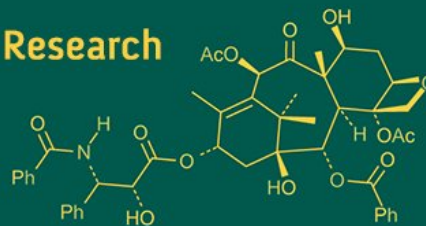


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Dinkar R Murkute
Department of Fish Processing
Technology, College of Fisheries,
Ratnagiri, Maharashtra,
India

Asif U Pagarkar
Department of Fisheries
Hydrography, College of Fisheries,
Ratnagiri, Maharashtra, India

Ketan J Chaudhari
Principal/Associate Dean, Fisheries
Engineering Polytechnic, Ratnagiri,
Maharashtra, India

Sachin B Satam
Marnie Biological Research Station,
Ratnagiri, Maharashtra, India

Varsha R Bhatkar
Department of Aquaculture, College of
Fisheries, Ratnagiri, Maharashtra,
India

Anamika Priya
Department of Fisheries
Hydrography, College of Fisheries,
Ratnagiri, Maharashtra, India

Paresh A Valu
Department of Fish Processing
Technology, College of Fisheries,
Ratnagiri, Maharashtra,
India

Rohit S Apte
Department of Fish Processing
Technology, College of Fisheries,
Ratnagiri, Maharashtra,
India

Rabita R
Department of Fisheries Engineering,
College of Fisheries, Ratnagiri,
Maharashtra, India

Rohit B Hajare
Department of Fish Processing
Technology, College of Fisheries,
Ratnagiri, Maharashtra,
India

Dhariniswara S
Department of Fish Processing
Technology, College of Fisheries,
Ratnagiri, Maharashtra,
India

Corresponding Author:
Dinkar R Murkute
Department of Fish Processing
Technology, College of
Fisheries, Ratnagiri,
Maharashtra, India

Development and standardization of water chestnut cookies enriched with seaweed and finger millet

Dinkar R Murkute, Asif U Pagarkar, Ketan J Chaudhari, Sachin B Satam, Varsha R Bhatkar, Anamika Priya, Paresh A Valu, Rohit S Apte, Rabita R, Rohit B Hajare and Dhariniswara S

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Abstract

Cookies were developed and standardized by using water chestnut flour, finger millet and seaweed powder, seaweed powder prepared from *sargassum tenerrimum*. The objective was to develop gluten-free cookies for the person having celiac disease, recently the demand for gluten-free food product is increased due to gluten indigestion. Cookies were prepared from water chestnut flour and enriched with finger millet and seaweed. Different ratios of cookies were developed and followed sensory evaluation by altering the water chestnut flour, finger millet flour and seaweed flour and other ingredients. The final standardized water chestnut-based seaweed cookies incorporated with 4% seaweed flour per 100 g total flour (67.2 water chestnut flour and 30 g finger millet flour) gained highest overall acceptability score. The proximate composition of standardized water chestnut-based seaweed cookies shows moisture $3.24 \pm 0.02\%$, protein $7.44 \pm 0.02\%$, fat $22.35 \pm 0.02\%$, ash $1.90 \pm 0.01\%$, carbohydrate $65.04 \pm 0.03\%$. The developed cookies were nutritionally enriched and also best substitute from available cookies in market for celiac disease persons.

Keywords: Water chestnut flour, Finger millet, Seaweed, *Sargassum tenerrimum*, Gluten-free cookies

Introduction

Bakery goods are among the most significant and largest groups of foods because of their ease of use, affordability and attractive characteristics such as a long shelf life, which makes bakery goods a prominent component of daily diets globally (Pareyt and Delcour, 2008; FAO, 2023) [23]. Cookies are one of the most popular bakery products because of their taste, crispy texture and easy-to-eat nature, along with good popularity with consumers among different groups of consumers (Manley, 2011; Gani *et al.*, 2015) [19, 9]. Traditionally, cookies are made from refined wheat flour, sugar and fat, which provide desirable organoleptic properties and lack sufficient dietary fiber; important minerals and bioactive substances (Sudha *et al.*, 2007; Dhingra & Jood, 2004) [34, 4]. Recently, consumers' growing awareness of the link between healthy eating and lifestyle contributed to the shift in their preferences towards products with beneficial nutrients as well as functional bakery products (Bigliardi and Galati, 2013; Granato *et al.*, 2020) [2, 11]. Researchers tend to introduce various non-traditional flours, grains, leguminous plants, fruits, vegetables and marine resources in baking in order to make baked goods healthy and tasty (Noort *et al.*, 2010; Gómez *et al.*, 2020) [21, 10]. Such methods of fortification not only boost protein, fiber, vitamins and antioxidants level but lead to the production of functional food promoting better health and meeting evolving consumer demands (Sharma and Gujral, 2019; Silva *et al.*, 2024).

Gluten-free (GF) foods are essential for individuals with celiac disease, a chronic autoimmune disorder triggered by the ingestion of gluten, a protein found in wheat, barley and rye. In affected individuals, gluten causes inflammation and damage to the intestinal villi leading to nutrient malabsorption, gastrointestinal issues and long-term complications such as osteoporosis, infertility and certain cancers (Green and Cellier, 2007) [7]. Non-celiac gluten sensitivity (NCGS) is a condition where individuals experience gastrointestinal or systemic symptoms when consuming gluten-containing foods, despite testing negative for celiac disease and wheat allergy (Sapone *et al.*, 2012) [27]. Gluten-free diets are increasingly adopted by individuals without gluten-related disorders, often perceived to improve digestion, energy

levels and overall well-being. However, this trend has sparked debate due to potential nutritional imbalances, as many gluten-free products are low in fiber, iron, calcium and B vitamins (Gaesser and Angadi, 2012) [8]. The global seaweed production in 2024 reached 38.9 million tonnes (FAO, 2026). Seaweeds are widely used in the food industry for their nutritional richness and functional roles. In Asian cuisines, they appear as nori, wakame and kelp. They contain hydrocolloids like agar, carrageenan and alginate used as gelling and thickening agents in jellies, dairy, sauces and more. Nutritionally, seaweeds are rich in vitamins A, C, B12, iodine, calcium, fiber and antioxidants contributing to their role in health foods and supplements (McHugh, 2003; Pagarkar *et al.*, 2015) [22]. India's coastline supports a rich diversity of seaweeds, with approximately 74,083 (wet weight) tonnes of seaweed produced in 2024 (PIB 2025). The aim of this study is to develop and standardize the water chestnut-based seaweed cookies.

Materials and Methodology

Raw material collection

Seaweed (*Sargassum tenerrimum*) was collected from the Ratnagiri coast and for identification brought to Marine Biological Research Station, Ratnagiri. After identification, it was washed with water and kept for drying and ground in powder form.

Preparation of seaweed (*Sargassum tenerrimum*) powder

Seaweed powder was prepared using the method given by Gaikwad which involves several stages such as collection, washing, drying, grinding and storage. Seaweed powder was packed in High Density Polyethylene (HDPE) bag of 100-micron thickness and stored in dry place.

Cookies preparation and standardization

Cookies were prepared from water chestnut flour, finger millet flour, seaweed flour, sugar, butter, milk and sodium bicarbonate. All ingredients were used for the standardization of water chestnut-based seaweed cookies and this shows the highest overall acceptability. All ingredients were mixed thoroughly and prepared dough then roll in sheet, shape by using mould and baked at 170 °C for 17 minutes in the microwave oven.

Standardization of water chestnut-based seaweed cookies

Water chestnut-based seaweed cookies were prepared with a tentative recipe of Chavan *et al.*, with some changes. Sensory evaluation of prepared cookies showed that 30:70 (Ragi: refined wheat flour) got the highest sensory score for the balanced colour, flavour better texture, test and highest score for overall acceptability, as the concentration increases of ragi a noticeable dark colour changes as compared to others. Similar ratio (30:70) finger millet to refined wheat flour used by Bhoite, Suneeta and Rao, (2019) [1] and Chavan *et al.* Sensory evaluation showed that (00:70) of refined wheat flour to water chestnut flour got the highest sensory score for the better colour, texture and overall acceptability as compared to other, lower concentration of water chestnut to refined wheat flour shows lower colour and texture as compared to higher concentration. Sensory evaluation showed that 70:00 (water chestnut: refined wheat flour) got highest sensory score for the appearance, colour, texture and overall acceptability, due to increasing water

chestnut flour increases whiteness and increase in colour and textural score. Similar finding was obtained by Pawaskar *et al.*, (2024) [24] the results showed that the cookies with 85% water chestnut and 15% finger millet flour was most preferred by panellist with an average score of 8 for overall acceptability. Similarly, Rupam and Jacob (2019) [26] developed fasting cookies using 50:35:15 (water chestnut: sweet potato: amaranth), 60:25:15, and 70:15:15 flour blends, along with a 100% water chestnut flour control. Among the formulations, the 70:15:15 blend (T3) exhibited the highest sensory acceptance, with improved protein (14.61%) content, and was recommended as the optimum formulation due to its superior sensory and textural properties. Sensory evaluation for sugar showed that among different ratios of sugar in water chestnut-based finger millet cookies, cookies formulated with 40:100 (sugar: total flour) ratio of sugar exhibited superior sensory characteristics compared with other formulations, lower concentration showed less sweet and in other hand higher concentration cookies were sweeter and also dark in colour. Similar results were obtained by Deasi and Bhodankar evaluated that 40:100 sugar ratio best for prepared cookies. Similarly, Sharma and Riar, (2020) [30] employed a sugar-to-total-flour ratio of 40:100 (w/w) in the formulation of cookies prepared from a composite minor millet flour blend. Sensory evaluation showed that cookies formulated with 50:100 ratio of fat to total flour got the highest sensory score as compared to other formulations, cookies with lower fat content showed hard texture and less flavour as compared to other likewise with higher concentration of fat shows smooth texture and greasy mouthfeel. Similar results were obtained by Rupam and Jacob, (2019) [26] formulated fasting cookies from water chestnut, sweet potato and amaranth flours using 50 g butter per 100 g flour blend, which produced cookies with desirable sensory and textural characteristics, likewise Hooda and Jood, (2005) [15] formulated fenugreek-fortified biscuits using about 50 g fat per 100 g flour, demonstrating improved tenderness and consumer acceptability. Sensory scores for milk suggested that cookies formulated with 12 ml showed highest sensory score for colour and texture, lower concentration of milk showed rough dough while preparing cookies and prepared cookies had cracks on the surface and with higher concentration cookies were baked from outside only and soft from inside. Similarly, Sibian and Riar, (2019) [31] used 20 g of skimmed milk powder instead of milk for the preparation of composite flour cookies. Sensory evaluation showed that 4 % seaweed powder (*Sargassum tenerrimum*) was got highest sensory scores, while increasing the percentage of seaweed powder in cookies showed darker colour, strong smell and bitter in taste. Similar findings were obtained by Hajare *et al.*, 4 % seaweed powder was got highest sensory score for overall acceptability, while cookies with a high proportion of seaweed powder (6% and 8%) had a considerable number of cracks on their surfaces. Kumar *et al.* (2018) [16] developed semi-sweet biscuits fortified with seaweed (*Caulerpa racemosa*) powder by substituting refined wheat flour at four incorporation levels: 0%, 1%, 5% and 10%. Sensory evaluation revealed a significant decline in overall sensory attributes at higher substitution levels (5% and 10%) relative to the 1% seaweed-supplemented formulation. Specifically, the overall

acceptability score declined from 7.78 for the control sample to 5.64 as the level of seaweed powder incorporation increased, indicating an inverse relationship between seaweed concentration and sensory acceptability of the biscuits. Sensory evaluation showed that 2 g sodium bicarbonate got the highest score for texture and overall acceptability as increasing the quantity showed cracks on the surfaces and bitter in taste. Shafi *et al.* (2016) ^[28] prepared wheat and water chestnut flour cookies using 1.1 g sodium bicarbonate per 100 g flour in formulations containing 0, 20, 40, 60, 80 and 100% water chestnut flour. They reported that sodium bicarbonate contributed to the production of cookies with desirable physical and textural properties, similarly Hajare *et al.* used 2 g sodium bicarbonate for preparation of cookies and got desirable texture and overall acceptability.

Sensory evaluation stated that 170°C baking temperature got the highest sensory score as compared to other formulations for baking of cookies as temperature increases darker colour of the cookies and while lower temperature cookies were unbaked. Gupta and Awasthi (2021) ^[14] baked water chestnut finger millet biscuits at 180°C for 15-20 min, while Rupam and Jacob (2019) ^[26] prepared cookies with water chestnut, sweet potato and amaranth cookies at 180°C for 20 min, obtaining products with satisfactory sensory quality. Desai and Bodhankar (2023) ^[3] also baked gluten-free cookies with water chestnut and almond flour at 180°C for 15 min and reported acceptable texture and flavour. In sensory evaluation panellists observed that cookies baked for shorter time had soft texture and like unbaked and higher time showed dark colour for this best time for baking cookies was 17 min got the highest sensory scores as compare to others. Pawaskar *et al.* (2024) ^[24] prepared cookies for 15 min time got the highest sensory score was achieved.

Proximate composition of water chestnut based finger millet seaweed cookies: The proximate composition of water chestnut based finger millet seaweed cookies such as moisture was 3.24±0.02 %, protein 7.44±0.02 %, fat 22.35±0.02 %, ash 1.90±0.01 % and carbohydrate 65.04±0.03 %. Suneeta and Rao recorded that the proximate composition of finger millet cookies was moisture 1.63 %, protein 5.18 %, fat 30.24 % and ash 0.62 %. Similarly, Din *et al.* (2024) ^[5] observed proximate composition of water chestnut-based finger millet cookies with replacement of wheat flour having moisture 7.7 ±0.2 %, fat 2.3 ± 0.1 %, ash 2.2 ± 0.1 % and protein 8.7 ±0.1 % in the replacement of water chestnut flour to white flour (60:40). Similarly, Deasi and Bhodankar evaluated the study of Water chestnut finger millet cookies fortified with almond flour at (80:20) and found moisture content was 12.39 %, ash 1.11 %, protein 10.97 %, fat 49.62 % and carbohydrate 61.91 %. Kumar *et al.* (2018) ^[16] incorporated *Caulerpa racemosa* powder at 0, 1, 5 and 10% in semi-sweet biscuits and found that protein content was 7.69 %, fat 14.48 %, moisture 4.1 %, ash 1.28 % and carbohydrate 72.37 %. Sivaraman *et al.* (2023) ^[33] incorporated *Portieria hornemanii* seaweed powder at 2.5, 5.0, 7.5 and 10% (along with a fixed 5% tilapia fish protein concentrate) in cookies and reported that 2.5% seaweed produced the highest sensory acceptability. Seaweed incorporation significantly increased protein (4.98 to 8.19%), ash (1.19 to 1.97%) and dietary fibre (0.79-3.35%), whereas fat content decreased at higher seaweed levels because of the naturally low lipid content of the seaweed.

Table 1: Yield (%) of seaweed powder from wet seaweed

Sr. no	Form of seaweed	Yield (%)
1.	Wet seaweed	100
2.	Seaweed powder	9.0

Table 2: Selection of recipe for water chestnut-based finger millet

Recipes Ingredients	A Siwela <i>et al.</i> (2009)	B Suneeta and Rao (2019)	C Chavan <i>et al.</i> (2023)
Refined wheat flour	480 g	70 g	70 g
Finger millet flour	350 g	30 g	30 g
Water	25 ml	-	-
Fat	250 g	74 g	50 g
Milk	-	-	12 ml
Milk powder	-	10 g	-
Coconut powder	-	10 g	-
Sugar	-	52 g	35 g
Salt	6 g	-	-
Sodium bicarbonate	8.5 g	2 g	2 g
Flavour	5 ml	-	-
Egg	60 ml	-	-

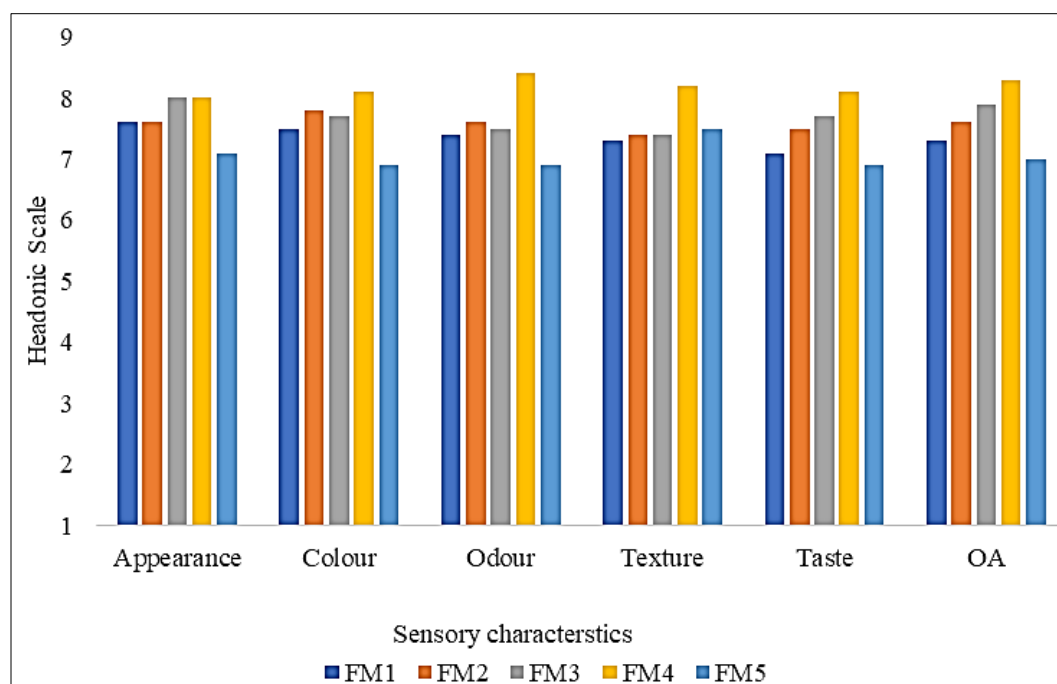


Fig 1: Mean sensory scores of finger-millet cookies prepared with different ratios of finger-millet to refined wheat flour. FM1 (00:100), FM2 (10:90), FM3 (20:80), FM4 (30:70) and FM5 (40:60)

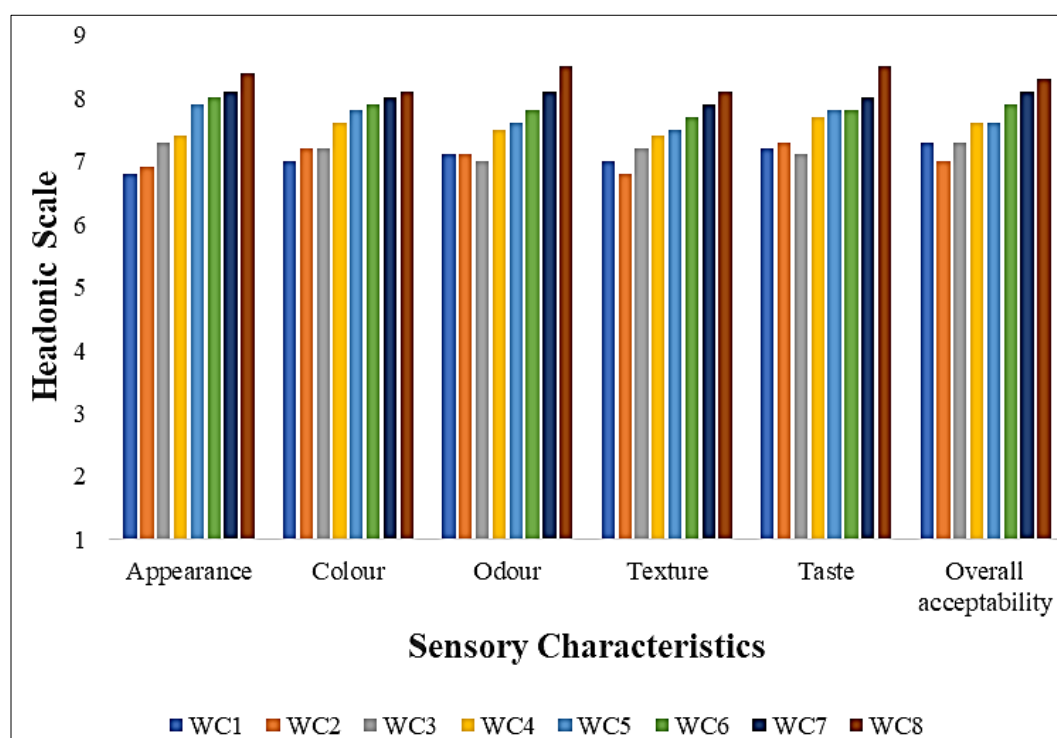


Fig 2: Mean sensory scores of finger-millet cookies with different ratios of water chestnut flour to refined wheat flour. WC1 (00:70), WC2 (10:60), WC3 (20:50), WC4 (30:40), WC5 (40:30), WC6 (50:20), WC7 (60:10) and WC8 (70:00).

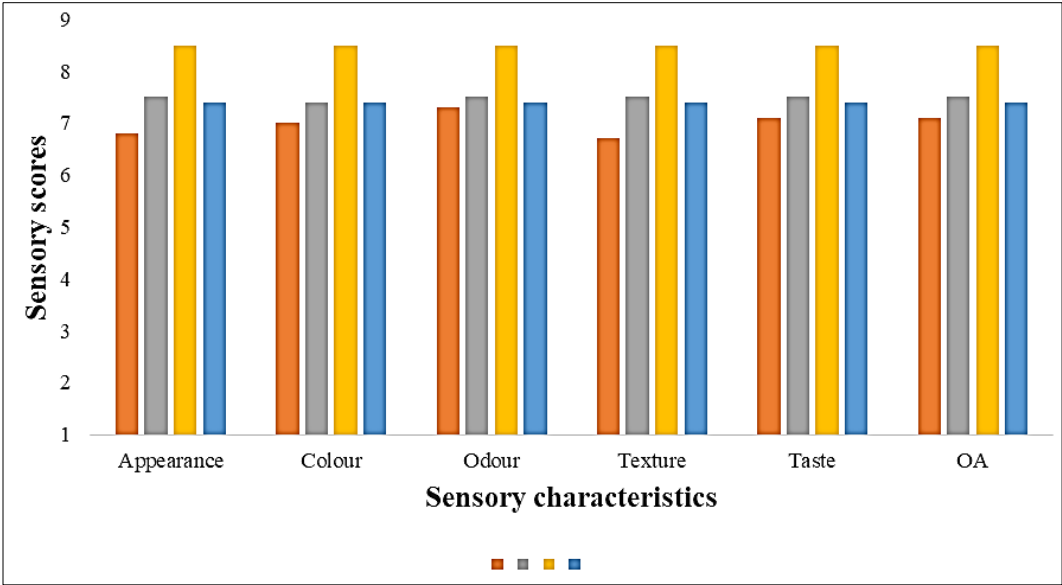


Fig 3: Mean sensory scores of seaweed powder in standardized water chestnut based finger millet cookies by replacing water chestnut flour in different percentages. SP1 (0%), SP2 (2%), SP3 (4%) and SP4 (6%).

Table 3: Standardized recipe of water chestnut-based finger millet seaweed cookies

Sr. No	Ingredients (g/ml)	Quantity (g)
		Water chestnut cookies with seaweed
1.	Seaweed powder	2.8
2.	Finger millet flour	30
3.	Water chestnut flour	67.2
4.	Sugar	40
5.	Fat	50
6.	Milk	12
7.	Sodium bicarbonate	02
Baking temperature		170 °C
Baking time		17 min

Table 4: Proximate composition of water chestnut based finger millet seaweed cookies

Sr. no	Parameter	Percentage (%)
1.	Moisture	3.24±0.02
2.	Protein	7.44±0.02
3.	Fat	22.35±0.02
4.	Ash	1.90±0.01
5.	Carbohydrate	65.04±0.03

Mean ± SD of water chestnut based finger millet seaweed cookies. Each value is the average of three determinations (n = 3).

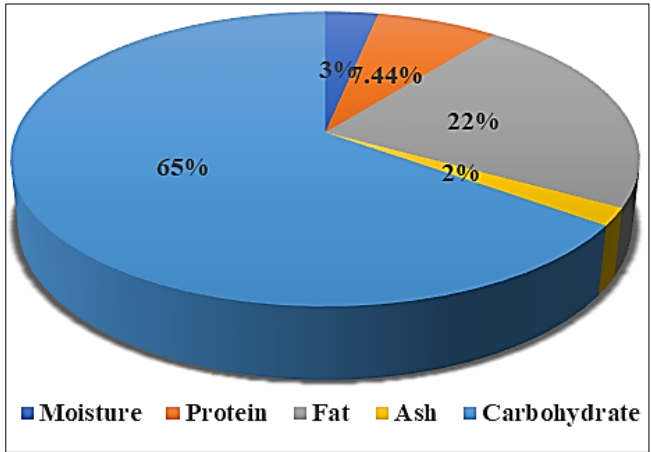


Fig 4: Proximate composition of water chestnut based finger millet seaweed cookies

Conclusion

The present study demonstrates that seaweed powder can be successfully incorporated into water chestnut based finger millet cookies. Among the various levels evaluated, cookies formulated with 4% seaweed powder exhibited the highest sensory acceptability, with superior scores for texture, flavour and overall acceptability compared to the other formulations. In addition to improved sensory attributes, the seaweed-enriched cookies showed an enhanced nutritional profile. These findings suggest that adding 4% seaweed powder gives the best balance between taste acceptance and nutritional benefits, making it a suitable and healthy ingredient for developing functional bakery products.

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