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Development of Seaweed Based Value Added Products: Nutritional, Functional and Shelflife Properties

Sivakumar K.P [a++*], B. Nallakurumban [b#], A.Vijayakumar [c++], A.Kalaiselvan [d#] and T.Balaji [e++]

[a] Department of Family Resource Management & Consumer Science, Community Science College & Research Institute, TNAU, Madurai, Tamil Nadu, India.
[b] ICAR-Krishi Vigyan Kendra, TNAU, Virudhunagar, Tamil Nadu, India.
[c] ICAR-Krishi Vigyan Kendra, TNAU, Ramanathapuram, Tamil Nadu, India.
[d] Department of Extension Education & Communication Management, Community Science College & Research Institute, TNAU, Madurai, Tamil Nadu, India.
[e] Department of Soil Science and Agricultural Chemistry, Agrl. College & Res. Instt., Vazhavachanur, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] Assistant Professor;
[#] Assistant Professor;
**Corresponding author: Email: sivakumar.kp@tnau.ac.in;*

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ABSTRACT

Seaweed (*Ulva lactuca Spp*.) is an edible marine alga. Due to its high nutrient content, seaweed was incorporated in many forms like powder and extract aiming to find out the best formulation for the production of seaweed-based cookies and beverages with better nutritional quality, consumer acceptability and shelf life of the seaweed-based products. Seaweed cookies and beverages were prepared by using the formulated seaweed mixtures by incorporating dry fine powdered for seaweed cookies preparation and seaweed extract for preparation of beverages and raw juices at different proportions with respective percentage of other raw ingredients. The developed seaweed cookies and beverages were subjected to sensory evaluation by an expert panel for the attributes, appearance, colour, aroma, texture, taste, flavour and overall acceptability using nine-point hedonic scales. The statistical analysis of variance (ANOVA) was used to compare the results in order to determine their significance level at P< 0.05. The findings showed that the prepared seaweed products differed significantly (P< 0.05) in terms of moisture, protein, fiber, ash, carbohydrate etc. The shelf life of the developed seaweed-based products was observed during storage period.

Keywords: Seaweed; bioactive compound; cookies; beverages; chemical analysis and shelf life.

1. INTRODUCTION

Marine plants are mainly exploited for the production of phycocolloids or foods. Seaweeds have been used in human and animal diets from early times. Green seaweeds are also consumed as sea vegetables. However, during the past decade, there has increase in seaweed consumption as sea vegetables or “novel foods.

Ulva lactuca is commercially available under the name of “sea lettuce.”. It was suggested that the seaweeds contain many biologically active components, which could be used as therapeutic agents in dietary supplements (Sarkar et al., 2019). Similarly, Ulva sp. (green algae) has been known for various functional bioactive compounds that have studied for their activities. U. lactuca is harvested from beaches in the world every year in huge quantity (Braune and Guiry, 2011). Since prehistoric time, seaweeds had been remained a staple and vital part in Chinese, Japanese and Korean diet. Interestingly, China and Japan are the main contributors in world production-consumption scenario (Mohibbullah et al., 2023; Debbarma et al., 2022). Twenty percent of Asian diet is comprised of seaweeds that are relished not for their nutritional viewpoint but of unique and enchanting flavour. But in Western diet, the seaweeds are just used as food additives or extracts (Vivek et al., 2022). Seaweeds are getting importance in various fields ranging from food to medical (Yu-Qing et al. 2016).

Seaweed not only possess nutrient potentials, but also nutraceutical potentials like antioxidant, antimutagenic, anticoagulant, anticancerous and antibacterial activity (Abirami & Kowsalya 2011). Hence, seaweeds can be considered as promising plants forming one of the important marine living resources of high nutritional value. Being plants of unique morphology and biochemical composition, *U. lactuca* could be exploited for their multifunctional properties in the form food, energy, medicine and as biotechnological tools (Abirami & Kowsalya 2011).

Fiber is an important food component, especially in maintaining a healthy and balanced function of the digestive system. The dietary fiber can absorb water as it passes through the human digestive tract. The utilization of seaweed can be maximized by diversifying seaweed products, such as developing seaweed-based biscuits. Biscuits are one of the food products that are well accepted by the public, including pregnant women, because they taste good, have a long shelf-life, and are convenient to consume anywhere and anytime.

2. MATERIALS AND METHODS

Sample collection and preparation:

- *Ulva lactuca Spp* Sea weed was collected from farmer, Mandapam, Ramanathapuram District.
- Immediately after collection, the seaweed sample was cleaned and washed with running tap water to remove sand and other extraneous matter.
- The sample was sorted and then thoroughly cleaned by rinsing with distilled water to remove the surface salty materials.

- The cleaned samples were subsequently kept in a container and stored in the refrigeration temperature for further analysis and product preparation.

General/physical characteristics of *Ulva lactuca Spp* sea weed:

- Sea weed is a green sheet-like in appearance.
- It ranges in size from 6 inches to 2 feet. It lives in high and low intertidal zones; water to six feet deep.
- Sea lettuce is a bright green algae composed of lobed, ruffle-edged leaves that are coarse and sheet-like and resemble a leaf of lettuce.
- The leaves may appear flat, thin, broad, and often rounded or oval. Its leaves are often perforated with holes of various sizes.

Preparation of value added products from seaweed: The value added products such as spiced raw juice, functional beverages and cookies prepared from seaweeds (*Ulva lactuca Spp)* and stored at room temperature.

List 1. General / Physical Characteristics

Size	2 inch 20 feet
Appearance	Thin sheet
Colour	Bright green

List 2. Nutritional Characteristics (On dry weight basis)

Moisture (%)	4.86
Carbohydrates (g)	64.20
Protein (g)	12.9
Fat (g)	1.2
Ash (g)	10.50
Dietary Fibre (g)	4.82
Calcium (mg)	1094
Phosphorous (mg)	86
Iron (mg)	2.3

Preparation and standardization of spiced seaweed raw juice: Processed seaweed was grind and juice was extracted. Add ginger and mint extract, packed and stored at refrigeration condition. Ginger and mint extracts were mixed with seaweed extract in different levels in order to find out the optimum level for obtaining a good quality of spiced seaweed raw juice. The percentage level of 1,2,3 and 4 per cent of ginger extract, 1,2,3,4, and 5 per cent of mint extract. Based on sensory evaluation, 2% of ginger and 4% of mint were highly accepted.

Preparation and standardization of seaweed based functional beverages:

Method

- ❖ The fresh clarified seaweed (500 ml.) was extracted. Add 3% ginger extract.
- ❖ Sugar (2.2 kg), citric acid (42 g) and water (3.8 lit.) were mixed and heated
- ❖ Sugar syrup was cooled and filtered through muslin cloth
- ❖ Cooled syrup was blended with clarified seaweed extract
- ❖ Preservative (Sodium benzoate -70 ppm) was added to the processed functional beverage and mixed well
- ❖ Prepared seaweed functional beverage was filled in the sterilized bottle/pet bottles and sealed
- ❖ Sealed bottles were pasteurized at 80^{o}C for 20 minutes
- ❖ After pasteurization the bottles were cooled, labelled and stored at room temperature.

Preparation and standardization of seaweed cookies: Seaweed was added for preparation of seaweed cookies as per standard procedure. Seaweed was cleaned separately with running tap water. The cleaned seaweed was used for preparation of cookies at different proportions in order to find out the optimum level for obtaining a good quality of seaweed based cookies. The seaweed incorporated cookies was standardized by adding 2,4,6,8,and 10% . Among five trails, 8% of seaweed was found to best in all sensory attributes.

Seaweed cookies were prepared by kneading of sugar, vanaspathi, ammonium bicarbonate and together and made into cream. The dough was prepared by adding kodo millet (Varagu), wheat flour (1:1 ratio) and seaweed and then make dough. Add mix cream and dough and then spreaded like a sheet on the tray and cut into small pieces with help of cookies cutter (Mould). Shaped dough were arranged in trays and baked at 185^{0}C for 25 - 30 minutes and cooled to ambient temperature. The cookies were packed in polypropylene bags and stored in room temperature (Thongram et al., 2016).

Storage studies: The prepared seaweed raw juice stored at refrigeration temperature, seaweed based functional beverages and cookies are stored at room temperature. The

storage behavior of seaweed based products were studied by observing their chemical changes, microbial load and their organoleptic characteristics.

Seaweed (*Ulva lactuca Spp)*
↓
Washing with running tap water
(Remove sand and other extraneous matter)
↓
Soaking in RO water for 3 days
(Remove odour)
↓
Surface drying
↓
Packaging
↓
Stored at refrigeration condition

Chart 1. Flow chart for seaweed cleaning

Sea weed
↓
Washing
↓
Juice extraction
↓
Addition of spices extract (ginger@2% and mint@4%)
↓
Clarification
↓
Bottling
↓
Storing in refrigeration condition

Chart 2. Flow chart for preparation of seaweed raw juice

Sea weed and ginger extract
↓
Mixing with strained sugar syrup solution
(Sugar, water, citric acid heated just to dissolve)
↓
Mixing
↓
Bottling
↓
Capping
↓
Pasteurization ($80^{o}C$ for 20 min)
↓
Cooling
↓
Storage

Chart 3. Flow chart for standardization of seaweed based functional beverages

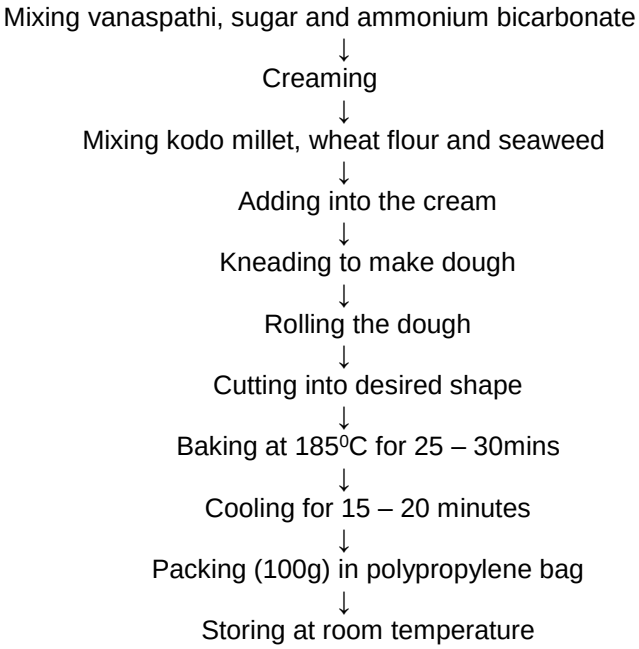

Chart 4. Flow chart for standardization of seaweed cookies

Chemical analysis: The various chemical constituents of the spiced seaweed raw juice, seaweed based functional beverages and cookies before and during storage at regular intervals. The chemical constituents of fresh spiced seaweed raw juice, seaweed based functional beverages and cookies analysed during storage period and presented in Tables 1, 2 and 3 respectively.

Storage stability of the standardized seaweed products:

Chemical composition- Chemical composition of seaweed based products were analysed and presented in the following tables (Padmanabhan, 2022).

Statistical Analysis: The data obtained were subjected to statistical analysis to find out the impact of storage period on the quality of prepared products during storage, factorial completely randomized design (FCRD) was adopted for analysis (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

A gradual increase in the TSS content was noted in spiced seaweed raw juice during storage. The initial TSS content of spiced seaweed raw juice was 4.00°Bx, which had decreased to 3.00°Bx at the end of storage period. A significant decrease in acidity was observed in spiced seaweed raw juice during storage. Remarkable changes (12.32 to 12.23g) in the total sugar content of the spiced seaweed raw juice was observed throughout the storage periods. There was negligible changes in the calcium, phosphorus and iron contents of spiced seaweed raw juice during storage period.

The data was statistically analysed and the impact of quality of the seaweed based products during storage period had highly significant except some chemical constituents such as acidity, .dietary fibre and iron.

The decrease in acidity of seaweed functional beverages was 0.410 and at the end of the storage period was 0.407. From the table, it was noted that the initial values of pH were 4.44 and it was slight reduction was observed during the storage period. After 180 day of storage, the pH of seaweed functional beverages was 4.56. Statistical analysis of the experimental results indicated that a significant difference in pH of beverages and storage period. A slight change in the total sugar content of the seaweed functional beverages was noted during the storage period. The functional beverages prepared seaweed showed little variation in the total sugar content before and after storage.

The data was statistically analysed and the impact of quality of the seaweed based products during storage period had highly significant except some chemical constituents.

Table 1. Chemical constituents of spiced seaweed raw juice during storage

Nutritional Characteristics (g/100ml)	Initial	1st week	2nd week	3rd week	4th week	5th week
Total Soluble Solids (°Brix)	4.00	3.80	3.60	3.20	3.00	3.00
Acidity (%)	0.330	0.327	0.324	0.324	0.322	0.321
pH	3.81	3.82	3.86	3.89	3.89	3.91
Total sugar (g)	12.32	12.32	12.30	12.29	12.26	12.23
Reducing sugar (g)	5.22	5.23	5.23	5.25	5.26	5.28
Protein (g)	14.91	14.91	14.91	14.90	14.90	14.89
Dietary Fibre (g)	5.62	5.62	5.61	5.61	5.61	5.60
Calcium (mg)	1110.42	1109.48	1109.32	1109.05	1108.52	1108.11
Phosphorous (mg)	92.12	92.10	92.10	92.08	92.08	92.08
Iron (mg)	2.81	2.81	2.79	2.78	2.78	2.76

	SED	CD(0.05)	CD(0.01)
TSS	0.0739	0.1610	0.2257**
Acidity (%)	0.0072	0.0156	0.0218NS
pH	0.1016	0.2214	0.3103*
Total sugar (g)	0.0816	0.1724	0.3212*
Reducing sugar (g)	0.1284	0.2797	0.3921**
Protein (g)	0.2707	0.5898	0.8269*
Dietary Fibre (g)	0.1508	0.3286	0.4608NS
Calcium (mg)	16.6013	36.1714	50.7118*
Phosphorous (mg)	0.9476	2.0647	2.8947*
Iron (mg)	0.2134	0.4231	0.6753NS

Table 2. Chemical constituents of seaweed functional beverages during storage

Nutritional Characteristics (g/100ml	Initial	30 Days	60 Days	90 Days	120 Days	150 Days	180 Days
Total Soluble Solids (°Brix)	15.60	15.50	15.50	15.30	15.30	15.10	14.60
Acidity (%)	0.410	0.410	0.409	0.408	0.408	0.408	0.407
pH	4.44	4.47	4.48	4.50	4.50	4.54	4.56
Total sugar (g)	13.61	13.60	13.57	13.55	13.54	13.51	13.48
Reducing sugar (g)	9.21	9.25	9.29	9.29	9.32	9.35	9.39
Protein (g)	10.54	10.53	10.51	10.48	10.48	10.44	10.40
Dietary Fibre (g)	4.42	4.42	4.41	4.40	4.38	4.37	4.34
Calcium (mg)	1032.14	1032.13	1032.10	1031.81	1031.49	1031.12	1031.02
Phosphorous (mg)	84.48	84.48	84.45	84.43	84.43	84.40	84.40
Iron (mg)	2.28	2.27	2.26	2.26	2.24	2.21	2.20

	SED	CD(0.05)	CD(0.01)
TSS	0.0673	0.2187	0.2634*
Acidity (%)	0.0931	0.1996	0.2771*
pH	0.2547	0.5464	0.7584 NS
Total sugar (g)	0.0734	0.1765	0.2387*
Reducing sugar (g)	0.1284	0.2797	0.3921**
Protein (g)	0.0855	0.1835	0.2546*
Dietary Fibre (g)	0.1602	0.3176	0.4207*
Calcium (mg)	21.2420	45.5645	63.2385NS
Phosphorous (mg)	0.8743	2.0762	2.3456NS
Iron (mg)	0.2435	0.4654	0.6523*

Table 3. Chemical constituents of seaweed cookies during storage

Nutritional Characteristics (g/100ml)	Initial	5th Days	10th Days	15th Days	20th Days
Moisture (%)	4.11	4.18	4.28	4.35	4.44
Carbohydrate (g)	62.43	62.41	62.35	62.32	62.26
Protein (g)	13.65	13.60	13.52	13.44	13.41
Fat (g)	17.56	17.47	17.43	17.38	17.35
Fiber (g)	10.12	10.12	10.09	10.05	10.00

	SED	CD(0.05)	CD(0.01)
Moisture (%)	0.0839	0.1869	0.2658*
Carbohydrate (g)	0.2756	0.6141	0.8735*
Protein (g)	0.2389	0.5124	0.7342NS
Fat (g)	0.1698	0.3167	0.4539**
Fiber (g)	0.2604	0.5802	0.8253NS

Seaweed spiced raw Juice

Seaweed cookies

Seaweed spiced beverages

Plate 1. Seaweed value added products

The chemical constituents of seaweed cookies, the moisture content only increased from 4.11 to 4.44 per cent and others such as carbohydrate, protein, fat and fiber were decreased during storage period. The data was statistically analysed and the impact of quality of the seaweed based products during storage period had highly significant except some of the chemical constituents (Alloyarova, 2024).

4. CONCLUSION

This study shows that the popular the seaweed based products, it has scored the highest consumer acceptance in terms of sensory perception as well as its value addition. The physic-chemical analysis was carried out for sea weed based value added products, which showed significant variations. Products made from seaweed have a promising approximate composition. According to proximate analysis, the seaweed products has high in carbohydrates as well as a good source of protein, fat, fiber, and minerals. It qualifies as a functional food because it contains nbioactive elements like flavonoids, which are regarded to be among the substances that could prevent cancer. Commercial seaweed products were not sampled for the current

investigation since it was not available in the local markets. The consumer can use this technique because manufacturing of seaweed based products are cheap and simple.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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