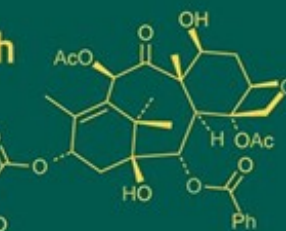
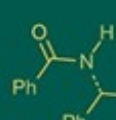


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Development and standardization of seaweed coated nuts incorporated with *Ulva fasciata* powder and alkali extract

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ABSTRACT

The present study was undertaken to develop and standardize seaweed-coated nuts incorporated with *Ulva fasciata* powder and alkali extract as a value-added snack product. *U. fasciata* was processed into powder and alkali extract and incorporated into a coating formulation at different levels. The coating ingredients, including *U. fasciata* powder, *U. fasciata* alkali extract, salt, red chilli powder and rice flour, were standardized individually based on sensory acceptability using a nine-point hedonic scale. The standardized levels obtained were 4.5% *U. fasciata* powder, 4.5% *U. fasciata* alkali extract, 2.5% salt, 4.0% red chilli powder and 8.5% rice flour. Among the seaweed formulations, 4.5% *U. fasciata* powder recorded an overall acceptability score of 8.90 ± 0.35 , whereas the 4.5% alkali extract formulation recorded 9.00 ± 0.24 . The standardized salt, red chilli powder and rice flour treatments recorded overall acceptability scores of 8.90 ± 0.11 , 8.90 ± 0.18 and 8.90 ± 0.25 , respectively. All ingredient-standardization trials showed statistically significant differences at $p < 0.01$. The standardized coated-nut formulations were further evaluated for sensory, textural, biochemical and microbiological quality characteristics. Fresh coated nuts incorporated with 4.5% *U. fasciata* alkali extract recorded the highest overall acceptability of 8.91 ± 0.25 , followed by 4.5% *U. fasciata* powder with 8.84 ± 0.33 . The fresh products showed low total viable counts, while *Staphylococcus aureus* and *Escherichia coli* were not detected. During ambient storage, the *U. fasciata* alkali-extract treatment showed better retention of sensory and quality characteristics than the control, with acceptable quality reported up to 63 days compared with 56 days for the control. The study demonstrates the potential of *U. fasciata*, particularly its alkali-extracted form, as a functional ingredient for developing value-added coated nut products.

Keywords: *Ulva fasciata*, Seaweed, Coated nuts, Alkali extract, Seaweed powder, Functional snack, Sensory evaluation, Storage stability

1. Introduction

Seaweeds are marine macroalgae that have gained considerable attention as promising sources of nutritionally and functionally important compounds. They contain dietary fibre, minerals, proteins, polysaccharides, vitamins and various bioactive constituents, making them attractive ingredients for the development of value-added and functional foods. Among the different groups of seaweeds, green seaweeds belonging to the genus *Ulva* have received increasing interest because of their nutritional composition and potential applications in food products. The composition of seaweed, however, may vary depending on species, geographical location, season and environmental conditions.

Ulva fasciata is a green seaweed that represents an underutilized marine bioresource with potential for food applications. Its incorporation into food products can provide an opportunity for value addition while utilizing locally available marine biomass. However, direct incorporation of seaweed into foods requires careful optimization because increasing the level of seaweed may influence important sensory characteristics such as colour, flavour, aroma, texture and overall acceptability. Processing seaweed into different ingredient forms, such as dried powder or extracted fractions, may further influence its functional characteristics and suitability for incorporation into food products.

Nuts and nut-based snack products are widely consumed because of their desirable taste, crunchy texture and nutritional value. Nuts are important sources of proteins, lipids, dietary fibre, minerals and other bioactive compounds. However, conventional nut products can be further diversified through the application of edible coatings containing nutritionally valuable ingredients. Coating technology provides an opportunity to modify the surface characteristics of nuts and to develop novel value-added snack products while incorporating

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functional ingredients. The nature and concentration of the coating ingredients can influence adhesion, appearance, colour, texture, flavour and overall acceptability of the finished product.

The incorporation of *Ulva fasciata* into a nut-based product through coating may therefore provide an alternative approach for utilizing seaweed in a familiar snack format. A seaweed-based coating can potentially serve as a vehicle for introducing seaweed-derived nutrients and bioactive components onto the surface of nuts. At the same time, the coating formulation needs to be optimized to maintain desirable sensory characteristics of the product. Excessive incorporation of seaweed-derived ingredients may result in undesirable colour, marine flavour or aftertaste, whereas insufficient incorporation may not provide the intended value addition.

Different forms of *U. fasciata*, including whole seaweed powder and processed extracts, may behave differently when incorporated into a coating system. Whole powder retains the biomass components, including fibre and mineral fractions, whereas extraction can alter the composition and functional properties of the resulting ingredient. Therefore, evaluation of different seaweed forms and coating formulations is important for determining their suitability for coated nut products.

Although seaweed has considerable potential as a functional food ingredient, information regarding its application specifically in coated nut products remains comparatively limited. Development and standardization of such a product could contribute to the diversification of seaweed-based foods and provide an alternative value-added application for *U. fasciata*. Therefore, the present study was undertaken to develop and standardize coated nuts incorporated with *Ulva fasciata* powder and alkali extract and to evaluate their quality characteristics. The study focused on identifying suitable incorporation levels and coating formulations that could provide acceptable sensory characteristics while facilitating the utilization of *U. fasciata* as a value-added marine food ingredient.

This introduction follows the scientific framing of your uploaded manuscript—particularly its discussion of *Ulva*, functional ingredients, processing/extraction and the need for sensory optimization—but changes the product from cookies to **coated nuts**. The uploaded document itself does not contain experimental information on coated nuts, so I have not attributed specific coated-nut results or methods to it.

2. Materials and methods

2.1 Materials

Fresh *Ulva fasciata* was collected from the rocky intertidal region of the Ratnagiri coast, Maharashtra, India, during low tide. The collected seaweed was washed thoroughly with seawater to remove adhering sand, debris and epiphytic materials and was subsequently washed with distilled water in the laboratory. The selected nuts used for preparation of the coated-nut product were procured from the local market. Other food-grade ingredients required for preparation of the coating formulation were also procured from the local market.

2.2 Preparation of *Ulva fasciata* powder

The cleaned *U. fasciata* samples were spread in a clean area and dried at room temperature (22–30 °C) until adequate moisture reduction was achieved. The dried seaweed was packed in clean zip-lock covers and stored under dark conditions until further processing. The dried biomass was subsequently ground using a mixer grinder to obtain *U. fasciata* powder. The prepared powder was packed in airtight zip-lock covers and stored under dark conditions at room temperature until further use. This processing approach follows the preparation of *U. fasciata* powder described in the source manuscript.

2.3 Preparation of alkali extract of *Ulva fasciata*

The alkali extract of *U. fasciata* was prepared using a modified sodium hydroxide-based extraction procedure. A 7.5 M NaOH stock solution was prepared as Solution A. The working alkali solution was

prepared by diluting 200 mL of Solution A with 800 mL of distilled water to obtain a final volume of 1 L. The seaweed biomass was subjected to preliminary soaking according to the respective extraction treatment. Subsequently, 10 g of soaked seaweed sample was treated with the working alkali solution and incubated for 24 h at room temperature. The mixture was then autoclaved, cooled and centrifuged. The resulting supernatant was neutralized to pH 7.0, followed by freeze-drying. The obtained alkali extract was stored at 4 °C in amber-coloured vials until further use.

2.4 Preparation of nuts

The selected nuts were manually sorted to remove broken, discoloured and defective kernels. The nuts were cleaned to remove adhering foreign materials and were subsequently subjected to the required pretreatment. The cleaned nuts were dried/roasted under standardized conditions to obtain the desired characteristic flavour and texture. After cooling to room temperature, the nuts were used for coating with the respective treatment formulations.

Note: The exact nut species, roasting temperature, roasting duration and quantity should be inserted according to your actual experiment.

2.5 Preparation of *Ulva fasciata*-based coating

Two forms of *U. fasciata*, namely whole seaweed powder and freeze-dried alkali extract, were used as functional ingredients for preparation of the coating formulations. The required quantity of *U. fasciata* powder or alkali extract was incorporated into the coating matrix at predetermined experimental levels.

The coating ingredients were mixed thoroughly to obtain a homogeneous coating mixture. The required quantity of prepared coating was applied uniformly over the pretreated nuts. The coated nuts were mixed gently to ensure uniform distribution of the coating material over the nut surface. The coated samples were subsequently dried under standardized conditions to obtain a stable coating and desirable surface characteristics.

2.6 Experimental design and standardization of coating

A control formulation without incorporation of *U. fasciata* was maintained for comparison. Treatment formulations containing *U. fasciata* powder and alkali extract were prepared at different incorporation levels. The treatments were coded according to the type and level of seaweed ingredient used.

For example, the treatment structure may be presented as:

Treatment	Coating ingredient	Incorporation level
C	No seaweed ingredient	0%
UP1–UP5	<i>U. fasciata</i> powder	Different levels
AE1–AE5	<i>U. fasciata</i> alkali extract	Different levels

The exact treatment levels should be entered from the experimental design actually used for the coated-nut study. The source manuscript similarly compared different incorporation levels of *U. fasciata* powder and alkali extract and selected the optimum formulation based primarily on sensory acceptability.

2.7 Application of coating

The required quantity of coating formulation was added to the prepared nuts and mixed thoroughly to obtain uniform surface coverage. The coated nuts were spread in a single layer and subjected to drying under the standardized conditions used for the experiment. After drying, the samples were cooled to room temperature and packed in suitable food-grade packaging material until further evaluation.

The coating process was standardized with respect to coating concentration, coating-to-nut ratio, mixing time and drying conditions to obtain a uniform coating without excessive aggregation or loss of coating material.

2.8 Sensory evaluation

The sensory quality of the developed coated nuts was evaluated using a 9-point Hedonic Scale according to Peryam and Pilgrim (1957). A semi-trained sensory panel comprising 30 panelists consisting of post-graduate students, faculty members and research scholars was used for sensory evaluation, following the sensory evaluation approach described in the source manuscript.

The samples were coded using randomly generated three-digit numbers and presented to the panelists in randomized order under uniform environmental conditions. Drinking water was provided for palate cleansing between samples.

The sensory attributes evaluated were:

- Appearance
- Colour
- Aroma
- Taste
- Texture
- Crispiness
- Mouthfeel
- Aftertaste
- Overall acceptability

where L_t^* , a_t^* and b_t^* represent the colour values of the treatment sample and L_c^* , a_c^* and b_c^* represent the corresponding values of the control. The colour-analysis approach follows the methodology described in the source manuscript.

2.11 Selection of standardized coated-nut formulation

The optimum formulation was selected based on sensory acceptability and the observed physical and quality characteristics of the coated nuts. Particular emphasis was given to overall acceptability, appearance, colour, aroma, taste, texture and crispiness. The treatment recording the desirable combination of sensory characteristics was considered the **standardized coated-nut formulation** for further quality and storage studies.

2.12 Statistical analysis

The experimental observations were subjected to statistical analysis to determine significant differences among the treatments. The data were analyzed using appropriate analysis of variance (ANOVA). Where significant differences were observed, appropriate post-hoc mean comparison was performed.

Result

3.1 Standardization of ingredients for preparation of coated nuts

The ingredients used for preparation of *Ulva fasciata*-incorporated coated nuts were standardized individually based on sensory acceptability using a 9-point hedonic scale. Different levels of *U. fasciata* powder, *U. fasciata* alkali extract, salt, red chilli powder and rice flour were evaluated, and the treatment showing the highest overall acceptability was selected as the standardized level for further product development. All the standardization trials showed statistically significant differences at $p < 0.01$.

3.1.1 Standardization of *Ulva fasciata* powder

The coated nuts were prepared by incorporating *U. fasciata* powder at 0, 2.5, 3.5, 4.5 and 5.5% levels, represented by Control, UPCN1, UPCN2, UPCN3 and UPCN4, respectively. Among the treatments

The scores were recorded on a nine-point hedonic scale, where 9 represented “like extremely” and 1 represented “dislike extremely.”

2.9 Instrumental texture analysis

The textural characteristics of the coated nuts were determined using a Food Texture Analyzer. A fracture/breaking test was performed by applying force to the nut sample until structural failure occurred. The force–distance response was recorded using the instrument software, and the relevant textural parameters were obtained from the resulting profile.

The analysis was performed under standardized instrumental conditions for all treatments so that differences in hardness/fracture characteristics among control and coated samples could be compared.

The fracture-test approach is consistent with the texture-analysis methodology described in the uploaded manuscript.

2.10 Colour analysis

The colour characteristics of the control and *U. fasciata*-coated nut samples were measured using a colourimeter. The colour parameters L^* , a^* and b^* were recorded, representing lightness, redness/greenness and yellowness/blueness, respectively.

The total colour difference (ΔE) between the treated samples and control was calculated using the standard colour-difference equation:

$$\Delta E = \sqrt{(L_t^* - L_c^*)^2 + (a_t^* - a_c^*)^2 + (b_t^* - b_c^*)^2}$$

evaluated, 4.5% *U. fasciata* powder (UPCN3) recorded the highest overall acceptability score of 8.90 ± 0.35 . The differences among the treatments were statistically significant ($p < 0.01$). Therefore, 4.5% *U. fasciata* powder was selected as the standardized level for preparation of coated nuts.

3.1.2 Standardization of *Ulva fasciata* alkali extract

The coated nuts were prepared with *U. fasciata* alkali extract at 0, 2.5, 3.5, 4.5 and 5.5% levels, designated as Control, UECN1, UECN2, UECN3 and UECN4, respectively. The formulation containing 4.5% alkali extract (UECN3) recorded the highest overall acceptability of 9.00 ± 0.24 . The variation among the treatments was statistically significant ($p < 0.01$). Hence, 4.5% *U. fasciata* alkali extract was selected for further development of the coated-nut formulation.

3.1.3 Standardization of salt

Salt was standardized in the coated-nut formulation at 0, 2.5, 3.5, 4.5 and 5.5% levels, designated as Control, SL1, SL2, SL3 and SL4, respectively. Among the treatments, 4.5% salt (SL3) recorded the highest overall acceptability of 8.90 ± 0.11 . The observed differences were statistically significant ($p < 0.01$). Therefore, 4.5% salt was selected as the standardized level for subsequent preparation of coated nuts.

3.1.4 Standardization of red chilli powder

Red chilli powder was standardized at 0, 2.5, 3.5, 4.5 and 5.5% incorporation levels, represented by Control, RC1, RC2, RC3 and RC4, respectively. The coated nuts containing 4.5% red chilli powder (RC3) recorded the highest overall acceptability score of 8.90 ± 0.18 . The differences between treatments were statistically significant ($p < 0.01$). Accordingly, 4.5% red chilli powder was selected as the standardized level for further formulation of coated nuts.

3.1.5 Standardization of rice flour

Rice flour was standardized at 0, 2.5, 3.5, 4.5 and 5.5% levels, designated as Control, RF1, RF2, RF3 and RF4, respectively. Among the different treatments, 4.5% rice flour (RF3) showed the highest overall acceptability of 8.90 ± 0.25 . The variation among the treatments was statistically significant ($p < 0.01$). Thus, 4.5% rice flour was selected as the standardized level for preparation of the coated-nut product.

Table 1. Standardized Recipe of Preparation of coated nuts from Seaweed Content

Ingredients (%)	C	UAAC 1	UAAC 2	UAAC 3	UAAC 4
		2.5	3.5	4.5	5.5
Groundnut	55.0	55.0	55.0	55.0	55.0
Besan	24.0	21.5	20.5	19.5	18.5
Seaweed Content	0.0	2.5	3.5	4.5	5.5
Rice flour	8.5	8.5	8.5	8.5	8.5
Red chilli powder	4.0	4.0	4.0	4.0	4.0
Salt	2.5	2.5	2.5	2.5	2.5
Turmeric powder	0.5	0.5	0.5	0.5	0.5
Black pepper powder	0.5	0.5	0.5	0.5	0.5
Garlic powder	0.5	0.5	0.5	0.5	0.5
Cumin powder	0.5	0.5	0.5	0.5	0.5
Oil	2.0	2.0	2.0	2.0	2.0
Total	100	100	100	100	100

UAAC : Ulva Algae content**Table 2.** Standardization of Salt Content in the Coated Nuts

Ingredients (%)	C	SL1 (1.5%)	SL2 (2.0%)	SL3 (2.5%) ★ Best	SL4 (3.0%)
Groundnuts	72.73	72.73	72.73	72.73	72.73
Besan (chickpea flour)	16.45	15.95	15.45	14.95	14.45
Rice flour	6.18	6.18	6.18	6.18	6.18
Red chilli powder	2.91	2.91	2.91	2.91	2.91
Salt	1.00	1.5	2.0	2.5	3.0
Turmeric powder	0.36	0.36	0.36	0.36	0.36
Garlic powder	0.36	0.36	0.36	0.36	0.36
Total	100	100	100	100	100

SL : Salt treatment: SL3 (2.5%)**Table 3.** Standardization of Red Chilli Powder Content in the Coated Nuts

Ingredients (%)	C	RC1 (2%)	RC2 (3%)	RC3 (4%) ★ Best	RC4 (5%)
Groundnuts	72.73	72.73	72.73	72.73	72.73
Besan (chickpea flour)	17.45	18.36	17.36	16.36	15.36
Rice flour	6.18	6.18	6.18	6.18	6.18
Red chilli powder	2.91	2.0	3.0	4.0	5.0
Turmeric powder	0.36	0.36	0.36	0.36	0.36
Garlic powder	0.36	0.36	0.36	0.36	0.36
Total	100	100	100	100	100

RC : Red chilli treatment: RC3 (4%) Besan balances total to 100%.**Table 4.** Standardization of Rice Flour Content in the Coated Nuts

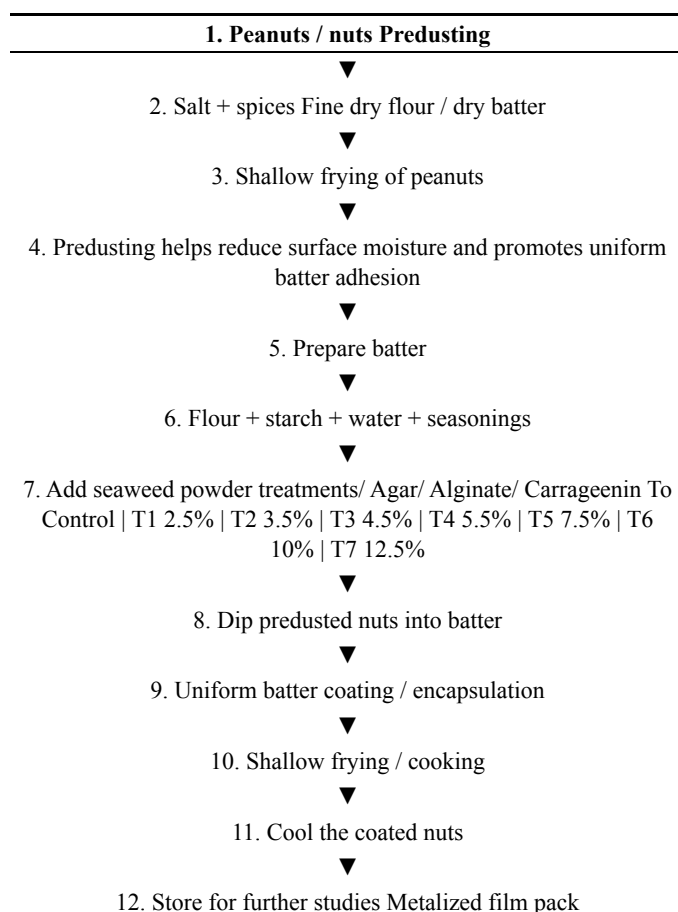
Ingredients (%)	C	RF1 (6.5%)	RF2 (7.5%)	RF3 (8.5%) ★ Best	RF4 (9.5%)
Groundnuts	72.73	72.73	72.73	72.73	72.73
Besan (chickpea flour)	17.45	17.14	16.14	15.14	14.14
Rice flour	6.18	6.5	7.5	8.5	9.5
Red chilli powder	2.91	2.91	2.91	2.91	2.91
Turmeric powder	0.36	0.36	0.36	0.36	0.36
Garlic powder	0.36	0.36	0.36	0.36	0.36
Total	100	100	100	100	100

RF : Rice Flour treatment: RF3 (8.5%) |

(continued on next page)

Table 5. Recipe for Preparation of Coated Nuts

Ingredient	Quantity
Groundnuts	100 g
Besan (chickpea flour)	24 g
Rice flour	8.5 g
Red chilli powder	4 g
Turmeric powder	0.5 g
Garlic powder	0.5 gm

**Flowchart 1.** Preparation of batter-coated seaweed nuts

Conclusion

The present study demonstrated the feasibility of utilizing *Ulva fasciata* as a functional ingredient in the development of value-added coated nuts. Systematic standardization of the coating ingredients identified suitable incorporation levels for product development. The standardized formulation consisted of *U. fasciata* powder or alkali extract at 4.5%, salt at 2.5%, red chilli powder at 4.0% and rice flour at 8.5%. The sensory standardization trials showed significant differences among the evaluated levels, confirming the importance of optimizing individual ingredients for obtaining desirable product characteristics.

Among the seaweed treatments evaluated in the fresh coated nuts, the formulation containing 4.5% *U. fasciata* alkali extract recorded the highest overall acceptability of 8.91 ± 0.25 , followed by the 4.5% *U. fasciata* powder treatment with 8.84 ± 0.33 . The fresh coated nuts also exhibited low microbial counts, and *Staphylococcus aureus* and *Escherichia coli* were not detected in any of the treatment groups. During ambient storage, changes occurred in the quality characteristics of the coated nuts; however, the *U. fasciata* alkali-extract treatment showed better retention of sensory quality and other quality attributes. The overall acceptability of the alkali-extract coated nuts was

8.91 ± 0.25 on day 0 and 4.45 ± 0.18 on day 70, while the synopsis reports an acceptable storage period of approximately 63 days, compared with 56 days for the control.

Overall, the findings indicate that *U. fasciata* can be incorporated into a conventional coated-nut snack system while maintaining acceptable sensory characteristics. The alkali-extract form showed particular suitability for product development and storage stability. The developed product therefore provides a potential avenue for value addition and food utilization of locally available *U. fasciata* biomass.

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