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Fortified noni (Morinda citrifolia L.) cookies: formulation, properties, antioxidant activity, sensory traits

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ABSTRACT

Background: Noni, also known as *Morinda citrifolia L.*, is a perennial herb with Southeast Asian origins that has been used medicinally for over 2000 years. Noni drew the interest of researchers from the pharmaceutical and food industries due to its adaptability and utilization of the plant's structures for various food applications. The essential industrial products of this plant are beverages, leaf powders, oil from seeds, and powders from dried fruits.

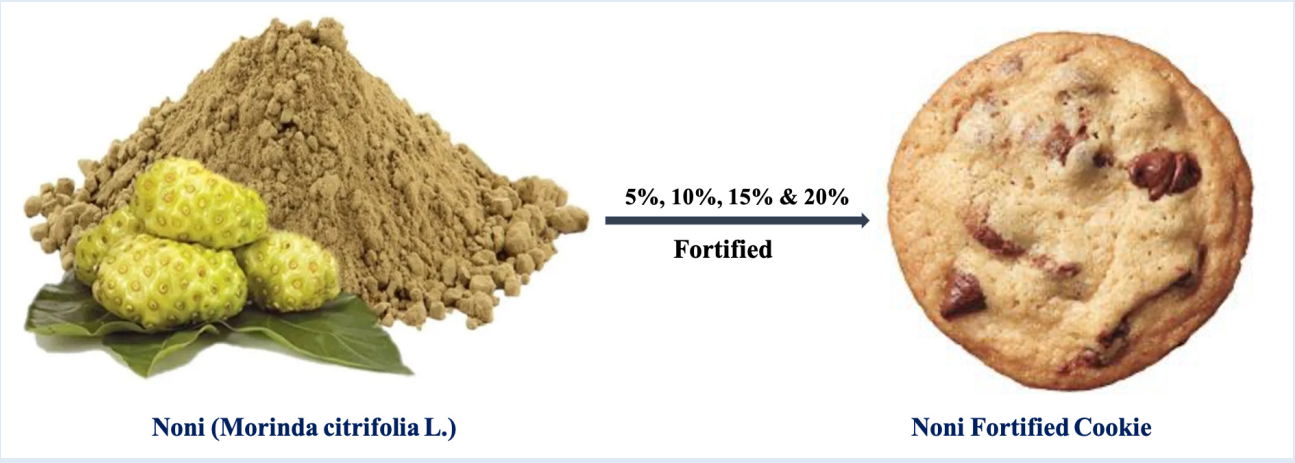
Objective: This study aimed to incorporate noni fruit powder with different concentrations to extend the cookie's shelf life and nutritional properties.

Methods: In the formulation of the cookies, noni fruit powder was fortified with four different concentrations (5% - NFPFC5, 10% -NFPFC10, 15% - NFPFC15, and 20% - NFPFC20) with wheat flour. The physical properties, antioxidant activity, and sensory characteristics of cookies fortified with noni fruit powder were studied.

Results: There was no significant change in the physical properties of fortified cookies with noni fruit powder. The antioxidant properties were enhanced with the higher concentrations of fruit noni powder fortified with cookies. Sensory panelists preferred cookies with 5% noni (NFPFC5) concerning organoleptic characteristics.

Conclusion: The present study is to understand the herb's value by recommending the nutritional qualities and sensory evaluation of noni fruit powder cookies. Future studies on the use of noni fruit powder in different food industries with its applications in terms of safety and quality are necessary.

Keywords: Noni powder, antioxidant, *Morinda citrifolia*, sensory acceptance, cookies.



INTRODUCTION

The "Indian mulberry" or noni (*Morinda citrifolia Linn*.), which is an evergreen shrub or small tree with a height range of 10 to 20 feet, is a member of the *Rubiaceae* family [1]. In India, noni was produced by 342 cultivators in an area of 653 acres. The highest production of noni fruits was in the Andaman and Nicobar Islands (192 acres), followed by Maharashtra (166 acres), and Tamil Nadu was the lowest producer of noni fruits (5 acres) with one cultivator [2]. According to traditional treatment and recent research reported, the noni plant has a broad range of therapeutic effects, including antibacterial, antiviral, antifungal, antitumor, anthelmintic, analgesic, hypotensive, anti-inflammatory, and immune-enhancing effects [3]. *Morinda citrifolia* L. is the "queen of health plants" and supports a robust immune system. A unique polysaccharide found in noni fruit powder promotes healthy cell tissue growth. Noni fruit powder is rich in antioxidants, amino acids, vitamins, and minerals to these health advantages. Noni powder has been shown to enhance healthy cellular tissue formation and fortify the immune system. Noni fruit powder is a rich source of vitamins, minerals, antioxidants, and polysaccharides. The polysaccharide 6-D-glucopyranose pent acetate found in noni powder increases the "destroying power" of white blood cells, enhancing their capacity to combat infection and bacteria. A significant recent development in the food sector is the use of industrial byproducts [4-8]. Reusing processing byproducts, such as noni fruit powder, could increase the raw material yield, thus minimizing the problems caused by the disposal of many industrial byproducts and expanding alternative food production [9]. Many authors reported byproducts' potential as natural colorants, thickening agents, or moisturizers in cosmetic products [10-12].

Cookies have become among the most desirable snacks for young and older adults due to their affordable price, suitability, extended shelf-life, and capability to help as a vehicle for chief nutrients [13-14]. Cookies are regularly baked products commonly prepared with three main ingredients: refined flour, sugar, hydrogenated fats,

and minor components like additives and emulsifiers [9]. The majority of customers from different nations generally accept and consume cookies, making them excellent dietary supplements for enhancing nutrition [15]. It provides an excellent means of improving food's nutritional quality (protein, minerals, vitamins, and bioactive compounds) by incorporating less expensive non-wheat flour for food product enrichment [16]. Recently, cookies have been prepared from composite flour or fortified with some other suitable source of nutrient flour such as whey protein concentrate, wheat germ, oyster mushroom, cassava, and water chestnut flour to improve their nutritional value [15-18].

A balanced diet must include bakery items, which may now be found in a wide range of grocery store shelves. Examples of bakery items include unsweetened goods, sweet goods (pancakes, doughnuts, waffles, and cookies), and filled goods (fruit and meat pies, sausage rolls, pastries, sandwiches, cream cakes, pizza, and quiches). Further examples include Bread, rolls, buns, crumpets, muffins, and bagels [19]. The objective is to boost the valuable components for daily intake while still creating conventional cookies, a more popular bakery product. With the market for functional foods growing by roughly 10% annually, consumers are becoming more aware of the valuable qualities of food products, influencing their purchasing decisions [20]. The present study aims to see how noni-fruit powder can formulate cookies. The present study aimed to develop a cookie formulation with good acceptability and evaluate the effects of noni fruit powder supplementation on the cookies' physical and sensory characteristics and antioxidant activities.

MATERIALS AND METHOD

Procurement of raw materials: Fully mature, noni fruit (*Morinda citrifolia L.*) was procured from Bhoopalam Botanicals in Bangalore, Karnataka, India. Bakery supplies such as wheat flour, sugar, vegetable shortening, and baking powder were purchased from a nearby grocery store in Kolar, Karnataka.

Preparation of cookies: Cookies were prepared in two sets via control cookies (CC) and noni fruit powder fortified cookies (NFPFC) according to the method proposed by Noor Aziah et al. (2012) with slight modifications [17]. The formula was used to prepare the cookies shown in Table 1. The wheat flour was replaced with noni fruit powder at different concentrations of 5, 10, 15, and 20 % to prepare NFPFC5, NFPFC10, NFPFC15, and NFPFC20, respectively.

Table 1 The formula for the production of cookies from NFP and Wheat Flour

Ingredients	Wheat Flour (g)	Sugar (g)	Noni fruit Powder (g)	Marvo Fat (g)
Control	150	75	-	100
NFPFC5	142.5	75	7.5	100
NFPFC10	135	75	15	100
NFPFC15	127.5	75	22.5	100
NFPFC*20	120	75	30	100

Notes: NFPFC5, Wheat flour supplemented with 5% noni fruit powder; NFPFC10, Wheat flour supplemented with 10% noni fruit powder; NFPFC15, Wheat flour supplemented with 15% noni fruit powder; NFPFC20, Wheat flour supplemented with 20% noni fruit powder.

Proximate composition analysis: Moisture, fat, crude protein, carbohydrate, crude fiber, and ash content were determined according to the official methods of the AACC (2000). All analyses were performed in triplicate.

The cookies were physically and chemically characterized by analysis of moisture (AOAC 930.15/2005) [21], crude protein (AOAC 955.45/1990) [22], crude fiber (AOAC 962.06/1990) [22] and ash (AOAC 923.03/2005) [21]. Carbohydrate content was estimated by difference [Carbohydrate (%) = 100 % − % (Moisture + Ash + Crude protein + Crude fat)].

Physical properties of cookies: The cookies' physical characteristics (weight, diameter, thickness, and spread ratio) were randomly chosen. The weight reduction was calculated by comparing the pre-and post-baking weights of the cookies. A caliper measured the height and diameter before and after baking. Cookies were placed in four samples side by side, and their combined diameter was measured to ascertain their diameter. The diameter of each cookie was measured after it had been turned 90°, 180°, 270° and 360°. The typical diameter was noted. Four cookies were stacked on top of one another and then restacked four times to determine the thickness of the cookies. A record of average thickness was made. By dividing, the spread ratio was determined.

Antioxidant activity of cookies (DPPH free radical scavenging assay): The radical-scavenging activity of the cookie samples was studied using the stable DPPH radical, as described by Blois (1958) [23], with some modifications [24]. Different concentrations (100 to 300 µg/mL) of samples and 2 mL of DPPH (100 µM) were added, made up to 3 mL with methanol, and the reaction mixture was incubated in the dark for 45 min at room temperature. At the end of the incubation period, absorbance was recorded using a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) at 517 nm against the blank (without sample/standard). The free radical scavenging capacity of the extracts was compared with BHT as a standard antioxidant, calculated and expressed in IC_{50} values.

Ferrous-ion chelating assay: The ferrous-ion chelating effect of cookies samples was determined according to Wolff [25] with the modification [26]; in brief, different concentrations (100 to 300 µg) of appropriately diluted samples were mixed separately with 0.05 mL of 2 mM FeCl2, and the reaction was initiated by adding 0.1 mL of 5 mM Ferro-zine and then incubated for 10 min at room temperature. The absorbance of the color produced was measured by spectrophotometer at 562 nm against the blank (Without sample/Standard). The percentage inhibition of Ferro zine–Fe2+ complex formation was calculated, and the results were expressed in IC_{50} values compared with EDTA as a standard antioxidant.

Sensory analysis: Semi-trained panelists from the Department of Clinical Nutrition and Dietetics at the Sri Devaraj Urs Academy of Higher Education and Research Tamaka, Kolar, assessed the biscuits' sensory qualities. The Quartermaster Meal Institute for the Armed Forces' nine-point hedonic scale was used for the sensory analysis to gauge how much people liked the meal items [27]. The panelists were instructed to rate the coded samples for each sensory quality, such as color, aroma, texture, taste, and overall acceptability, based on their degree of like (1 = dislike extremely; 2 = dislike very much; 3= dislike moderately:4= dislike slightly; 5= neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much: 9= like extremely.

Statistical analysis: The studies examined the impact of noni fruit powder at various concentrations in cookies' nutritional value and shelf life. The results of the tests, which are presented as mean values with standard deviation, were tested in triplicate. Using JPM software,

different mean values were examined using analysis of variance (ANOVA) and least significant difference (LSD).

RESULTS AND DISCUSSION

Proximate compositions of cookies: The cookie's proximate composition changes by incorporating NFP in different concentrations (NFPFC0 (Control), NFPFC5, NFPFC10, NFPFC15, and NFPFC20) are presented in Table 2. The results show a significant change in the cookie's moisture, ash, fat, and crude fiber contents with NFP added. Similar results of the proximate composition of cookies fortified with noni are consistent with the research of Desai et al. and Saah and Adu-Poku [28-29]. Consumers believe cereal items to be beneficial to their health, according to a 2007 survey. However, different consumer groups perceive whole grain products to be better than products made with white flour differently [30]. Incorporating NFP into wheat flour beyond the 5 % level increased the moisture content of cookies. The highest value of moisture content (2.88 %) was observed in NFPFC20 (20 % NFP-incorporated cookies), followed by NFPFC15 (2.59 %), NFPFC10 (2.57 %) and NFPFC5 (2.41 %). The ash content of the cookies increased from 0.36 % to 0.49 %. The maximum ash (0.49 %) content was observed in the NFPFC20, while the lowest ash content (0.36 %) was reported in the NFPFC5. The protein, lipid, and carbohydrate levels are enhanced when NFP is used in place of wheat flour at a rate of 5 to 20%. The highest concentration of crude fiber (1.72 %) was observed in NFPFC5 (5 % NFP-incorporated cookies), followed by NFPFC10 (1.70 %), NFPFC0 (Control) (1.52 %), NFPFC15 (1.51 %) and NFPFC20 (1.45 %).

Table 2 Proximate composition of cookies

Composition (%)	Control	NFPFC5	NFPFC10	NFPFC15	NFPFC20
Moisture	$2.67^{a} \pm 0.01$	$2.41^{b} \pm 0.01$	$2.57^{ab} \pm 0.01$	$2.59^{ab} \pm 0.11$	$2.88^{a} \pm 0.01$
Ash	$0.46^{ab} \pm 0.01$	$0.36^{b} \pm 0.01$	$0.44^{ab} \pm 0.11$	$0.48^{a} \pm 0.11$	$0.49^{a} \pm 0.01$
Crude protein	$6.3^{a} \pm 0.11$	$6.1^{b} \pm 0.11$	$6.1^{b} \pm 0.11$	$6.3^{a} \pm 0.11$	$6.4^{a} \pm 0.11$
Fat	$38.6^{ab} \pm 0.11$	$38.2^{b} \pm 0.11$	$38.7^{a} \pm 0.11$	$38.7^{a} \pm 0.09$	$38.6^{ab} \pm 0.11$
Crude fiber	$1.52^{ab} \pm 0.011$	$1.72^{a} \pm 0.01$	$1.70^{a} \pm 0.01$	$1.51^{ab} \pm 0.01$	$1.45^{b} \pm 0.01$
Carbohydrate	$50.3^{b} \pm 0.11$	$50.4^{b} \pm 0.11$	$50.8^{a} \pm 0.30$	$50.6^{ab} \pm 0.11$	$50.2^{b} \pm 0.11$

Values represent the mean ± standard deviation. Values with the same superscript letters in the row are not significantly different (P>0.05).

Notes: NFPFC5, Wheat flour supplemented with 5% noni fruit powder; NFPFC10, Wheat flour supplemented with 10% noni fruit powder; NFPFC15, Wheat flour supplemented with 15% noni fruit powder; NFPFC20, Wheat flour supplemented with 20% noni fruit powder.

Cookies' physical characteristics: Evaluation of the physical characteristics of cookies plays a significant role in determining the product's quality from the standpoint of the customer's appropriateness. Cookie's physical characteristics rely on the composition of the dough and how well they bake. The variables are spread ratio, diameter, thickness, and weight reduction. The physical properties of cookies were tabulated in Table 3. Results of the study indicated that there is a significant change between NFP-containing flour and control (NFPFC0) in terms of diameter, thickness, weight loss, and spread ratio. Maximum weight loss (0.75g) was observed in

NFPFC10, while minimum weight loss (0.51mm) was reported in NFPC15. The highest diameter (49.25mm) and thickness (8.99mm) were reported in control NFPFC0 cookies. NFPFC5 cookies had a maximum diameter of 48.89mm and a minimum thickness of 8.10mm. The NFPFC5 cookies had the highest spread ratio (5.56mm), while the NFPFC10 and NFPFC20 cookies had the lowest spread ratio (5.23mm).

Table 3 Physical properties of cookies

Parameters	Control	NFPFC5	NFPFC10	NFPFC15	NFPFC20
Weight loss (g)	0.58^{b}±0.30	0.62^{ab} ±0.16	0.75^{a}±0.16	0.51^{c} ±0.30	0.58^{b} ±0.26
Diameter (mm)	49.25^{a} ±2.80	48.89^{ab} ±1.01	48.47^{b} ±1.80	48.22^{b} ±0.82	48.07^{b} ±1.82
Thickness (mm)	8.99^{a} ± 0.77	8.10^{a} ±1.47	8.90^{b} ±0.78	8.9^{a} ±1.46	8.82^{ab} ±0.44
Spread ratio (mm)	5.50^{a} ±0.45	5.56^{a} ±0.94	5.23^{b} ±0.47	5.41^{ab} ±0.75	5.23^{b} ±0.31

Values represent the mean ± standard deviation. Values with the same superscript letters in the row are not significantly different (P>0.05).

Notes: NFPFC5, Wheat flour supplemented with 5% noni fruit powder; NFPFC10, Wheat flour supplemented with 10% noni fruit powder; NFPFC15, Wheat flour supplemented with 15% noni fruit powder; NFPFC20, Wheat flour supplemented with 20% noni fruit powder.

Total phenolics, flavonoids, and radical scavenging activity: The results regarding cookies' TPC, flavonoids, and antioxidant capacity are presented in Table 4. The TPC of the NFP cookies ranged from 82.73 to 104.4 µg/mg GAE, and flavonoid content ranged from 12.27 to 22.27 µg/mg QE. The data indicate that adding NFP to the wheat flour at different concentrations significantly increases the TPC and flavonoid content of the cookies. The highest concentration of TPC 104.4 µg/mg GAE and flavonoids 22.27 µg/mg QE was observed in NFPFC20 when compared to control cookies TPC 96.06 µg/mg GAE and flavonoids 18.38 µg/mg GAE respectively.

Table 4 Total phenols, Flavonoid content, and Antioxidant scavenging activities of cookies.

Samples	Polyphenols (µg/mg GAE)	Flavonoids (µg/mg QE)	DPPH (µg/mL)	Iron chelating (µg/mL)
Control	96.06^{b} ± 3.05	18.38^{a} ± 2.54	317.72^{a} ± 0.13	284.44^{a}± 0.02
NFPFC5	82.73^{c} ± 1.52	12.27^{c} ± 3.46	304.70^{a}± 0.01	259.29^{b}± 0.02
NFPFC10	89.4^{c} ± 4.58	14.5^{bc} ± 3.33	283.79^{b}± 0.05	225.25^{a}± 0.05
NFPFC15	92.06^{b} ± 4.04	16.72^{b} ± 2.54	269.85^{c}± 0.02	219.01^{a}± 0.04
NFPFC20	104.4^{a} ± 3.60	22.27^{a} ± 2.54	264.54^{a}± 0.00	209.34^{c}± 0.04
Standard			51.27^{a}± 0.01 (BHT)	49.04^{a}± 0.02 (EDTA)

Values represent the mean ± standard deviation. Values with the same superscript letters in the same column are not significantly different (P>0.05).

Notes: NFPFC5, Wheat flour supplemented with 5% noni fruit powder; NFPFC10, Wheat flour supplemented with 10% noni fruit powder; NFPFC15, Wheat flour supplemented with 15% noni fruit powder; NFPFC20, Wheat flour supplemented with 20% noni fruit powder.

Cookies produced at substitution levels of 5%, 10%, 15%, and 20% were tested for their radical scavenging activity using the DPPH and iron chelating assays. The DPPH results are shown in Table 4; the results revealed that substituting NFP with wheat flour at various concentrations increased the antioxidant activity in the cookies. Similar results can be seen in the data from the iron chelating assay, shown in Table 4. Regarding DPPH, IC50 values of scavenging DPPH radicals for the NFPFC15 and NFPFC20 were 269.85 and 264.54µg/ml, respectively (Table 4). The study revealed that NFPFC15 and NFPFC20 have prominent antioxidant activity compared to the control cookies (317.72µg/ml) and similar results obtained from the iron chelating assay. The results were consistent with the research of Yang et al. and Li et al. [31-33].

Sensory analysis: The sensory assessment of a food product is one of the most significant factors in determining its acceptability and quality. Table 5 displays the results of the sensory evaluation of cookies. According to statistical data, treatments and storage times substantially impacted the cookie's sensory attributes, including aroma, taste, color, texture, mouth feel, and overall acceptability. According to studies on sensory evaluation, cookies with up to 5 % of NFPFC5 (8.02 ± 0.71) and control cookies (8.1 ± 0.93) had colors and appearances that the panel found to be acceptable, whereas cookies with 10 % (NFPFC10), 15 % (NFPFC10 & 20 % (NFPFC10 had the least amount of approval. However, all of the cookie samples scored within the acceptable range. The panelists ranked NFPFC5 (7.76 ± 1.04) in the second and control (7.78 ± 1.11) in the first position when all the mean values were calculated for the flavor of cookies compared to the control. The overall acceptability of the cookies was assessed using their aroma, taste, color, texture, and mouth-feel scores. NFPFC5 (8.02 ± 0.71), in terms of overall quality compared to NFPFC10, NFPFC15, and NFPFC20 control cookies, were discovered to be more suited from a sensory perspective. Similar results of sensory characteristics were obtained from wheat-based ingredients for the evaluation of cake and bread [34-35].

Table 5 Sensory evaluations of cookies

Parameter	Control	NFPFC5	NFPFC10	NFPFC15	NFPFC20
Color	7.76^{a} ± 1.14	7.66^{a} ± 0.79	7.46^{a} ± 1.01	7.18^{a} ± 1.20	7.06^{a} ± 1.40
Texture	7.88^{a} ± 1.15	7.8^{a} ± 0.88	7.7^{b} ± 0.99	7.7^{b} ± 0.81	7.42^{c} ± 0.88
Taste	7.66^{a} ± 0.93	7.7^{a} ± 0.99	7.34^{ab} ± 1.11	7.28^{c} ± 0.94	7.41^{b} ± 1.08
Aroma	7.78^{a} ± 1.11	7.76^{a} ± 1.04	7.76^{a} ± 1.02	7.2^{c} ± 0.96	7.28^{b} ± 1.20
Overall acceptability	8.1^{a} ± 0.93	8.02^{a} ± 0.71	7.8^{b} ± 1.12	7.56^{ab} ± 0.88	7.46^{ab} ± 1.09

Values represent the mean ± standard deviation. Values with the same superscript letters in the row are not significantly different (P>0.05). Notes: NFPFC5, Wheat flour supplemented with 5% noni fruit powder; NFPFC10, Wheat flour supplemented with 10% noni fruit powder; NFPFC15, Wheat flour supplemented with 15% noni fruit powder; NFPFC20, Wheat flour supplemented with 20% noni fruit powder.

CONCLUSION

M. citrifolia L. has biologically active components, including minerals, fatty acids, vitamins, amino acids, and carbohydrates. Despite the lack of complete knowledge of this plant's medicinal and nutritional benefits, these bioactive components show promise for food industry applications. It is regarded as an acceptable ingredient to substitute for wheat flour in cookie recipes. Cookies created with combined wheat and noni fruit powder flour showed higher protein levels, calories, carbs, ash, and fiber compared to cookies made exclusively with wheat flour. They also had good sensory qualities in appearance, aroma, texture, color, and flavor, which allows the production of these products as an alternative use of noni fruit powder to benefit from its functional properties.

Author contributions: SCS and SL conceptualized, designed the study, acquired, and interpreted the data, and significantly contributed to writing and revising the manuscript. AM and SA analyzed, interpreted, and revised the manuscript critically. SCS was involved in designing the study, interpreting data, revising the manuscript, and final approval of the version to be submitted. The authors have read and approved the manuscript.

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Conflict of Interest: The authors have no conflicts of interest relevant to this article's contents.

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