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Nutritional insights, Antinutritional factors, and value addition of the edible hypocarp of a significant wild fruiting species *Semecarpus anacardium* L. f

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Abstract
Semecarpus anacardium L. f., is a nutritionally significant wild edible fruit with great potential for addressing malnutrition and supporting sustainable livelihoods. This study investigates the nutritional composition, antinutritional factors, and value addition of *Semecarpus anacardium* fruits to enhance their dietary adoption and commercial viability. The fruit is rich in macronutrients, including carbohydrates (38.87 g/100g), proteins (5.63 g/100g), and dietary fiber (3.62 g/100g), as well as essential micronutrients such as potassium, magnesium, iron, and vitamins like vitamin C and B-complex. The antinutritional factors, including tannins, oxalates, phytic acid, saponins, and phenolic compounds, are present in minute amounts within permissible ranges. The development of value-added products such as candies and pickles showcase the fruit's potential for functional food applications. This study supports the achievement of SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 8 (Decent Work and Economic Growth) by promoting the use of nutrient-rich, value-added products from *Semecarpus anacardium*. Additionally, it contributes to SDG 12 (Responsible Consumption) and SDG 9 (Industry and Innovation) by advocating for sustainable resource utilization and food innovation. By improving the versatility of *Semecarpus anacardium*, this research aligns with health-focused and specialty food trends while creating economic opportunities for rural and tribal communities.

Keywords: *Semecarpus anacardium*, nutritional composition, anti-nutritional factors, value addition, functional foods

Introduction

Humanity has long relied on the abundant biodiversity of plants to sustain food security, medicinal needs, and economic livelihood. Forest ecosystems, as natural and renewable resources, play a vital role in maintaining this biodiversity, particularly by providing wild edible fruits that are integral to the nutritional well-being of indigenous and rural communities (Rabiei *et al.* 2022) [6]. These fruits, whether consumed fresh or dried, are rich in bioactive compounds and essential nutrients that can play a key role in preventing malnutrition and chronic diseases such as cardiovascular disorders (Howes & Simmonds 2014; Arruda *et al.* 2017) [8, 11]. For instance, fruits like Capparis mitchelii and Flacourtia jangomas are particularly high in vitamin C, offering immune-boosting benefits (Biswas *et al.* 2022) [7]. In light of the growing challenges posed by food insecurity and chronic diseases, dietary interventions that incorporate wild plant-based foods have emerged as an effective strategy for improving public health, especially in low-resource settings (Koffi *et al.* 2020; FAO 2019) [16, 9]. Despite the substantial nutritional and therapeutic value of wild edible fruits, they often remain underutilized, especially in resource-limited regions. Studies have shown that wild fruits typically contain higher levels of proteins, vitamins, minerals, and phenolic compounds compared to their cultivated counterparts (Bhutia *et al.* 2018) [10]. Their consumption has been associated with reduced risks of non-communicable diseases, further highlighting their importance in public health strategies (Koffi *et al.* 2020) [16]. These fruits hold particular significance for tribal and rural communities, offering not only critical nutritional support but also income-generation opportunities. However, challenges such as limited market demand, consumer awareness, and insufficient research on their distribution and cultivation continue to hinder their broader adoption (Angami *et al.* 2024) [5].

The underutilization of these fruits is further exacerbated by post-harvest losses, which remain a significant issue in developing countries like India. It is estimated that between 30-40% of fruits in India are lost between harvest and the consumer point, leading to substantial economic losses (Patil *et al.* 2013) [21]. India, being the second-largest fruit producer globally, is home to a wide variety of fruits that are rich in essential vitamins and minerals, yet less than 2% of these fruits are processed (Patil *et al.* 2013) [21]. This presents a significant opportunity for the development of value-added products, such as jams, jellies, fruit bars, and fruit toffees, particularly when local communities are trained in processing techniques that enhance food security and livelihood opportunities. Although global research on wild edible fruits has been increasing (Pereira *et al.* 2020; Adamu *et al.* 2022; Dissanayake *et al.* 2023) [4, 2, 3], there is a notable gap in studies focusing on the potential of these fruits in regions like central India. Urbanization, industrialization, and shifting cultivation have led to a decline in wild edible fruit species, many of which are now endangered (Angami *et al.* 2024) [5]. Despite these challenges, the potential of these fruits to combat malnutrition and bolster food security remains significant if effectively promoted. In this context, *Semecarpus anacardium* L. f., commonly known as the marking nut or Bhilawa, emerges as a promising but underutilized species with substantial nutritional and pharmacological value. The edible portions of this fruit, particularly the fleshy orange thalamus and kernels, are rich in proteins, lipids, vitamins, and minerals, providing energy and immune-boosting benefits (Misra & Misra 2016) [19]. Traditionally consumed raw, roasted, or dried, *Semecarpus anacardium* offers a means of extending its shelf life, thus supporting food security (Dangol *et al.* 2017) [14]. However, it also contains antinutritional factors such as phytic acid, tannins, and oxalates, which can hinder the bioavailability of vital nutrients like calcium, iron, and zinc (Liener 1994) [1].

This study aims to explore the nutritional value, antinutritional factors, and the potential for value addition of *Semecarpus anacardium* fruits. By highlighting these aspects, the study seeks to pave the way for the integration of these fruits into functional food products that can contribute to improved nutritional status and enhanced livelihoods for rural and tribal communities.

Material and Methodology

Fruit Collection and Preparation: Fruits of *Semecarpus anacardium* were harvested from various locations in the Mandla district of Madhya Pradesh, India, during the peak harvesting period of March to April. Upon collection, the fruits were transported to the processing centre in cotton bags to minimize damage and ensure swift handling. The mature false fruit (orange hypocarp) was separated from the black seed (nut) (Fig. 1), washed thoroughly, and processed for subsequent analysis and preparation of nutritional, antinutritional, and value-added products.

Fig. 1: Separation of mature edible hypocarp (orange in colour) from nut (black in colour) for value-added product preparation

Nutritional Value Analysis: The nutritional composition of the raw *Semecarpus anacardium* fruits was analysed following the standard test protocols prescribed by the Food Safety and Standards Authority of India (FSSAI). The following parameters were evaluated:

- Calorific value, total carbohydrates, and total sugars were assessed using the methods outlined in EBRS/CHEM/NV/01:2023 and IS 2650:1975 RA 2020.
- Total protein content was determined according to IS 7219:1973 RA 2020.
- Moisture content was measured as per IS 1011:2002 RA 2019.
- Total ash, crude fiber, and total fat were evaluated using the standard protocols in IS 12711:1989 RA 2020.
- The content of essential minerals including sodium, potassium, iron, zinc, magnesium, and copper was analyzed following the FSSAI Manual of Methods of Analysis of Foods for metals.

Antinutritional Analysis: The antinutritional properties of the *Semecarpus anacardium* fruit were evaluated using several prescribed FSSAI test methods:

- Cellulose content was determined using EBRS/SOP/CHEM/27.
- Total phenolic content, oxalates, phytates, tannins, and saponins were analysed following EBRS/SOP/CHEM/30. These analyses provided a comprehensive assessment of the key antinutritional compounds present in the fruit.

Preparation of *Semecarpus anacardium* Candy: To prepare *Semecarpus anacardium* candy, ripe fruits were thoroughly washed, halved, and sun-dried for several hours. The dried fruits were then placed in an airtight jar and completely submerged in sugar. The jar was sealed and left for 2-3 days to allow the sugar to dissolve, causing the fruit to float. Afterward, food colouring and cardamom powder were added, and the mixture was steeped for an additional 3 days. The mixture was strained, and the fruit was sun-dried for 2 days before being transferred to an airtight container. The final product was powdered with sugar and stored.

Preparation of *Semecarpus anacardium* Orange and Green Pickle: To prepare *Semecarpus anacardium* orange and green pickle, unripe fruits were washed, halved, and sun-dried for 1-2 days. Meanwhile, mustard oil was heated, slightly cooled, and combined with roasted, powdered spices. This spice mixture was then thoroughly blended with the dried fruit and stored in a jar. The jar was kept in sunlight for 2-4 days to enhance the flavours, and after this period, the pickle was transferred to an airtight container for storage.

Nutritional Analysis of Value-Added Products: The nutritional properties of the value-added products, including *Semecarpus anacardium* candy and orange and green pickle, were analysed using the prescribed FSSAI methods for various parameters. For the candy, the following tests were conducted:

- Calorific value, total carbohydrates, total sugar, and total protein content were measured using EBRS/CHEM/NV/01:2023 and IS 2650:1975 RA 2020.
- Moisture content was analysed according to IS 1011:2002 RA 2019.
- Total ash, crude fibre, and total fat were evaluated using IS 12711:1989 RA 2020.
- Sodium content was assessed following the FSSAI Manual of Methods of Analysis of Foods: Metals.

For the *Semecarpus anacardium* orange and green pickle, similar nutritional tests were performed, including the analysis of:

- Calorific value, carbohydrates, total sugar, total protein, moisture, total ash, crude fibre, and total fat using the relevant methods (IS 2650:1975 RA 2020, IS 4624:1978 RA 2018, IS 10226 (Part-I):1982 RA 2020, IS 4684:1975 RA 2020).
- Sodium content was also measured according to the FSSAI guidelines for metal analysis.

These tests enabled a comprehensive nutritional profiling of both value-added products.

Result

Nutritional Composition of fruit: The nutritional composition of *Semecarpus anacardium* fruits highlights their significance as a dietary resource rich in essential macronutrients and micronutrients (Table 1). They are an excellent source of carbohydrates (38.87 g/100g), providing energy, along with proteins (5.63 g/100g) that support muscle repair and growth, and dietary fibre (3.62 g/100g), which aids in digestion and blood sugar management. The fruit contains key vitamins like vitamin C and B-complex vitamins, which boost immunity and support metabolic processes. It is also abundant in minerals such as potassium (1058.82 mg/Kg), magnesium (149.51 mg/Kg), and iron (8.34 mg/Kg), which contribute to bone health, blood pressure regulation, and oxygen transport. Additionally, its low fat content (0.45 g/100g) and moderate calorific value (182.05 Kcal/100g) make it a healthy and energy-efficient food choice. The high moisture content (54.03 g/100g) enhances hydration, while minerals like zinc and copper further promote immunity and metabolic functions, establishing *Semecarpus anacardium* as a valuable nutritional resource.

Table 1: Nutritional Properties of *Semecarpus anacardium* hypocarp

Nutritional Test Parameters	Quantity
Calorific Value	182.05 Kcal/100
Total Carbohydrate	38.87 g/100g
Total Sugar	2.51 g/100g
Total Protein	5.63 g/100g
Moisture	54.03 g/100g
Total Ash	1.02 g/100g
Crude Fibre	3.62 g/100g
Total Fat	0.45 g/100g
Sodium	36.66 mg/Kg
Potassium	1058.82 mg/Kg
Iron	8.34 mg/Kg
Zinc	5.97 mg/Kg
Magnesium	149.51 mg/Kg
Copper	6.5 mg/Kg

Antinutritional profile: Antinutritional factors in *Semecarpus anacardium* fruits are compounds that can interfere with the absorption and utilization of essential nutrients, impacting their overall dietary value. Key antinutritional elements include tannins (94.37 mg/100g), which bind to proteins and reduce their digestibility, limiting amino acid availability. Oxalates (16.8 mg/100g) can form insoluble complexes with calcium, potentially increasing the risk of kidney stone formation when consumed in excess. Phytic acid (3.72 mg/100g) chelates vital minerals like iron, zinc, and calcium, decreasing their bioavailability for absorption. Saponins (6.428 mg/100g) and phenolic compounds (102.09 mg/100g) also contribute to these inhibitory effects (Table 2). Despite these factors, proper processing techniques, such as soaking, cooking, or fermentation, can help mitigate their impact and enhance the fruit's nutritional benefits, ensuring its safe and effective dietary utilization.

Table 2: Antinutritional Properties of *Semecarpus anacardium* hypocarp

Anti-nutritional Test Parameters	Quantity
Cellulose	6.2 g/100g
Total Phenolic Content	102.09 mg/100g
Oxalate	16.8 mg/100g
Phytate	3.72 mg/100g
Tannin	94.37 mg/100g
Saponin	6.428 mg/100g

Value Addition: Value addition has significantly transformed *Semecarpus anacardium* from a wild fruit with limited commercial appeal to a valuable, nutritionally rich product. These processes (Fig. 2) make the fruit suitable for a variety of consumer products, including candies and pickles expanding its market potential. The incorporation of additional nutrients or blending with other nutrient-rich ingredients further boosts its health properties. Nutritional analysis of products like Bhilwa candy and pickles (orange and green) reveals their high content of carbohydrates, proteins, and essential minerals, showcasing the fruit's versatility (Table 3). For example, Bhilwa candy has a calorific value of 370.29 kcal per 100g, with significant amounts of carbohydrates (85.07 g), protein (4.51 g), and fat (1.33 g). Similarly, the orange and green pickles exhibit good nutritional value, with varied caloric values and macronutrients, as well as notable levels of sodium and fiber. These findings indicate that *Semecarpus anacardium*, through value-added products, holds substantial potential for both nutritional enhancement and commercial success in diverse markets.

Fig 2: Value-added products of *Semecarpus anacardium* A. Candy B. Green Pickle C. Orange Pickle

Table 3. Nutritional Properties of *Semecarpus anacardium* value added products

Nutritional Test parameter	Candy	Orange pickle	Green pickle
Calorific value (calculated value)	370.29 Kcal/100g	255.3 Kcal/100g	245.01 Kcal/100g
Total carbohydrates (calculated value)	85.07 g/100g	46.14 g/100g	27.58 g/100g
Total sugar	9.48 g/100g	2.48 g/100g	1.16 g/100g
Total protein(N´6.38)	4.51 g/100g	6.21 g/100g	6.29 g/100g
Moisture	7.23 g/100g	35.78 g/100g	41.56 g/100g
Total ash (on dry basis)	1.86 g/100g	6.77 g/100g	12.4 g/100g
Crude fiber	1.23 g/100g	3.22 g/100g	3.68 g/100g
Total fat	1.33 g/100g	5.1 g/100g	12.17 g/100g
Sodium	347.16 mg/kg	401.14 mg/kg	404.17 mg/kg

Discussion

Semecarpus anacardium, commonly known as the marking nut or Bhilawa, is emerging as a valuable wild edible fruit (WEF) due to its high nutritional content. Traditionally consumed in rural and tribal areas, this fruit plays a significant role in improving food security and supplementing nutrition, particularly in resource-limited regions with restricted access to diversified diets. The fruit's rich nutrient profile, including essential macronutrients (carbohydrates, proteins) and micronutrients (vitamins and minerals), makes it an important food source for underprivileged communities. Additionally, the fruit's long shelf life, supported by traditional preservation methods like drying and roasting, offers a sustainable solution to food insecurity, especially during periods of scarcity (Dangol *et al.* 2017) [14].

Despite its nutritional potential, the consumption of *Semecarpus anacardium* is hindered by the presence of antinutritional factors, such as tannins, oxalates, phytic acid, and saponins, which can reduce the bioavailability of key nutrients like calcium, iron, and zinc. These compounds interfere with nutrient absorption and may pose health risks, such as kidney stone formation due to excessive oxalates or decreased protein digestibility due to tannins. These issues present challenges to the widespread adoption of the fruit in mainstream diets (Liener *et al.* 1980; Savage 2002) [17, 22]. In their analysis, Ngurthankhumi *et al.* (2024) [20] examined the nutritional and antinutritional properties of wild edible fruits from northeast India. They highlighted Garcinia xanthocymus for its high sugar and vitamin E content, and Artocarpus heterophyllus for its significant carbohydrate and starch levels. Similarly, Citrus jambhiri was identified as a good source of moisture, vitamin C, and phosphorus, while other fruits like Prunus jenkinsii and Rubus treutleri were noted for their high antioxidant and mineral content. These findings emphasize the potential of wild fruits, including *Semecarpus anacardium*, to combat malnutrition and promote biodiversity conservation.

Traditional food processing methods such as roasting, soaking, and fermentation, widely practiced in regions where *Semecarpus anacardium* is consumed, help mitigate these negative effects. These techniques enhance the fruit's edibility and nutritional profile (Thompson & Yoon 1984) [23]. Thus, preserving and improving indigenous knowledge related to food processing is essential to make the fruit safer and more accessible to a broader population.

Nutritional analysis of raw *Semecarpus anacardium* reveals it as a rich source of carbohydrates (38.87 g/100g), proteins (5.63 g/100g), and dietary fiber (3.62 g/100g), which support digestive and metabolic health. The fruit also provides key micronutrients, including potassium (1058.82 mg/kg), magnesium (149.51 mg/kg), iron (8.34 mg/kg), and zinc (5.97 mg/kg), which contribute to bone health, immune function, and oxygen transport. These findings highlight the potential of *Semecarpus anacardium* as a functional food that could provide significant benefits for malnourished populations (Misra & Misra 2016) [19]. In a study by Bayang *et al.* (2021) [12], significant nutritional variations were observed among 23 wild edible fruits from the Far North Region of Cameroon. For example, Ziziphus mauritiana and Ziziphus spina-christi exhibited the highest dry matter content, while Pleiocarpa reclinata had the highest carbohydrate levels. These fruits, along with others like Balanites aegyptiaca, serve as rich sources of energy, protein, and bioactive compounds that contribute to health and nutrition.

Value addition through processing *Semecarpus anacardium* into products such as candy and pickles enhances its flavor, shelf life, and nutritional value. Bhilawa candy, made by drying and soaking the fruit in sugar, offers a calorific value of 370.29 kcal/100g and contains 85.07 g of carbohydrates per 100g, making it an excellent energy source. Similar value-added products have been successfully developed from other fruits, such as Syzygium cumini (Chavan & Patil 2013) [13] and Anola (Ravani & Joshi 2014) [24]. These products demonstrate the fruit's versatility and potential for commercialization, especially in the growing functional food and nutraceutical markets.

The successful incorporation of *Semecarpus anacardium* into value-added products aligns with Sustainable Development Goal (SDG) 2, which seeks to end hunger and improve nutrition. By harnessing the nutritional and pharmacological benefits of wild fruits like *Semecarpus anacardium*, food security can be enhanced, diets diversified, and rural economies supported. Additionally, value-added products provide income-generating opportunities for rural communities, promoting sustainable agricultural practices and biodiversity conservation (Maikhuri *et al.* 1994) [18].

In conclusion, *Semecarpus anacardium* holds significant potential both as a nutritional resource and as a commercially viable product. Addressing the antinutritional factors through appropriate processing methods is critical for maximizing its health benefits. With continued research and innovation in food processing techniques, *Semecarpus anacardium* can play a vital role in improving food security and supporting the livelihoods of rural and tribal communities.

Conclusion and Future Perspectives

Semecarpus anacardium fruits, though nutrient-rich, pose challenges due to the presence of antinutritional factors that require careful processing to optimize their nutritional value. Addressing issues like consumer acceptance through awareness campaigns and ensuring regulatory compliance for safety can significantly boost its market potential. With advancements in technology and further research into its phytochemical properties and health benefits, this fruit holds great promise as a superfood and therapeutic agent. By leveraging effective value addition techniques and exploring innovative product development, *Semecarpus anacardium* can contribute to enhanced food security, economic growth, and improved nutrition, unlocking its potential as a vital resource for sustainable development. Value addition in fruits significantly enhances their economic value, shelf life, and marketability, benefiting both producers and consumers. Limitations preventing domestication such as unawareness about utility can be overcome by adopting proper post-harvest technology and processing the fruits into number of value-added products. For *Semecarpus anacardium*, value addition is particularly important due to its limited time of availability and underutilization. Despite its nutritional potential, much of the fruit goes to waste each year. Developing and standardizing post-harvest technologies and products like Bhilwa candy and pickles can extend the fruit's shelf life and provide sustainable income opportunities for rural and tribal communities. Increasing awareness and adopting proper processing methods are key to fully utilizing this valuable resource.

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