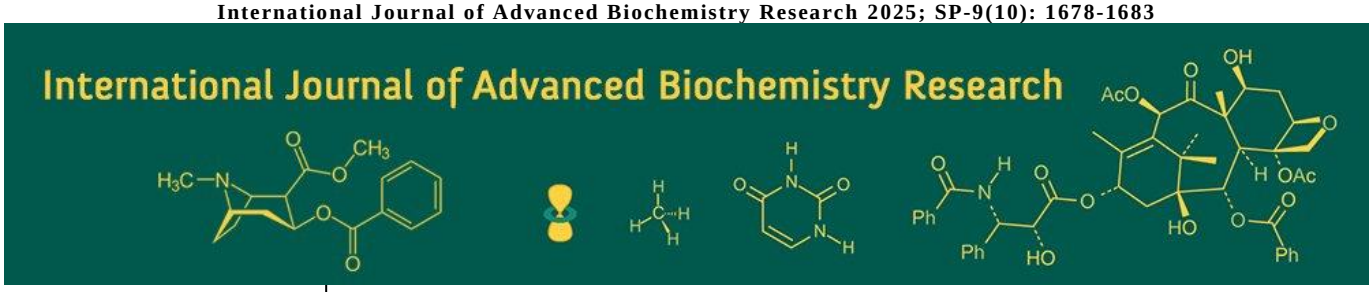

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Jiwtode SN
M.tech. Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Pawar VS
Professor & Head, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Shinde NA
M.tech. Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Thakur PP
Senior Research Assistant, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Joshi DR
M.tech. Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
Jiwtode SN
M.tech. Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Development and quality assessment of immunity booster jaggery cubes enriched with spices

Jiwtode SN, Pawar VS, Shinde NA, Thakur PP and Joshi DR

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Abstract
This study aimed to enhance the nutritional, functional, and sensory qualities of jaggery cubes through the incorporation of raw turmeric juice, cardamom powder, and nutmeg powder, all of which are rich in bioactive compounds and phytochemicals. Four formulations (T0-control, T1, T2, and T3) were prepared, with varying turmeric juice levels while maintaining constant proportions of cardamom and nutmeg. Sensory evaluation indicated that formulation T2 (89.8% liquid jaggery, 10% raw turmeric juice, 0.10% cardamom, and 0.10% nutmeg) achieved the highest overall acceptability score (8.6), along with superior taste and flavour. The findings demonstrate that spice-enriched jaggery cubes, particularly T2, possess improved nutritional value, enhanced sensory appeal, and extended shelf life, offering a health-oriented alternative to conventional sweeteners.

Keywords: Jaggery cubes, turmeric, cardamom, nutmeg, functional food

Introduction
The quest for more nutrient-dense and healthful food has had a big impact on how the confectionery industry has changed recently. Customers are actively looking for healthier options as they become more conscious of the negative health effects linked to consuming large amounts of traditional sweets, which are frequently heavy in fats, processed sugars, and artificial additives. Food manufacturers have been prompted by this change in customer behavior to investigate functional ingredients and natural sweeteners that improve flavor while also providing additional health advantages. India is making a significant contribution to this development and is well-known throughout the world for its solid agricultural base. India supports a sizable population worldwide and is a major producer of essential crops, such as sugarcane, by making the most of its land and water resources (Saxena, 2022) [26].
In addition to refined sugar, the main ingredient used to make jaggery, a traditional unrefined sweetener prized for its mineral content and nutritional advantages, is sugarcane (Manimozhi *et al*., 2021) [18]. In the meantime, throat infections have become a common condition in today's healthcare environment. Despite their prevalence, they are sometimes underappreciated, which can result in consequences such pharyngitis or, in more severe and protracted cases, the emergence of throat cancers (Mishra *et al*., 2017) [19].
One of the oldest and best-documented medical systems in the world is thought to be that of India. It is even thought to be more successful than contemporary Western treatment in some situations. Ayurveda distinguishes out among these systems as a complete, self-governing healthcare system that has persisted for centuries. The fundamental ideas of Ayurveda are said to have been developed in India between 2500 and 500 BCE, while its precise beginnings are lost to history. Ayurveda, which is often regarded as the oldest medical text still in existence, is believed to have originated around 900 BCE. "The science of life" is the term's literal meaning,
which is derived from the Sanskrit terms "Ayur" (life) and "Veda" (knowledge or science) (Ramya, 2021) [24].
The sugar sector holds the position of being the second-largest agro-based industry in India and plays a pivotal role in enhancing the socioeconomic status of the rural population (Chougule *et al*., 2021) [5]. It offers direct employment opportunities to approximately half a million individuals, including both skilled and semi-skilled workers, while also supporting the livelihoods of nearly 50 million farmers and their families. At present, India's annual

output includes about 27.7 million metric tonnes of refined sugar and 6.6 million metric tonnes of jaggery (Bashir and Yousuf, 2022; Jagannadha Rao *et al*., 2007) [3, 13].

Liquid jaggery is a promising component for creative applications in the confectionery industry because of its unique nutritional profile and related health advantages. Its incorporation into lollipop recipes is both appropriate and opportune, satisfying the growing customer need for goods that offer improved nutritional value in addition to a pleasing taste. Traditional candies are often associated with disease, including diabetes, obesity, and dental decay. The healthier option, on the other hand, is liquid jaggery, which is made from processed sugarcane juice. It has additional medicinal benefits beyond its inherent sweetness, such as strengthening the immune system and having cleansing qualities (Rao *et al*., 2007) [13].

India produces 300 million tonnes of sugarcane annually, of which 53% is turned into granulated sugar, 36% into jaggery and khandsari, 3% into chewable cane juice, and 8% into seed cane (Hirpara *et al*., 2020; I. Rajendran, 2020; Dilip Pawar *et al*., 2017) [10, 23, 22].

There are several regional names for jaggery, including Gur (Jaggery) in India, Desi in Pakistan, Panela in Mexico and South America, Jaggery in Burma and other African countries, Hakuru in Sri Lanka, and Naam Taanoi in Thailand (A. K. Thakur, 1999; Madhu *et al*., 2018; D Pawar *et al*., 2017; P Verma *et al*., 2019; Pankaj Verma *et al*., 2019; W R Jaffe, 2015) [27, 17, 22, 28, 12].

Materials and methods Raw Material Procurement

Raw materials such as liquid jaggery, Raw turmeric juice, Cardamom and nutmeg powder were procured from chandrapur district.

Methodology for preparation of jaggery cubes

Liquid jaggery was heated in a pan until it attained the striking point, corresponding to a temperature range of 118-123 °C. During heating, the syrup was continuously stirred to avoid scorching and to ensure uniform heat distribution. The attainment of the striking point was confirmed using the cold-water method, wherein a drop of syrup was introduced into chilled water and its consistency was examined. Different combinations of fresh turmeric rhizome juice, cardamom powder, and nutmeg powder were incorporated to improve both nutritional value and sensory attributes. Upon achieving the required concentration, the pan was withdrawn from the furnace, and the hot syrup was transferred to a cooling tray, followed by the addition of the turmeric juice, cardamom powder, and nutmeg powder. The mixture was then agitated with a wooden beater for 10-15 minutes to promote uniform cooling and to incorporate air, aiding in the setting process. The semi-solid mass was subsequently poured into pre-sanitized cube-shaped molds of varying capacities (250 g to 1 kg). The molding process was completed promptly to prevent premature crystallization.

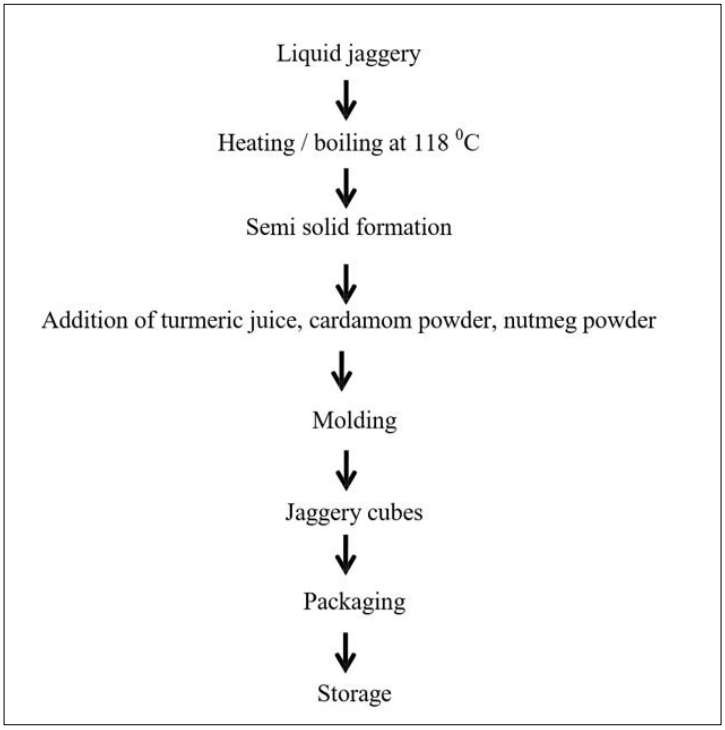

Fig 1: Process Flow chart of jaggery cubes incorporated with spices

Table 1: Standardization of process and recipe formulations of jaggery cubes

Ingredients			Quantity	
Liquid Jaggery		Raw turmeric juice	Cardamom powder	Nutmeg powder
T0	100	-	-	-
T1	94.80	5 ml	0.10	0.10
T2	89.80	10ml	0.10	0.10
T3	84.80	15ml	0.10	0.10

- **T_0:** 100 per cent liquid jaggery
- **T_1:** 94.80 per cent liquid jaggery + 5 per cent Raw turmeric juice + 0.10 Cardamom powder + 0.10 Nutmeg powder
- **T_2:** 89.80 per cent liquid jaggery + 10 per cent Raw turmeric juice + 0.10 Cardamom powder + 0.10 Nutmeg powder
- **T_3:** 84.80 per cent liquid jaggery + 15 per cent Raw turmeric juice + 0.10 Cardamom powder+0.10 Nutmeg powder

For the preparation of the jaggery cubes, all the ingredients were combined in accordance with the recommended ratio. The jaggery cubes was prepared with liquid jaggery as a base with varying concentration of liquid jaggery, fresh rhizome turmeric juice, cardamom powder and nutmeg powder.

Organoleptic evaluation of Jaggery cubes

For color, flavor, taste, texture and overall acceptability was carried out using hedonic scale rating test Deepthi *et al*., (2022).

Proximate analysis of Raw materials

The chemical composition of the raw materials was analyzed for parameters including moisture, ash, fat, protein, and total carbohydrate content. All determinations were conducted in triplicate, and the mean values were recorded. The analyses were carried out following the respective standard procedures outlined by the Association of Official Analytical Chemists (AOAC, 2005) [1].

Determination of Total phenol content

The total phenolic content (TPC) of each raw material was quantified using the Folin-Ciocalteu method. Briefly, 0.5 mL of the sample was transferred into a Falcon tube and combined with 0.5 mL of Folin-Ciocalteu reagent. The reaction mixture was neutralized by adding 1 mL of 7.5% sodium carbonate (Na_2CO_3) solution, followed by the addition of 8 mL of distilled water. The contents were vortexed for 20 seconds and allowed to stand at ambient temperature for 35 minutes. The mixture was then centrifuged at 1968×g for 10 minutes. The absorbance of the resulting supernatant was recorded at 725 nm using a spectrophotometer. TPC values were calculated from a gallic acid standard calibration curve and expressed as g/g gallic acid equivalents, following the procedure outlined by Halim *et al*. (2024) [15].

Determination of Total flavonoid

The total flavonoid content (TFC) was estimated using a colorimetric assay with minor modifications to the method described by Rahman *et al*. (2024). In brief, 1 mL of the extracted sample was diluted with 4 mL of distilled water and combined with 0.3 mL of 5% sodium nitrite ($NaNO_2$) solution. After a 5-minute reaction period, 0.3 mL of 10% aluminum chloride ($AlCl_3$) was added, and the mixture was incubated at ambient temperature for 1 minute. Subsequently, 2.4 mL of distilled water and 2 mL of 1 M sodium hydroxide (NaOH) were introduced, followed by vortexing for 20 seconds. The solution was centrifuged at 1968×g for 5 minutes and kept in the dark at room temperature for 15 minutes. The absorbance of the resulting supernatant was recorded at 510 nm using a spectrophotometer. A standard calibration curve was prepared using catechin, and the TFC was expressed as grams of catechin equivalent per gram of sample.

Determination of curcumin

The percentage of dried turmeric fingers was determined using a solvent extraction followed by a spectrophotometric assay. Approximately 1 g of the sample was refluxed with 75 mL of acetone for 1 hour, after which the extract was filtered and the volume adjusted to 200 mL. From this solution, 1 mL was further diluted to 100 mL in a volumetric flask. To prevent photodegradation of curcumin, the flasks were wrapped in dark-colored paper and maintained under light-protected conditions. The absorbance of the prepared solution was measured at 420 nm using a UV-visible spectrophotometer. A standard UV spectrum was obtained for pure curcumin as described by Geethanjali *et al*. (2016) [9]. The obtained absorption of samples was compared with the standard curcumin in samples calculated using formula:

Calculation

Curcumin (%) = [Ds*As/100*Ws*1650]*100

Where,

Ds - Dilution volume of the sample (i.e., 200 ×100 =20000ml) Ws - Weight of the sample taken in grams 62

As - Absorbance of the sample 1650 - Standard value calculated by experts

Statistical analysis

The data obtained was analyzed statistically by Completely Randomized Design (CRD) as per the procedure given by Panse and Sukhatme (1967) [21]. The analysis of variance revealed at significance of $P<0.05$ level, S.E. and C.D. at 5% level is mentioned wherever required.

Results and Discussion

The proximate composition of the raw materials—liquid jaggery, raw turmeric juice, cardamom powder, and nutmeg powder—was evaluated to assess their nutritional contribution and functional role in the formulation of jaggery cubes. The compositional analysis included key parameters: moisture, fat, protein, carbohydrate, crude fiber, and ash content, which are vital indicators of food quality, stability, and nutritional value. The results are presented in Table 4.1.

Liquid jaggery, the base ingredient of the product, exhibited a moisture content of 32.44±0.04%, which ensures sufficient pliability and shelf stability. The carbohydrate content was found to be 63.54±0.10%, making it a concentrated energy source. The product also contained protein (0.51±0.03%), fat (0.25±0.02%), crude fiber (0.34±0.25%), and ash (2.92±0.08%), contributing to its minor but significant nutritional and mineral profile. These findings are in close agreement with those reported by Wadmare *et al*. (2024) [29], confirming the nutritive value of traditionally prepared liquid jaggery.

Table 2: Proximate composition of raw materials

Sample			Parameters (%)			
	Moisture	Fat	Protein	Carbohydrate	Crude fiber	Ash
Liquid Jaggery	32.44±0.04	0.25 ±0.02	0.51±0.03	63.54±0.10	0.34±0.25	2.92±0.08
Raw turmeric juice	78.43±0.09	0.85±0.10	3.11±0.09	14.48±0.20	1.04±0.06	1.98±0.17
Cardamom powder	17.67±0.16	13.63±0.25	1.16±0.15	44.61±0.09	14.90±0.11	7.95±0.19
Nutmeg powder	11.21±1.16	24.26±0.18	16.63±0.11	34.15±0.13	13.84±0.13	3.15±0.13
*Values expressed as the mean±SD (n=3)						

Raw turmeric juice, added for its functional and therapeutic properties, demonstrated a high moisture content (78.43±0.09%). It also contributed carbohydrates (14.48±0.20%),
protein (3.11±0.09%), fat (0.85±0.10%), crude fiber (1.04±0.06%), and ash (1.98±0.17%). The appreciable levels of protein and fiber suggest its potential to enhance the nutritional and textural attributes of the jaggery cubes. These values align closely with those reported by Gaikwad *et al*. (2024) [8], indicating reliability in the composition of turmeric as a bioactive-rich additive.

Cardamom powder, known for its aromatic and medicinal properties, presented a diverse proximate profile. The composition analysis revealed moisture (17.67±0.16%), fat (13.63±0.25%), protein (1.16±0.15%), carbohydrate (44.61±0.09%), crude fiber (14.90±0.11%), and ash (7.95±0.19%). The high fat content is characteristic of cardamom seeds and contributes to its flavor retention properties. These findings are consistent with the results reported by Jadav and Mehta (2019) [11], validating the use of cardamom as both a flavoring and nutritionally relevant ingredient.

Nutmeg powder exhibited a rich proximate composition with fat (24.26±0.18%) and protein (16.63±0.11%) being the dominant constituents. The carbohydrate content was recorded at 34.15±0.13%, while moisture (11.21±1.16%), crude fiber (13.84±0.13%), and ash (3.15±0.13%) were also observed. The high fat and protein values signify its potential as a functional ingredient capable of enhancing both the energy density and structural stability of jaggery cubes. These results corroborate the findings of Okiki *et al*. (2023) [20], underlining nutmeg's nutritional richness and applicability in functional food development.

Phytochemical of raw materials

The total phenolic content of liquid jaggery 3.96±0.11 (mg/gm) and total flavonoids of liquid jaggery 1.33±0.66 (mg/ml) were observed and are closely agreement with Aralkar *et al*., (2023) [2].

Table 3: Quantitative phytochemical analysis of raw materials

Phytochemicals			
Sample	Total phenols (mg/gm)	Total flavonoids (mg/ml)	Curcumin
Liquid Jaggery	3.96±0.11	1.33±0.66	
Raw turmeric juice	265.08±0.13	80.29±0.13	5.99±0.11
Cardamom powder	16.21±0.16	0.76±0.14	
Nutmeg powder	77.90±0.22	16.02±0.18	
*Values expressed as the mean±SD (n=3)			

The total phenolic content, total flavonoid and curcumin of raw turmeric juice was 265.08±0.13 mg/gm, 80.29±0.13 mg/ml, 5.99±0.11 respectively. The research are aligned with research finding of (Sahu & Saxena, 2013) [25].

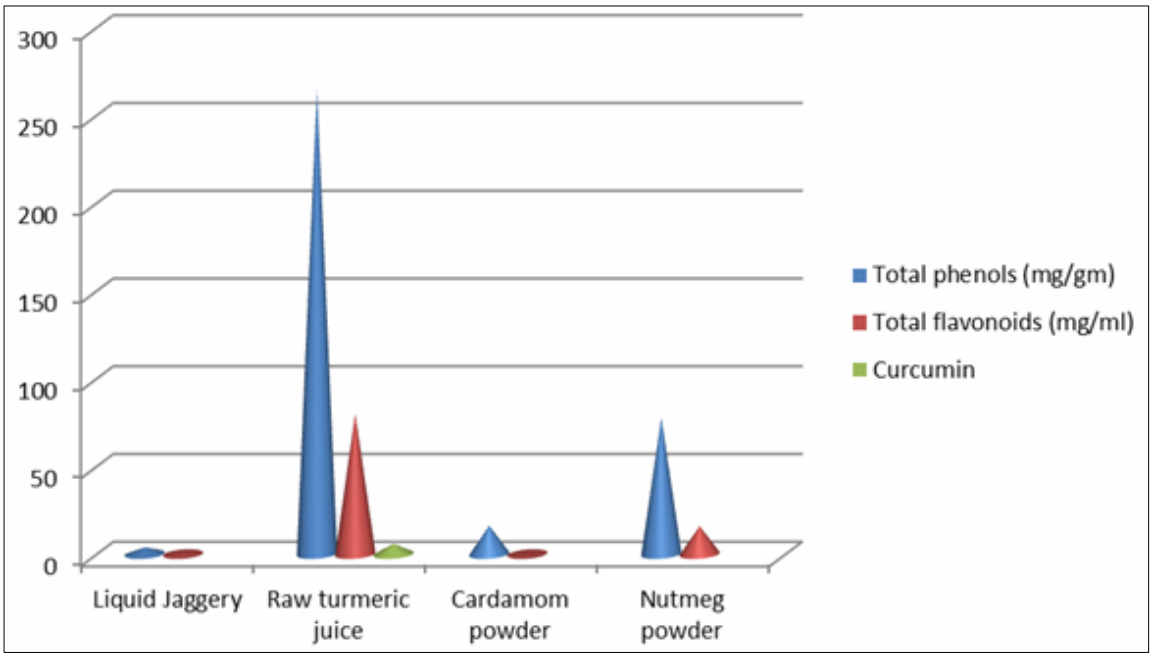

Fig 2: Quantitative phytochemical analysis of raw materials

It was observed that 16.21±0.16 (mg/gm), 0.76±0.14 (mg/ml) of total phenolic content and total flavonoid in cardamom powder were found respectively were in line with Bhatti *et al*., (2010) [4].

The total phenolic content and total flavonoid of nutmeg powder were found 77.90±0.22 (mg/gm) and 16.02±0.18 (mg/ml) respectively. These results were related with the results reported by (Erizal *et al*., 2023) [7].

Organoleptic evaluation

Organoleptic assessment is a critical parameter in determining the market preference of food products. The developed jaggery cubes were evaluated for sensory attributes, including colour, flavour, taste, texture, and overall acceptability, using a 9-point hedonic scale. The results were compared with those of a control sample and a commercially available market sample, as presented in Table 3. Among all treatments, formulation T2 achieved the highest overall acceptability score (8.6), reflecting superior consumer preference. This treatment also obtained the highest ratings for taste (9.0) and flavour (8.8), which substantially influenced its overall acceptance. The results indicate that the specific formulation of T2 significantly improved the sensory characteristics, particularly enhancing palatability and aromatic quality compared to the control and other treatments.

Table 4: Sensory evaluation of jaggery cubes

Sample			Sensory attributes		
Colour		Flavour	Taste	Texture	Overall acceptability
Control	8.9	7.5	7.8	8.5	8.1
T1	8	7.9	8.5	8.5	8.2
T2	8.5	8.8	9	8.4	8.6
T3	8	8.2	7.5	8.4	8
SE±	0.06	0.10	0.15	0.15	0.10
CD at 5%	0.18	0.31	0.45	0.46	0.29
* Each value is the mean value of all sensory reports					

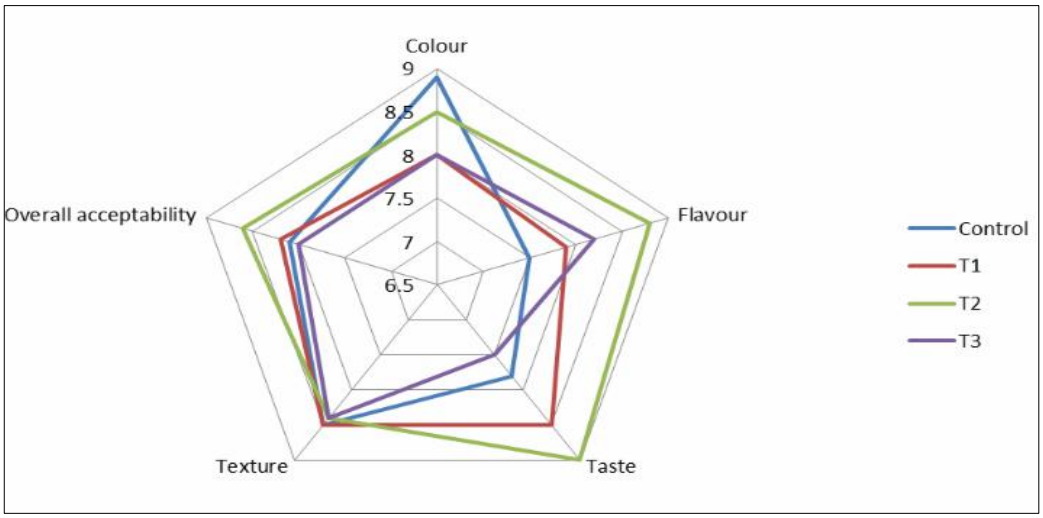

Fig 2: Organoleptic evaluation of jaggery cubes incorporated with spices

Conclusion

From the present investigation it was concluded that jaggery cubes prepared with incorporation of fresh turmeric rhizome juice, cardamom powder, and nutmeg powder had good nutritional and sensory quality attributes. It was also concluded that sample T2 got highest score for overall acceptability and it was taken for further analysis.

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