phytic acid levels. Additionally, the polyphenol content in Type I biscuits (253.40±3.16 mg/100g) was significantly higher than the control (241.21±0.45 mg/100g) with a p-value of 0.05 (6.61^{*}), suggesting enhanced antioxidant properties. The results obtained for control biscuits were lower than the moisture content reported by Singh (2003). The phytic acid hinders minerals absorption (iron, zinc, magnesium, calcium) by binding them, reducing their uptake. According to Coulibaly *et al.* (2011), grains have a phytic acid concentration that ranges from 0.5 to 2 g/100 g. Pearl millet contains between 307 to 714 mg of polyphenols per 100 grams (Abdelrahman *et al.,* 2005).

Shelf life study of biscuits

Sensory evaluation: The overall acceptability scores of the biscuits showed (table 5) a decline as the storage period (90 days) increased. This decline indicates that the sensory appeal and consumer preference for both types of biscuits may decrease over time. Notably, at day 60 and day 90, the Type I biscuits received slightly lower overall acceptability scores compared to the control biscuits. These differences were statistically significant at day 60 ($p < 0.05$, *) and day 90 ($p < 0.01$, **). These changes in sensory attributes are common during prolonged storage and are attributed to various factors, including lipid oxidation, moisture migration, and changes in volatile compounds. A similar trend was observed in a corresponding study by Thaplial (2011), who reported that the overall acceptability mean scores of biscuits (melting moments prepared from chickpea flour) were almost similar up to 30th day (liked very much) and significantly declined during storage in the category of 'liked moderately' on 90thday. Fat acidity and peroxide value: As the storage period progressed, the fat acidity of both types of biscuits increased significantly that suggests that the fats and oils used in their preparation underwent hydrolysis, leading to the formation of free fatty acids. The higher fat acidity observed in the control (28.08 to 118.36 mg KOH/100g), biscuits

Plate 1: Pearl millet

Plate 2: *Jamun* seed Powder

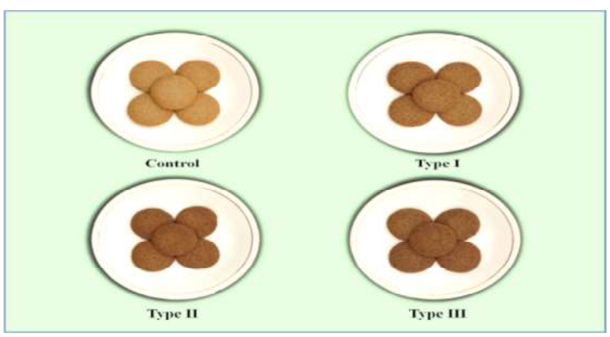

Plate 3: Types of value-added biscuits

may be attributed to the presence of unsaturated fats, which are more susceptible to hydrolytic reactions. Higher peroxide values indicate greater oxidative deterioration and decreased product quality. Throughout the storage period, both types of biscuits showed a significant increase in peroxide value. The peroxide value of control biscuits from zero to 90 day varied from 3.64 to 11.57 meq/1000g of fat, and in Type I biscuits it was increased from 3.52 to 10.87 meq/1000g of fat. The incorporation of *jamun* seed powder in Type I biscuits may have contributed to the antioxidants, such as polyphenols, present in *jamun* seeds, which could have delayed the onset of lipid oxidation compared to the control biscuits. Singh (2003) reported a similar trend of increasing fat acidity of biscuits during 90 days of storage, but the mean values for fat acidity were contradictory to the results obtained in the present study.

CONCLUSION

The study results revealed promising nutritional content, acceptable sensory attributes, and an extended shelf-life for these value-added biscuits, making them a viable and healthy snack option. *Jamun* seeds possess hypoglycemic properties and these are widely consumed by diabetic people. But the direct consumption of *jamun* seed powder is uneasy, hence, these value-added products can easily be consumed by normal healthy people as well as diabetic people. Biscuits supplemented with *jamun* seed powder can be consumed by diabetic as well as health-conscious people to get a daily dose of *jamun* seed powder in a tastier manner. The sensory evaluation confirmed that the biscuits maintained their palatability while offering additional health benefits. Moreover, the extended shelf-life suggests that these biscuits can be stored without compromising their quality, making them suitable for commercial production and distribution.

Recommendations: These findings can guide further product development and optimization to enhance the sensory attributes of the biscuits. Manufacturers must strike a balance between value addition and sensory quality to create successful and appealing value-added biscuits for consumers. Further research and consumer preference studies may be required to understand the reasons behind the differences in acceptability and make targeted improvements in the biscuit formulation.

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