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FOX NUT AS AN EMERGING PLANT-BASED FUNCTIONAL FOOD IN SOUTHERN INDIA

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Fayas Ahamed S[1], PG Scholar
Balaji R[1], Associate Professor
Indumathi V M[1], Associate Professor
Gangai Selvi R[2], Professor
Anand M[3], Associate Professor
[1]Department of Agricultural and Rural Management
[2]Department of Physical Science and Information Technology, AEC&RI
[3]Department of Food Process Engineering, AEC&RI,
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, 641003

Correspondence:
Balaji R
E-mail: balaji.r@tnau.ac.in

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Abstract. Urban food systems are in the midst of a rapid "dietary shift" where consumers' food habits are changing, with a rise in demand for plant-based and health-functional foods due to a variety of factors, such as changing lifestyles and increased nutritional awareness. Makhana (Euryale ferox Salisb.) is an aquatic plant which has a high nutritive value and is gaining importance in the market. The empirical literature on the factors affecting consumer adoption in urban markets is still very limited. The current research aims to explore the consumer awareness, preference structure, influencing factors and purchase constraints of foxtail nut consumption in the urban market. Descriptive-analytical research design was used and primary data were gathered from 300 urban consumers by using a structured interview schedule. To determine awareness and preference pattern, percentage analysis was employed. The exploratory factor analysis (EFA) performed with Principal Component Analysis (PCA) and varimax rotation showed the most important determinants of consumer preference, and the Garrett ranking technique was used to rank the purchase constraints. The results suggest that consumers are very aware, mostly through interpersonal communication and exposure to organised retail outlets. The results of Factor Analysis indicated that fox nut acceptance was multidimensional, where the most significant factors are health and nutritional attributes, followed by availability and accessibility, sensory and product quality, price perception and value for money, packaging and branding and social influence. Although awareness is high and perception is favourable, consumption is still mainly occasional, mainly because of the high prices and limited retail availability. The findings highlight the need for strategic market and policy measures that make prices more accessible and boost distribution systems. These strategies can help make fox nut (makhana) a staple functional food in the urban markets.

Keywords: consumer preference; factor analysis; Fox Nut (makhana); garrett ranking technique; purchasing constraints; urban consumers

Introduction. Formulation of the problem

As urban Indian people become more aware of their health, the lifestyle-related disorders are on the rise and growing concern about the nutritional value of deep fried and highly processed snack foods, the trends in food consumption are slowly evolving. This has led consumers to increasingly turn to plant-based foods, viewing them as natural, functional and healthier options [1,2]. This change in eating habits has generated new interest in some of the historic crops which are now reinterpreted as modern health foods. Fox nut (*Euryale ferox* Salisb.) is a water crop of the Nymphaeaceae family which is traditionally cultivated in stagnant water bodies like ponds, lakes and marshes, primarily in eastern Indian region. India is the largest producer of fox nut (makhana) and Bihar contributes to the maximum part of the production followed by Assam, West Bengal, Manipur and parts of eastern Uttar Pradesh [3,4]. Historically, the intake of fox nut (makhana) was generally region-specific and intimately related with fasting periods, religious rites and traditional eating customs [5]. Over the past few years, nutrition and functional studies have increasingly unveiled the health-promoting and nutritional advantages of fox nut (makhana) making it a more popular choice for health-conscious people. The characteristics of Fox nut (makhana) are low fat, gluten free, complex carbohydrates, moderate protein, presence of essential amino acids and minerals (calcium, magnesium) [6,7]. Moreover, antioxidant properties and a low glycaemic index have been found in makhana, which makes it a great choice for the health-conscious consumer and people suffering from lifestyle diseases like diabetes and obesity [8,9]. Because of these qualities, snakelike

meals made from fried and processed foods are being replaced by the fox nut. The fox nut (makhana) is not only a healthy nut but has experienced a significant transformation in recent years. Fox nut (makhana) is traditionally sold in unbranded and loose versions, but is also being sold more and more in packed, branded, flavoured and value-added versions in supermarkets, organised retail outlets and online platforms [10,11]. Government activities targeted at value addition, processing and branding of traditional crops have further boosted the visibility of fox nut (makhana) in non-traditional production and consumption locations, particularly urban markets [12]. Although these advances have been made, existing studies on the fox nut (makhana) have primarily focused on farming methods, processing technologies and value-chain analysis in the key producing areas, particularly Bihar and eastern India [4,10]. Empirical research on consumer awareness, perceived and consumption patterns in non-producing urban economies is limited. The level of cultural familiarity is less important to make decisions about consumption, and the factors such as health consciousness, knowledge of nutritional benefits, price perception, product availability and exposure through structured retail channels are more important [13–15] in such economies. Research on consumer behaviour for traditional food products and functional food products shows that consumer awareness and perception have a significant impact on consumer behaviour. Some barriers like the price of the product, its limited supply and product diversity can make it difficult to consume the product regularly even though perceptions are high [16-18]. Knowing these behavioral traits are therefore critical in order to grow the domestic market for plant-based functional meals. The present study is aimed to study the consumer awareness, preference, consumption behaviour, factors influencing preference and consumer purchasing constraints about fox nut (makhana) in the southern part of India with special reference of Tamilnadu and particularly Coimbatore City as the study area. The study aims to create empirical evidence from a consumption market away from production in the region for enlightenment of policy makers, marketers and stakeholders interested in promoting plant based functional foods in urban India.

Analysis of recent research and publications

As urban Indian people become more aware of their health, the lifestyle-related disorders are on the rise and growing concern about the nutritional value of deep fried and highly processed snack foods, the trends in food consumption are slowly evolving. This has led consumers to increasingly turn to plant-based foods, viewing them as natural, functional and healthier options [1,2]. This change in eating habits has generated new interest in some of the historic crops which are now reinterpreted as modern health foods. Fox nut (*Euryale ferox* Salisb.) is a water crop of the Nymphaeaceae family which is traditionally cultivated in stagnant water bodies like ponds, lakes and marshes, primarily in eastern Indian region. India is the largest producer of fox nut (makhana) and Bihar contributes to the maximum part of the production followed by Assam, West Bengal, Manipur and parts of eastern Uttar Pradesh [3,4]. Historically, the intake of fox nut (makhana) was generally region-specific and intimately related with fasting periods, religious rites and traditional eating customs [5]. Over the past few years, nutrition and functional studies have increasingly unveiled the health-promoting and nutritional advantages of fox nut (makhana) making it a more popular choice for health-conscious people. The characteristics of Fox nut (makhana) are low fat, gluten free, complex carbohydrates, moderate protein, presence of essential amino acids and minerals (calcium, magnesium) [6,7]. Moreover, antioxidant properties and a low glycaemic index have been found in makhana, which makes it a great choice for the health-conscious consumer and people suffering from lifestyle diseases like diabetes and obesity [8,9]. Because of these qualities, snakelike meals made from fried and processed foods are being replaced by the fox nut. The fox nut (makhana) is not only a healthy nut but has experienced a significant transformation in recent years. Fox nut (makhana) is traditionally sold in unbranded and loose versions, but is also being sold more and more in packed, branded, flavoured and value-added versions in supermarkets, organised retail outlets and online platforms [10,11]. Government activities targeted at value addition, processing and branding of traditional crops have further boosted the visibility of fox nut (makhana) in non-traditional production and consumption locations, particularly urban markets [12]. Although these advances have been made, existing studies on the fox nut (makhana) have primarily focused on farming methods, processing technologies and value-chain analysis in the key producing areas, particularly Bihar and eastern India [4,10]. Empirical research on consumer awareness, perceived and consumption patterns in non-producing urban economies is limited. The level of cultural familiarity is less important to make decisions about consumption, and the factors such as health consciousness, knowledge of nutritional benefits, price perception, product availability and exposure through structured retail channels are more important [13–15] in such economies. Research on consumer behaviour for traditional food products and functional food products shows that consumer awareness and perception have a significant impact on consumer behaviour. Some barriers like the price of the product, its limited supply and product diversity can make it difficult to consume the product regularly even though perceptions are high [16-18]. Knowing these behavioral traits are therefore critical in order to grow the domestic market for plant-based functional meals. The present study is aimed to study the consumer awareness, preference, consumption behaviour, factors

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Research materials and methods

Study area and research design. The study was conducted in southern India, focusing on the state of Tamil Nadu, with Coimbatore City selected as the specific study area. Tamil Nadu is one of the most urbanised and economically developed states in the region, characterised by changing dietary patterns, increasing health awareness and rising demand for value-added food products. Coimbatore, a major industrial and commercial urban centre with a large middle-income population and higher purchasing power, represents diverse urban food consumption behaviour. The presence of organised retail channels such as supermarkets, hypermarkets, dry fruit stores and online platforms, along with the availability of fox nut (makhana) despite being distant from traditional production regions, makes Coimbatore a suitable production-distant urban market for analysing consumer awareness, preferences and purchasing behaviour toward makhana [19].

A descriptive research design was utilized to examine consumer awareness and preferences towards fox nut (makhana), along with the factors influencing consumer preference and the limits affecting its adoption. Descriptive research designs are extensively employed in consumer behaviour studies to evaluate existing patterns, attitudes and preferences without modifying study variables [20].

Sampling technique and sample size. A non-probability multistage sampling technique was employed for the study. In the first stage, retail outlets where fox nut (makhana) is commonly available—namely supermarkets, hypermarkets and dry fruit stores were purposively selected based on product availability and relevance to the study objectives [21].

In the second stage, consumers were selected using convenience sampling from the identified retail locations. Respondents who were available and willing to participate at the time of the survey were interviewed using a structured interview schedule. This approach is commonly adopted in urban consumer studies conducted at retail points where a complete sampling frame is unavailable [22].

A total of 300 respondents were surveyed. Among them, respondents who reported awareness of fox nut (makhana) were considered for detailed analysis of consumer preferences, factors influencing preference and purchasing constraints. Similar sampling approaches have been effectively used in earlier studies on consumer awareness and preference for traditional and functional food products [13–15].

Data collection. Primary data were collected using a structured interview schedule developed with reference to earlier studies on consumer awareness and preferences related to traditional and health-oriented food products [14–18]. The interview schedule was designed to elicit information on the socio-economic characteristics of the respondents, awareness of fox nut (makhana), preferences regarding the type of fox nut (makhana) consumed, flavour, packaging size and place of purchase, factors influencing preference towards fox nut (makhana) and constraints affecting its consumption.

Prior to the main survey, the interview schedule was pre-tested among a small group of respondents to assess clarity, relevance and consistency of the questions. Based on the feedback obtained during the pre-testing stage, necessary modifications were made to improve the reliability and comprehensibility of the instrument [19].

Tools of analysis. The following statistical tools were used for analysing and interpreting the data. Percentage analysis, mean score analysis and factor analysis were employed in the study. Percentage analysis was used to interpret socio-demographic characteristics, levels of awareness and distribution of consumer preferences towards fox nut (makhana) [19]. Factor analysis was used to identify the key factors influencing consumer preference towards fox nut (makhana) [23]. All statistical analyses were carried out using IBM SPSS statistical software.

Descriptive analysis. Simple percentage analysis was used to interpret the socio-demographic characteristics of the respondents such as age, gender, educational qualification, occupation, annual income, family size and type of food consumed regularly. Percentage analysis was also employed to assess consumer awareness and sources of awareness regarding fox nut (makhana), as well as preference patterns related to product type, flavour, packaging size and place of purchase [19].

$$\text{Percentage analysis} = \left(\frac{\text{Number of respondents}}{\text{Total number of respondents}}\right) \times 100 \quad (1)$$

Factor analysis. Factor analysis is a multivariate statistical technique used to reduce a large number of interrelated variables into a smaller set of underlying factors based on their correlation structure. In the present study, Principal Component Analysis (PCA) with varimax rotation was applied to extract the factors influencing consumer preference towards fox nut (makhana).

The analysis included variables related to taste, perceived health benefits, nutritional value, packaging, shelf life, availability, price, brand awareness and advertisement, selected based on the objectives of the study and their relevance in earlier research on consumer preference for traditional and health-oriented food products. The suitability of the data for factor

analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity.

Factors with eigenvalues greater than one were retained in accordance with the Kaiser criterion. Varimax rotation was applied to improve interpretability of the factor structure, and factor loadings of 0.50 and above were considered significant for assigning variables to the respective components. These criteria ensured a reliable identification of the underlying dimensions influencing consumer preference towards fox nut (makhana).

The factor model used in the study can be expressed as:

$$X_i = A_{i1}F_1 + A_{i2}F_2 + A_{i3}F_3 + \cdots + A_{im}F_m + V_iU_i \quad (2)$$

where

X_i= i^{th}standardized variable ($i = 1,2,3, \ldots, k$)

A_{ij}= standardized multiple regression coefficient of variable $i$on common factor j

F_j= common factor ($j = 1,2,3, \ldots, m$)

V_i= standardized regression coefficient of variable $i$on the unique factor

U_i= unique factor associated with variable i

Garrett ranking technique. The Garrett ranking technique was employed to analyse and rank the constraints faced by consumers in purchasing and consuming fox nut (makhana). The percent position was calculated using the formula [24].

$$\text{Percent position} = \frac{(R_{ij} - 0.5)}{N_j} \times 100 \quad (3)$$

Where

R_{ij}= rank given for the i^{th}constraint by the j^{th}respondent

N_j= total number of constraints ranked by the j^{th}respondent

Results of the research and their discussion

Socio-economic profile of respondents

The socio-economic profile of the surveyed respondents in Coimbatore City are given in Table 1. The profile offers a valuable background on consumer awareness, perception, and consumption behaviour of fox nut (makhana).

The socio-economic characteristics of the respondents are presented in Table 1. The results show that male respondents constituted 65.7%, while females accounted for 34.3% of the sample. Nearly half of the respondents belonged to the 21–30 years age group (47.7%), followed by those aged 31–40 years (24.0%), indicating dominance of young urban consumers. With respect to education, a majority of respondents were undergraduates (60.7%), while 15.3% had postgraduate qualifications. In terms of occupation, 63.3% of the respondents were salaried employees, followed by 26.7% who were self-employed. A large proportion of respondents belonged to nuclear families (80.3%). Regarding income, the highest share of respondents fell under the ₹40,001–60,000 monthly family income group (39.7%), followed by higher income categories. These socio-demographic characteristics indicate that the sample is predominantly young, educated, and middle-income, with diverse dietary choices and substantial representation from the private and salaried employment sector.

Table 1. Socio-economic profile of respondents (n = 300)

Variable	Category	Frequency (n=300)	Percentage, (%)
Gender	Male	197	65.7
	Female	103	34.3
Age (years)	21–30	143	47.7
	31–40	72	24.0
	41–50	54	18.0
	Above 50	31	10.3
Education	School level	46	15.3
	Undergraduate	182	60.7
	Postgraduate	46	15.3
	Professionals	26	8.7
Occupation	Salaried / Employed	190	63.3
	Self-employed / Business	80	26.7
	Homemaker	24	8.0
	Others	6	2.0
Family type	Nuclear	241	80.3
	Joint	59	19.7
Monthly family income (₹)	20,001–40,000	55	18.3
	40,001–60,000	119	39.7
	60,001–80,000	42	14.0
	80,001–1,00,000	41	13.7
	Above 1,00,000	43	14.3

Awareness status of the respondents. The awareness of the respondents towards fox nut (makhana) are presented in Table 2.

Table 2. Awareness of the respondents towards fox nut (makhana)

Particulars	Response	Frequency	Per-cent (%)
Awareness of fox nut (makhana)	Aware	230	76.7
	Not aware	70	23.3

The results show that 76.7% of the respondents were aware of makhana, indicating that the product is fairly well known among urban consumers in Coimbatore. The source of awareness shows that most respondents came to know about fox nut (makhana) through friends and relatives (37.6%), followed by retail stores and supermarkets (24.8%) and social media (23.3%). Awareness through gym trainers or fitness centres (10.5%) reflects the growing link between fox nut (makhana) and health-oriented consumption. Very few respondents reported learning about fox nut (makhana) through television, newspapers (2.3%), or doctors and nutritionists (1.5%), indicating limited formal promotion. Overall, the results suggest that awareness of fox nut (makhana) is mainly shaped by personal contacts and retail exposure, rather than mass media or professional advice.

Consumer preferences towards fox nut. Consumer preferences were analysed among 198 respondents who had consumed fox nut (makhana). Preferences related to the type of fox nut (makhana), flavour, packaging size and place of purchase were collected using multiple-response questions, wherein respondents were allowed to select more than one option. Accordingly, responses were converted into percentages based on the total number of responses. Examining consumer preferences helps to understand how favourable perception is translated into actual product choices in production-distant urban markets, as also reported in earlier studies on fox nut (makhana) consumption and marketing [3,6].

Consumer preference for various types of fox nut (makhana) is presented in Fig. 1. The results indicate that consumers predominantly prefer fox nut (makhana) in forms that retain its health-oriented and natural image. A higher preference was observed for plain fox nut (makhana) (34.9%) and lightly processed variants. At the same time, a sizeable proportion of respondents expressed preference for flavoured or masala variants, indicating openness towards value-added products, provided that perceived health benefits are not compromised. Similar patterns of preference have been observed in studies on traditional and functional food products, where consumers favour minimally processed forms while gradually accepting flavoured and packaged variants [3,6,15].

Consumer preference for different flavours of fox nut (makhana) is presented in Fig. 2. The results indicate that flavour preference further reinforces the health-oriented positioning of fox nut (makhana), as consumers largely preferred plain and mildly seasoned flavours, while sweet and strongly flavoured variants were less favoured. This pattern suggests that fox nut (makhana) is primarily perceived as a functional or health-oriented snack rather than an indulgent food. Similar observations have been reported in earlier studies on makhana consumption and marketing, where consumers showed greater acceptance of minimally flavoured variants that retain perceived nutritional benefits [3,6].

Consumer preference for packaging size of fox nut (makhana) is presented in Fig. 3. Preferences related to packaging indicate a strong inclination towards moderate pack sizes, particularly 100 g packs (60.3%), followed by smaller packs. This preference reflects price sensitivity and value-for-money considerations, suggesting that consumers prefer pack sizes that balance affordability with quantity. Similar observations have been reported in fox nut (makhana) value-chain studies, where small and medium pack sizes were found to encourage trial purchase and reduce perceived financial risk among consumers [4,10].

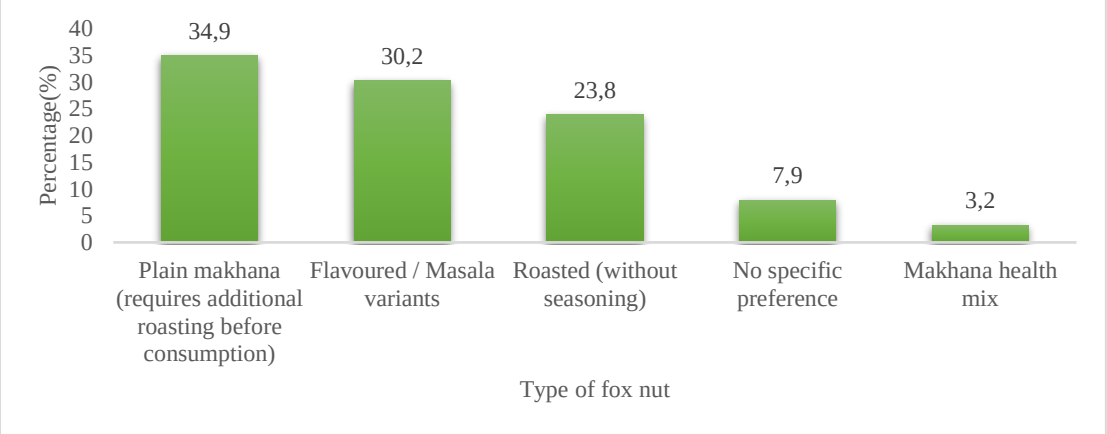

Fig. 1. Preferred type of fox nut among consumers

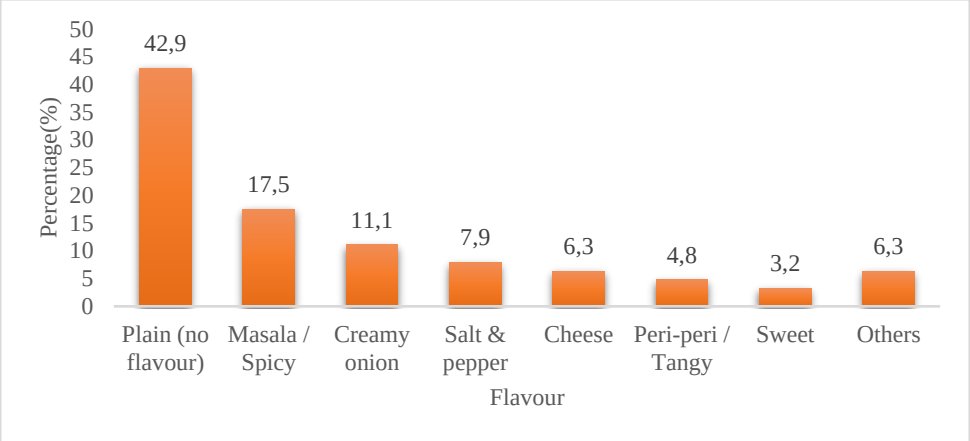

Fig. 2. Preferred flavour of fox nut among consumers

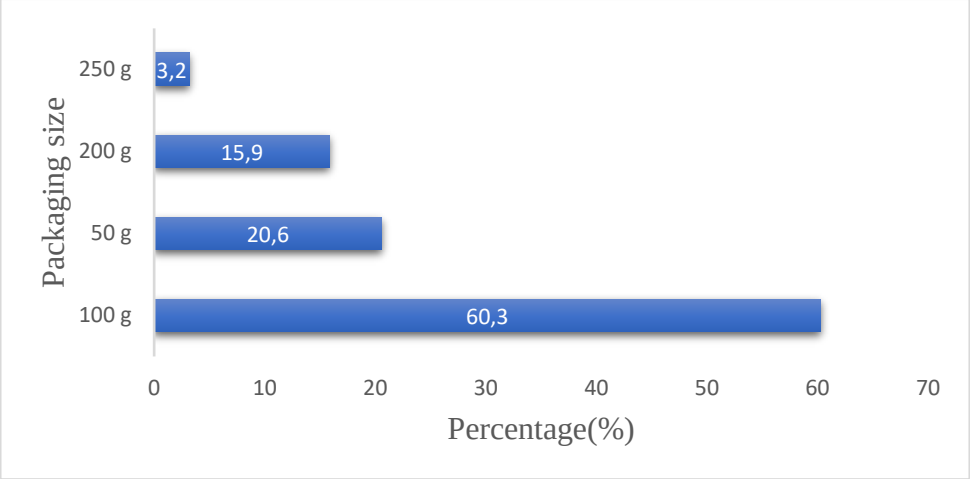

Fig. 3. Preferred packaging size of fox nut among consumers

The frequency of consumption of fox nut (makhana) among consumers is presented in Fig. 4. Despite favourable perception and clearly expressed preferences, fox nut (makhana) was largely consumed on an occasional basis, indicating that positive attitudes do not necessarily translate into habitual intake. This finding supports earlier studies, which reported that while health awareness and preference increase the likelihood of consumption, they do not always ensure regular use due to economic and market-related constraints [4,18].

The preferred place of purchase of fox nut (makhana) is shown in Fig. 5. With respect to purchase channels, consumers predominantly preferred supermarkets, hypermarkets and online platforms, highlighting the importance of organised retail formats for fox nut (makhana) in production-distant urban markets. Earlier studies on the fox nut (makhana) value chain have similarly emphasised the role of modern retail systems in improving product visibility, consumer trust and market access [4,10]

Factors motivating consumer preference towards fox nut (makhana) are presented in Figure 6. Health benefits emerged as the primary motivating factor for consumer preference, followed by taste, indicating that while health considerations drive preference and trial, sensory attributes remain important for sustaining consumer interest.

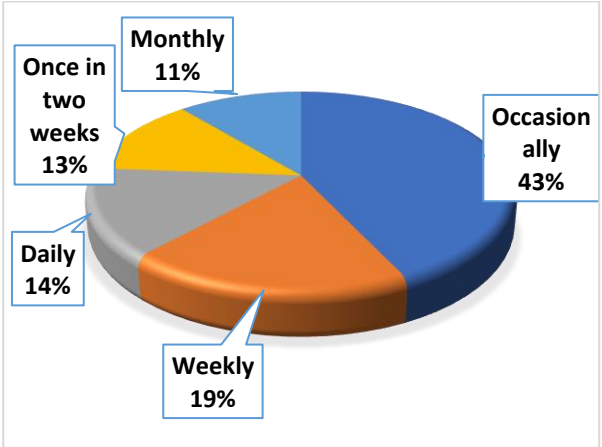

Fig. 4. Frequency of consumption of fox nut

This pattern aligns with earlier fox nut (makhana)-specific studies, which identified health and nutrition as key drivers of acceptance, with taste influencing repeat consumption [6,23]

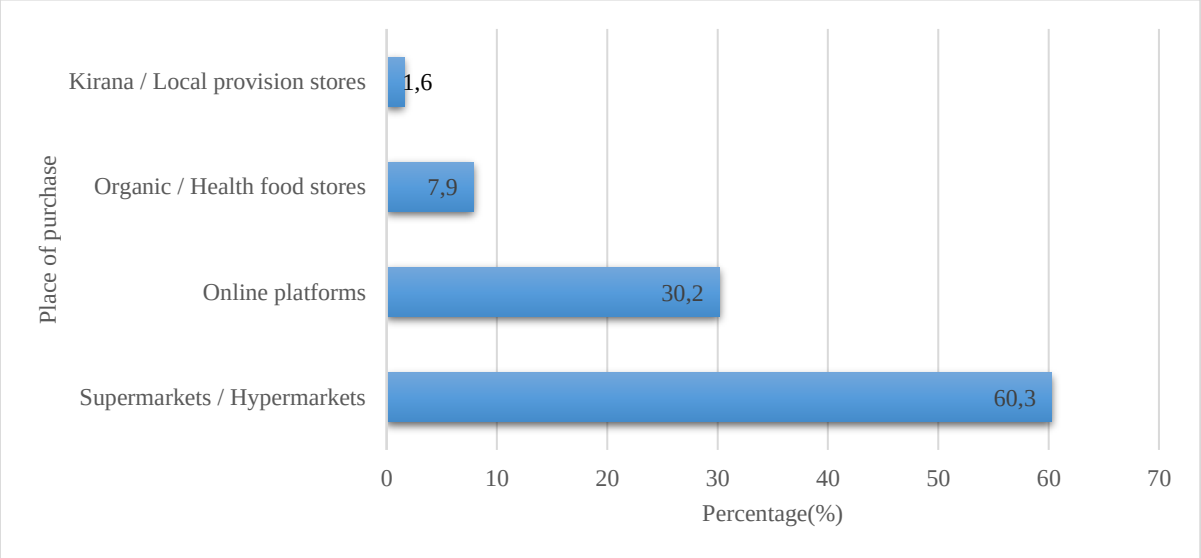

Fig. 5. Preferred place of purchase of fox nut

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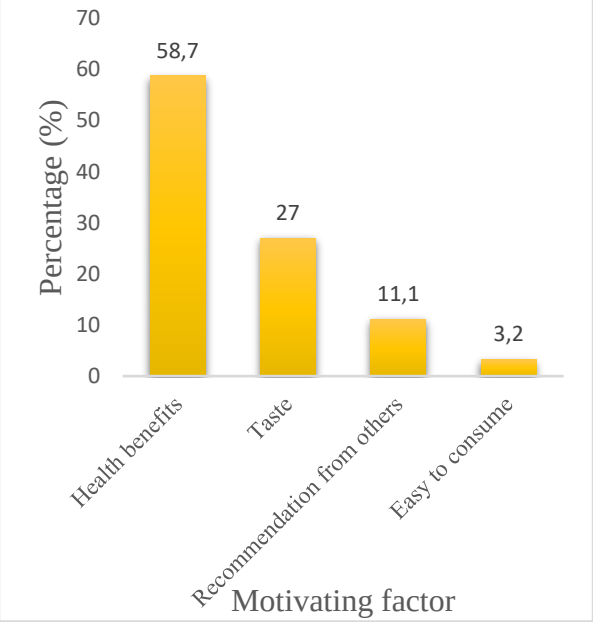

Fig. 6. Factors motivating preference for fox nut

Overall, the preference results indicate that consumers perceive fox nut (makhana) primarily as a health-oriented food and therefore favour plain, lightly processed and mildly flavoured variants. Health benefits emerge as the dominant factor influencing preference, confirming that nutritional considerations drive initial acceptance. However, preferences for moderate pack sizes and occasional consumption highlight the influence of price sensitivity and value for money concerns. Thus, while positive health perception supports preference and trial, economic and market-related factors limit regular consumption of fox nut (makhana) in production-distant urban markets.

Factor analysis. To investigate the factors influencing respondents' preference towards fox nut (makhana), exploratory factor analysis was employed using Principal Component Analysis (PCA) with varimax rotation. Factor analysis is a widely used multivariate statistical technique for reducing a large number of interrelated variables into a smaller set of underlying factors based on their correlation structure [24].

The adequacy and suitability of the data for factor analysis were assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity, and the results are presented in Table 3. The KMO value was 0.684, exceeding the recommended minimum threshold of 0.50, indicating that the sample was adequate for factor analysis. Bartlett's Test of Sphericity yielded an approximate chi-square value of 1797.645 with 153 degrees of freedom, which was statistically significant at $p < 0.001$, confirming that factor analysis was appropriate for examining the underlying dimensions influencing consumer preference towards fox nut (makhana) [24].

Table 3. KMO and Bartlett's test

Particulars	Values
Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	0.684
Bartlett's test of sphericity - Approx. Chi-square	1797.645
Degrees of freedom	153
Significance (p-value)	0.000

The number of factors to be retained was determined based on eigenvalues greater than one, following the Kaiser criterion, along with visual examination of the scree plot [24]. The scree plot (Fig. 7) showed a clear point of inflection after the sixth component, indicating diminishing explanatory power of subsequent components. Accordingly, six factors were retained for further analysis.

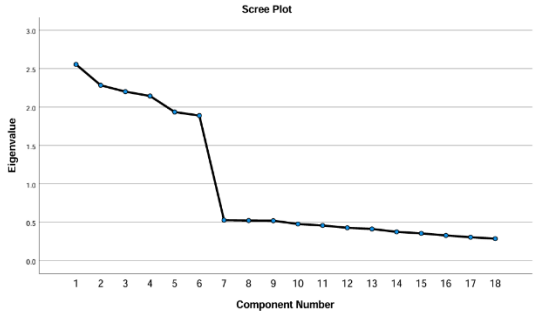

Fig. 7. Scree plot showing eigenvalues and number of components retained

The eigenvalues and the percentage of variance explained by each factor before and after rotation are presented in Table 4. The six extracted components together explained 72.24 per cent of the total variance, which is considered satisfactory in behavioural and consumer research (14). The first factor accounted for 14.19 per cent of the variance, followed by the second (12.68%), third (12.22%), fourth (11.91%), fifth (10.75%) and sixth factor (10.49%). The relatively high cumulative variance explained suggests that the extracted factors provide a robust representation of the key determinants influencing consumer preference towards fox nut.

Varimax rotation was applied to improve the interpretability of the factor structure by maximising the variance of squared loadings within each factor

Table 4. Total variance explained by principal component analysis

Component	Initial eigenvalue	% of variance	Cumulative %
1	2.554	14.190	14.190
2	2.283	12.682	26.872
3	2.200	12.223	39.094
4	2.143	11.907	51.002
5	1.935	10.749	61.751
6	1.888	10.490	72.241

. Factor loadings of 0.50 and above were considered significant for assigning variables to the respective factors, in accordance with standard recommendations in multivariate analysis [24]. The rotated component matrix is presented in Table 5, which shows a clear and interpretable clustering of variables across the six retained factors. The factor structure illustrating the relationship between observed variables and the six extracted components influencing consumer preference towards fox nut (makhana) is presented in Fig. 8.

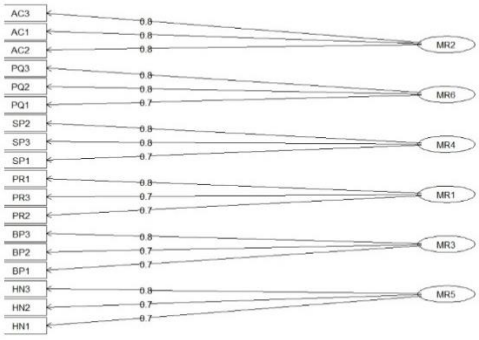

Fig. 8. Factor structure of consumer preference towards fox nut

Table 5. Rotated component matrix showing factors influencing consumer preference towards fox nut (makhana) (Note: Factor loadings ≥ 0.50 are shown.)

Variables	**F I**	**F II**	**F III**	**F IV**	**F V**	**F VI**
Online availability encourages purchase	0.861					
Easy availability influences purchase	0.860					
Availability in nearby retail outlets affects decision	0.847					
Low fat and calorie content influences purchase		0.861				
Perceived health benefits motivate purchase		0.851				
Recommendations from family and friends influence purchase		0.823				
Taste consistency influences repeat purchase			0.855			
Freshness of fox nut is an important factor			0.847			
Overall quality of fox nut influences purchase decision			0.844			
Price of fox nut affects purchase decision				0.871		
I compare prices of different brands before buying				0.843		
Fox nut offers good value for the price paid				0.819		
Hygienic and sealed packaging increases confidence					0.856	
Attractive and informative packaging affects choice					0.833	
Brand reputation influences purchase decision					0.830	
Fox nut is a healthier alternative to fried snacks						0.845

Based on the nature of variables with high factor loadings, the extracted factors were appropriately named and summarised in Table 6. The first factor, labelled Availability and accessibility, highlights the importance of organised retail outlets and online platforms in influencing purchase decisions in a non-producing urban market. The second factor, Health and nutritional attributes, underscores the role of health consciousness and perception of fox nut (makhana) as a low-fat, nutritious snack. The third factor, Sensory and product quality attributes, reflects the importance of taste consistency, freshness and perceived quality in repeat purchase behaviour. The fourth factor, Price perception and value for money, indicates consumer sensitivity towards pricing and brand comparison. The fifth factor, Packaging and brand-related attributes, emphasises hygiene, trust and visual appeal, while the sixth factor, Social influence and lifestyle orientation, highlights the role of peer recommendations and positioning of fox nut (makhana) as a healthier alternative to fried snacks.

Table 6. Identified factors and variance explained

Factor	Factor name	Variance explained (%)
I	Availability and accessibility	12.31
II	Health and nutritional attributes	12.15
III	Sensory and product quality attributes	12.13
IV	Price perception and value for money	12.04
V	Packaging and brand-related attributes	11.91
VI	Social influence and lifestyle orientation	11.70
Total		**72.24**

Overall, the factor analysis reveals that consumer preference towards fox nut (makhana) is multidimensional in nature. While health and nutritional considerations play a dominant role in initiating preference, factors such as availability, price perception, product quality, packaging, branding and social influence significantly determine sustained consumption. These findings are consistent with earlier studies on functional and plant-based foods, which suggest that both intrinsic product attributes and extrinsic market-related factors jointly shape consumer choice behaviour [1,24].

Constraints faced by consumers in purchasing fox nut. Despite favourable awareness and preference towards fox nut (makhana), several constraints were found to limit its regular consumption. The major purchasing constraints perceived by consumers were analysed using the Garrett ranking technique, and the results are presented in Table 7. Among the identified constraints, high price emerged as the most severe, followed by preference for alternative snack products and limited availability. This indicates that, although fox nut (makhana) is widely recognised as a healthy snack, its relatively premium pricing restricts frequent purchase, particularly among price-sensitive urban consumers.

Table 7. Garrett ranking of constraints faced by consumers in purchasing fox nut

Constraint	Rank
High price	I
Limited availability	II
Lack of information	III
Limited product variants	IV
Quality concerns	V
Unfamiliar consumption methods	VI

The prominence of price as a major constraint explains the earlier observation that fox nut (makhana) is consumed mainly on an occasional basis despite positive perception and preference. Similar constraints have been reported in studies on fox nut (makhana) and other traditional health foods, where higher prices limited regular consumption [3,18].

Limited availability further points to gaps in retail penetration, particularly outside organised outlets, which may restrict product visibility, impulse purchases and trial behaviour. In addition, constraints such as lack of information, limited product variety and unfamiliar consumption methods underline the need for improved consumer education and product innovation. Collectively, these constraints suggest that while health perception initiates interest in fox nut (makhana), market-related and economic barriers ultimately determine actual consumption behaviour. Addressing these constraints is essential for expanding fox nut (makhana) consumption in production-distant urban markets [4,10].

Conclusion

The present study shows that consumers recognise the fox nut (makhana) product in the production distant city Coimbatore, South India, and have shown a positive preference towards the healthy effect of the product. Majority of respondents were aware of fox nut/Makhana (76.7%) and their preference was influenced by health and nutritive value. Based on exploratory factor analysis, six important dimensions affecting the consumer acceptance were identified: availability and accessibility, health and nutritional attributes, sensory and product quality, price perception and value for money, packaging branding, social influence. The combined effect of these factors accounted for 72.24% of the total variance, suggesting that both product

characteristics and market factors play a role in the adoption of fox nut (makhana) in production distant urban markets. The Garrett ranking analysis also showed that high price was the largest factor impacting regular consumption, with limited availability and lack of information coming in second. The results indicate that raising consumers' awareness is not enough to guarantee their consumption, meaning that coordinated market and policy measures are needed. An increase in the price accessibility, encouragement to price rationalization, widening retail outlets and improving marketing and information dissemination will be important measures that can help in the consumer adoption of fox nut (makhana) product. In general, the study delivers empirical findings regarding the growing demand for functional foods in the emerging urban markets and can be viewed as an opportunity for functional food like makhana as a healthy plant-based snack that has tremendous potential in the urban markets of India and elsewhere.

Limitations of the Study. The present study is constrained by certain limitations which should be taken into consideration while interpreting the findings. First, the study was restricted to Coimbatore City and the results might not be applicable to consumer behavior on the fox nut (Euryale ferox Salisb.) in other urban area of India which is having different socio-cultural and economic Backgrounds. Second, the study used a non-probability sampling technique (that of convenience) which might prevent the results from being generalisable to the wider population. Third, the analysis is mostly based on the perceptions and self-reported responses of the consumers during the survey period which can be biased by the respondents and varying market conditions. Furthermore, only the main factors of awareness, preference behaviour and purchasing restrictions were looked into, and some factors like long term consumption behaviour, nutritional knowledge, willingness to pay and comparative analysis with other healthy snack products were not investigated in detail. In addition, the study focused exclusively on urban consumers, and did not involve rural consumption behaviour and other supply-chain actors (e.g. retailers and distributors).

Future Research Directions. Future studies may involve other cities and states of the country to get a wider perspective of consumer attitude towards fox nut in various geographical areas and demographic groups. A comparative study of rural and urban consumers would help to gain more insight into the differences in awareness, acceptance and consumption pattern. Other studies could also explore the willingness to pay, brand loyalty and promotional strategies and their effect on purchase behavior among consumers. Furthermore, longitudinal studies could be conducted to examine the variations in consumption over time, given that the market of plant-based functional food products is continually developing. The product diversification, sensory evaluation and development of innovative value added fox nut products to specific consumer segments can also be explored in future studies. The retailer/processor/four participants in this chain study should be expanded to understand how the markets are integrated and to enhance the efficiency of distribution of fox nut products in emerging urban markets.

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