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Exploring the nutritional advantages of bamboo (*Dendrocalamus strictus*) shoot powder fortification in biscuits

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Abstract
The utilization of bamboo shoot powder (BSP) in food fortification presents a promising avenue for enhancing the nutritional value of staple foods. This research explores the nutritional advantages of incorporating *Dendrocalamus strictus* shoot powder into biscuits, aiming to provide healthier snack options to consumers. Bamboo, a sustainable and versatile resource abundant in India, offers a rich source of nutrients and bioactive compounds. The study delves into the proximate analysis of biscuits fortified with BSP, assessing moisture content, protein, fat, fibre, ash, carbohydrates, and calorie levels. Through meticulous experimentation, bamboo shoots were processed into powder form, and biscuits were formulated with varying levels of BSP. Sensory evaluation revealed favourable perceptions of biscuits fortified with BSP, particularly at lower fortification levels. Proximate analysis indicated an increase in protein, fibre, and carbohydrate content with higher BSP fortification levels, while fat content exhibited a gradual decrease. Additionally, calorie content decreased with higher fortification levels, suggesting the potential for low-calorie fortified products. These findings underscore the nutritional benefits of incorporating BSP into biscuits, offering enhanced protein, fibre, and mineral content while reducing fat and calorie density. The study contributes valuable insights into the development of healthier snack options and underscores the transformative potential of bamboo shoot fortification in enhancing the nutritional landscape of biscuits.

Keywords: Bamboo, *Dendrocalamus Strictus*, bamboo shoot powder, fortification, biscuits

Introduction
Bamboo, a vital Non-Timber Forest Produce (NTFP), thrives abundantly across India, exhibiting remarkable growth rates and adaptability to diverse climatic and soil conditions. Recognized for its versatility, resilience, and eco-friendliness, bamboo stands as a cornerstone of sustainable agriculture. With a short growth cycle of 3 to 5 years, it offers a renewable resource that can be harvested sustainably, ensuring its long-term viability. India ranks second only to China in bamboo resources, boasting a rich diversity of 24 genera and 134 species. Enriched bamboo ecosystems are prevalent in regions such as the North-eastern states, the Western Ghats, Bastar region in Chhattisgarh, and Andaman and Nicobar Islands. Notably, the North-eastern states harbour 66% of the nation's bamboo stock, underlining their pivotal role in bamboo conservation and utilization efforts.

The bamboo-rich landscapes of Madhya Pradesh and Chhattisgarh collectively span nearly 15,000 km^2, representing the second-largest bamboo-growing area in India (FSI, 2021). *Dendrocalamus strictus* emerges as the predominant bamboo species in Madhya Pradesh, complemented by sporadic occurrences of *Bambusa bambos*, *Gigantochloa rostrata*, and *Schizostachyum pergracile.* Meanwhile, Chhattisgarh witnesses extensive distribution of *D. strictus* across various districts. Beyond its ecological significance, bamboo serves as a source of edible shoots, deeply ingrained in traditional cuisines across India, particularly in the North-eastern regions. Despite the burgeoning demand for processed bamboo shoots, India lacks significant cultivation efforts and a structured supply chain for raw shoots, presenting untapped economic opportunities.

Bamboo shoots, celebrated for their culinary appeal, boast a rich nutritional profile characterized by proteins, carbohydrates, minerals, and fibre, coupled with low fat and sugar content (Chen *et al*., 1999; Kumbhare and Bhargava, 2007; Nirmala *et al*., 2007, 2008; Satya

et al., 2010; Choudhury *et al*., 2012) [4, 7, 9, 10, 11, 5]. Additionally, they contain phytosterols and high fibre content, positioning them as potential nutraceuticals with cholesterol-lowering properties and other health benefits (Brufau *et al*., 2008) [3]. Numerous studies underscore the nutritional richness of bamboo shoots, highlighting their high dietary fibre, vitamin, mineral, protein, and antioxidant content, along with their low fat composition. Moreover, they harbour bioactive compounds like phytosterols, flavonoids, and phenolic acids, exhibiting anti-cancer, anti-diabetic, and anti-hypertensive properties (Singhal *et al*., 2013) [12]. The bamboo species *D. Strictus* remains underutilized, primarily consumed by tribal communities in Chhattisgarh either as a vegetable or in fermented form. However, its potential extends further as powdered bamboo shoot can be incorporated into fortified food products, thereby expanding its utilization among broader populations (Nayak & Palta, 2022) [8].

Food fortification emerges as a strategic intervention to address micronutrient deficiencies within populations, aiming to enhance the nutritional quality of staple foods and industrial products. Through deliberate addition of essential nutrients, fortification endeavors to mitigate nutritional deficiencies and promote public health, complementing efforts in biofortification, dietary diversification, and pharmacological supplementation (WHO and FAO, 2006).

In this context, our research explores the potential of fortifying biscuits with bamboo shoot powder, aiming to enhance their nutritional value and cater to consumer demand for healthier snack options. By leveraging the nutritional advantages of bamboo shoots, we envision novel food products that not only satisfy taste preferences but also contribute to improved dietary intake and overall well-being. Through comprehensive analysis and experimentation, we aim to elucidate the transformative potential of bamboo shoot fortification in enhancing the nutritional landscape of biscuits.

Material and Methods

Collection of raw material

The raw material was collected by gathering edible bamboo (*Dendrocalamus stictus*) shoots aged 2 to 20 days after emerging from the ground from the local market of Bastar, Chhattisgarh, India. The samples were then packed in LDPE polybags and placed in corrugated paper boxes for transportation to the laboratory within 24 hours of collection. In the laboratory, the shoots were defoliated and washed, with unwanted parts removed, and the soft edible portions utilized for preliminary studies. The shoots were stored at 4 °C until further processing (Nayak & Palta, 2022) [8]. Additionally, commercially available wheat flour, fat, sugar, skim milk powder, common salt, and baking soda (sodium bicarbonate) were procured from the local market, all of which were of analytical grade.

Preparation of bamboo shoot powder (BSP)

For the preparation of bamboo shoot powder (BSP), the shoots were sliced into smaller pieces and blanched for 30 minutes, with water changed every 10 minutes. Subsequently, they were dried in a tray dryer at 70 °C (Satya *et al*., 2010) [11] until they reached an equilibrium moisture content of about 5%. The dried shoot pieces were then ground into powder, passed through a sieve of 100 mesh size, and stored in polyethylene pouches with proper sealing. Proximate analysis of the bamboo shoot powder was then conducted.

Preparation of Biscuits

Table 1: Treatment and their list of ingredients for various level of fortified biscuit formulations

Ingredients	Treatments			
	T_0	T_1	T_2	T_3
Wheat flour	100 g	95 g	90 g	85 g
BSP	--	5 g	10 g	15 g
Ghee	30 g	30 g	30 g	30 g
Sugar	40 g	40 g	40 g	40 g
Milk	60 ml	60 ml	60 ml	60 ml
Baking Powder	2 g	2 g	2 g	2 g

Preparation Procedure

Step 1: Control biscuits were prepared using 100 g of wheat flour, representing 100% of the formulation.

Step 2: Bamboo shoot powder was utilized as a fortifying agent for the biscuits at varying ratios of 5%, 10%, and 15%.

Step 3: The wheat flour in the formulation was replaced with 5%, 10%, and 15% of bamboo shoot powder accordingly.

Step 4: Additional components included 30 grams of ghee or clarified butter, 40 grams of sugar, 60 ml of milk, and 2 grams of baking powder for each batch.

Step 5: All ingredients for each formulation were thoroughly mixed for duration of 5-10 minutes to create cohesive dough.

Step 6: The dough was then rolled to a consistent thickness of 3 mm using a wooden rolling pin.

Step 7: Circular biscuits with a diameter of 2.5 cm were cut from the dough and baked for 15-20 minutes at 200 °C in a baking oven.

Step 8: Following baking, the biscuits were allowed to cool at room temperature and subsequently packed in airtight containers to facilitate further analyses.

Step 9: A total of four different formulations of biscuits were prepared for evaluation in this study.

Formulation of fortified biscuit includes

- Control biscuits (T0)
- 5% bamboo shoot powder fortified biscuits (T_1)
- 10% bamboo shoot powder fortified biscuits (T_2)
- 15% bamboo shoot powder fortified biscuits (T_3)

Fig 1: Baked biscuits on the baking tray

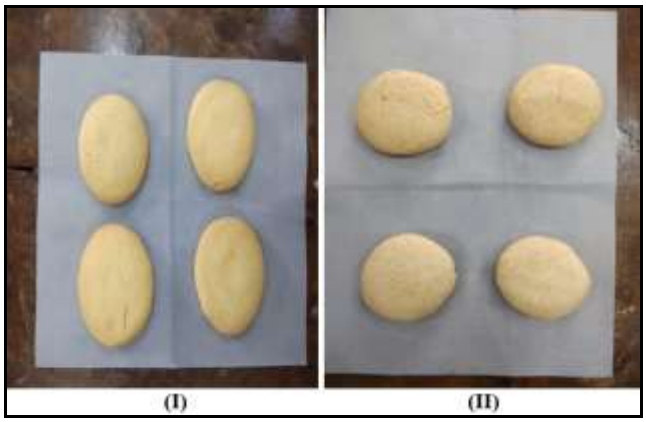

Fig 2: (I) Control biscuit (II) 5% BSP fortified biscuit (T_1)

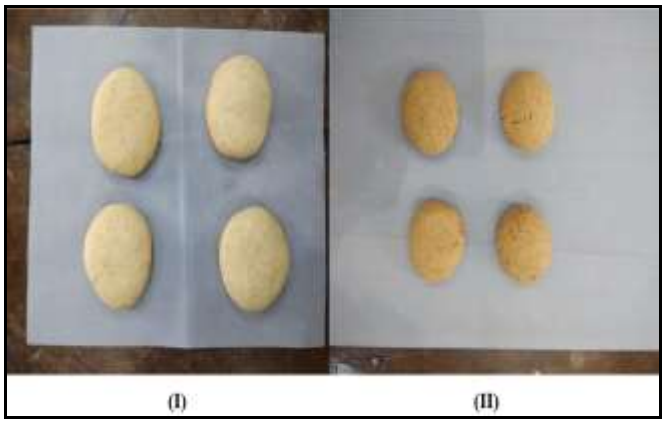

Fig 3: (I) 10% BSP fortified biscuit (T_2) (II). 15% BSP fortified biscuit (T_3)

Nutritional Analysis of biscuits

The bamboo shoot powder underwent analysis to determine its moisture, fat, protein, ash content, and crude fibre using established protocols (AOAC, 2019). Carbohydrate content was calculated by deducting the combined values of moisture, fat, protein, fibre, and ash from the total weight of the sample. Caloric content was determined by applying standard calorie values for carbohydrates (4 kcal/g), proteins (4 kcal/g), and fats (9 kcal/g).

Result and Discussions

Sensory evaluation of fortified biscuits: Sensory evaluation was carried out for fortified biscuit in selected parameters which includes colour, aroma, texture, taste and overall acceptability. The sensory analysis of biscuit samples fortified with Bamboo Shoot Powder (BSP) compared to the control biscuit is presented in Table 02, providing valuable insights into the participant's perceptions and preferences.

Upon conducting sensory analysis of the products, it was observed that the T_1 (5% BSP fortified biscuit) and T_2 (10% BSP fortified biscuit) samples exhibited higher overall acceptability when compared to the control biscuit (T0) and the T_3 (15% BSP fortified biscuit). It is noteworthy that the T0 received the highest rating in terms of aroma and texture, with scores of 7.21 and 7.56, respectively. On the other hand, the T_2 sample received the highest rating in colour and taste, scoring 7.25 and 7.22, respectively.

Interestingly, both the T_1 and T_2 samples were found to be more acceptable than the other samples across various parameters. However, the T_3 sample received the lowest rating in all sensory parameters evaluated. Moreover, when considering overall acceptability, the T_3 sample obtained the lowest rating among all the samples analysed.

Table 2: Sensory comparison of control and different formulations of BSP fortified biscuit using 9-point hedonic scale (1-Extremely dislike to 9-Extremely like)

S. No.	Biscuit	Colour	Aroma	Texture	Taste	Overall
1	T_0	6.43±1.12	7.21±1.22	7.56±0.79	6.68±1.05	7.07±0.64
2	T_1	6.69±0.94	7.12±1.28	7.35±0.94	6.94±1.30	7.54±1.06
3	T_2	7.25±0.88	7.15±0.76	7.17±1.26	7.22±0.76	7.42±1.41
4	T_3	5.29±1.18	5.87±1.36	6.27±1.21	6.14±0.88	5.77±1.39

These findings highlight the sensory preferences of participants and indicate that the inclusion of BSP in biscuit formulations can positively influence overall acceptability. The control biscuit stood out in terms of aroma and texture, while the T_2 sample exhibited favourable attributes in colour and taste. Additionally, the T_1 and T_2 samples garnered higher overall acceptability scores compared to the control and T_3 samples, indicating their potential as preferred options among the tested variations.

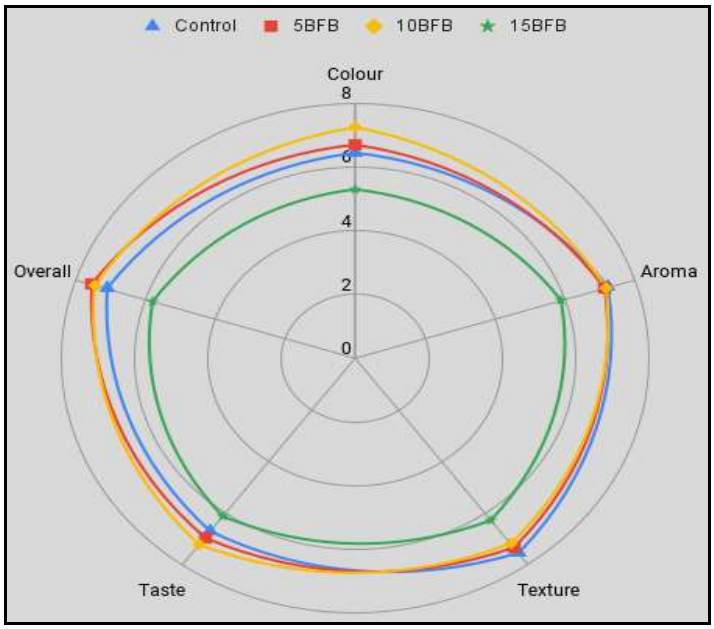

Fig 4: Radar chart of the average sensory scores of different formulations of BSP fortified biscuit using 9-point hedonic scale (1-Extremely dislike to 9-Extremely like)

Proximate Analysis of Fortified Biscuits

Moisture Content: Analysis of both control and fortified biscuits revealed moisture content ranging from 5.12g/100 g dr. wt. to 5.87g/100 g dr. wt. with fortification levels from 5% to 15%. Comparatively, the control biscuit displayed a moisture content of 4.72g/100 g dr. wt. The increase in moisture content with higher fortification levels suggests the influence of fortification on biscuit moisture. This is crucial as moisture content affects texture, shelf life, and quality.

Protein

Protein content analysis showed the control biscuit at 7.28g/100 g dr. wt., while fortified biscuits at 5%, 10%, and 15% fortification levels exhibited increased protein content, reaching 9.76g/100 g dr. wt., 11.12g/100 g dr. wt., and 12.09g/100 g dr. wt., respectively. The higher protein content in fortified biscuits signifies the nutritional enhancement through fortification, offering potential health benefits for consumers.

Fat

Fat analysis revealed a gradual decrease in fat content as fortification levels increased. Control biscuits had the highest fat content at 25.22g/100 g dr. wt., while fortified biscuits with 5%, 10%, and 15% BSP fortification levels exhibited reduced fat contents of 19.82g/100 g dr. wt., 15.70 g/100 g dr. wt., and 12.80 g/100 g dr. wt., respectively. This reduction suggests fortified biscuits as a potentially healthier option for fat-conscious consumers.

Table 3: Proximate analysis of biscuits

S. No.	Biscuits	Moisture (g)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	Carbohydrates (g)	Calorie (Kcal)
1	T0	4.72±0.50	7.28±0.37	25.22±0.85	1.03±0.13	0.82±0.03	60.93	499.82
2	T_1	5.12±0.25	9.76±0.15	19.82±0.33	1.68±0.09	1.07±0.11	62.55	467.62
3	T_2	5.32±0.22	11.12±0.22	15.70±0.42	1.89±0.13	1.12±0.08	64.85	445.18
4	T_3	5.87±0.15	12.09±0.20	12.80±0.10	2.02±0.13	1.21±0.10	66.01	427.60

Fibre

Fibre content increased with higher BSP fortification levels, demonstrating values of 1.68g/100 g dr. wt., 1.89g/100 g dr. wt., and 2.02g/100 g dr. wt. for 5%, 10%, and 15% fortification levels, respectively. The higher fibre content in fortified biscuits indicates potential digestive health benefits and aligns with consumer preferences for fibre-rich foods.

Ash

Ash content increased with higher BSP fortification levels, indicating mineral incorporation from bamboo shoot powder. Control biscuits had the lowest ash content, while 15% BSP fortified biscuits exhibited the highest. Understanding ash content aids in assessing mineral composition and potential health benefits of fortified biscuits.

Carbohydrates

Carbohydrate content increased with higher fortification levels, showcasing values of 62.55g/100 g dr. wt., 64.85g/100 g dr. wt., and 66.01g/100 g dr. wt. for 5%, 10%, and 15% fortification levels, respectively. The increase in carbohydrate content offers additional energy, appealing to consumers seeking energy-rich snack options.

Calorie

Calorie analysis revealed a decrease in calorie content with higher fortification levels, with control biscuits having the highest calorie content at 499.82 Kcal/100 g. Fortified biscuits exhibited lower calorie values, suggesting a potential for low-calorie fortified products catering to health-conscious consumers.

Understanding the nutritional composition of fortified biscuits provides insights for consumers seeking healthier snack options and aids manufacturers in developing products aligned with consumer preferences and dietary needs.

Conclusion

The research into the nutritional advantages of fortifying biscuits with bamboo shoot powder (BSP) concludes with compelling insights into the potential of this novel approach to enhance the nutritional landscape of snack foods. Through meticulous experimentation and analysis, the study reveals several key findings. The sensory evaluation indicates favourable perceptions of biscuits fortified with BSP, particularly at lower fortification levels, suggesting their potential as healthier snack options. However, higher fortification levels may affect sensory attributes negatively. Proximate analysis of the fortified biscuits demonstrates significant improvements in nutritional content with BSP fortification. Higher levels of fortification correlate with increased protein, fibre, and carbohydrate content, while fat content decreases gradually. This shift in composition aligns with consumer preferences for healthier, nutrient-rich options. Moreover, the study highlights the potential for low-calorie fortified products, as calorie content decreases with higher fortification levels. This aspect addresses the growing demand for healthier snack alternatives among health-conscious consumers.

Overall, the research underscores the transformative potential of bamboo shoot fortification in biscuits, offering enhanced nutritional benefits while maintaining sensory appeal. These insights contribute valuable knowledge to the development of healthier snack options and emphasize the role of innovative food fortification strategies in addressing public health challenges.

Recommendations

Moving forward, future research should focus on refining the fortification levels of bamboo shoot powder (BSP) in biscuits to achieve an optimal balance between nutrition and sensory acceptability. Exploring alternative processing techniques for BSP could enhance its functional properties and compatibility with biscuit formulations. Additionally, assessing the shelf life and stability of fortified biscuits, conducting consumer perception studies on a larger scale, and diversifying product applications beyond biscuits could provide valuable insights into market acceptance and preferences. Investigating the functional properties of BSP and promoting sustainable sourcing practices are also essential for advancing the utilization of bamboo shoot powder in fortifying biscuits and developing healthier and more sustainable food options for consumers.

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