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Formulation, Nutritional Characterization, Antioxidant Potential and Shelf-life Evaluation of Lemon Enriched Coconut Chia Seeds Ladoo

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Abstract

The present study was undertaken to Develop and Evaluate a Novel Functional Food Product Lemon Coconut Chia Seeds Ladoo**,** enriched with dietary fiber, essential minerals and antioxidants. Three formulations (T_1, T_2, T_3) were prepared by varying the quantity of chia seeds, jaggery, almonds, coconut and ghee. Nutritional profiling was carried out to determine moisture, macronutrient content and micronutrients using standard AOAC methods. Antioxidant activity was assessed via DPPH, ABTS, and FRAP assays. Microbial stability and shelf life were evaluated over 30 days under ambient and refrigerated conditions. Sensory evaluation was performed using a 7-point hedonic scale. Among the formulations, T_3 exhibited the highest overall acceptability (6.48 ± 0.38) and antioxidant potential (ABTS: 120.5 mg/100g). The microbial load remained within permissible limits throughout the storage period. The study demonstrates the potential of this Ladoo as a palatable and nutrient-rich functional snack.

Keywords: Functional food, Lemon Coconut Ladoo, Chia seeds, Antioxidants, Shelf life, Nutritional composition, Sensory evaluation

1. Introduction

Functional foods, which provide health benefits beyond basic nutrition are increasing Demand after health-conscious by consumers. Incorporation of superfoods like chia seeds**,** lemon and coconut offers a exploring for developing nutrient-rich snacks. Chia seeds are known for their high omega-3 fatty acid and fiber content (Curhan *et al*., 1999) [2]. while lemons provide vitamin C and natural antioxidants (González-Molina *et al*., 2010) [3]. Coconut contributes to both flavor and dietary fiber, making it an ideal ingredient for functional snack development.

The present study focuses on three major functional ingredients**:** chia seeds (*Salvia hispanica* L.)**,** lemon and coconut flakes**.** Chia seeds are known to be rich in omega-3 fatty acids, dietary fiber, and plant-based protein, making them highly effective in supporting digestive health and reducing cardiovascular risk (Curhan *et al*., 1999; USDA, 2020) [2, 9]. Lemon zest and juice are natural sources of vitamin C**,** flavonoids and limonene**.** which have been associated with antioxidant, anti-inflammatory and lipid-lowering effects (Kawakami *et al*., 2010; Komori *et al*., 1995) [4, 5]. Coconut provides medium-chain triglycerides (MCTs) and dietary fiber, both of which support energy metabolism and gut health (Morton, 1987) [7]. The increasing consumer demand for plant-based, nutrient-rich alternatives to conventional sweets has sparked interest in natural and preservative-free snack innovations. This study focuses on developing a Lemon enriched Coconut Chia Seeds Ladoo, exploring its nutritional, antioxidant, microbial and sensory properties.

2. Materials and Methods

2.1 Standardized Procedure for Ladoo Preparation

The preparation of Lemon enriched Coconut Chia Seeds Ladoo involved multiple steps to ensure optimal flavor, texture and nutritional retention. First, 20 g of chia seeds were lightly roasted in a dry pan or ground coarsely to enhance aroma and digestibility. Separately, freshly grated dry coconut was roasted with 2 teaspoons of ghee for a few seconds until aromatic. In a separate pan, 10 g of jaggery

was gently melted over low heat to form a syrup; additional ghee was added at this stage to improve binding. The roasted chia seeds and coconut were then mixed into the jaggery syrup, followed by the addition of lemon juice, lemon zest, and a pinch of cardamom powder to impart flavor and antioxidant properties. The mixture was stirred thoroughly until it thickened and achieved a cohesive, sticky consistency. After slight cooling, the mixture was shaped into uniform bite-sized Ladoos by hand. The finished Ladoos were stored in airtight containers either at room temperature or under refrigeration to maintain freshness and prolong shelf life.

2.2 Product Formulation

Three formulations (T_1, T_2, T_3) of Lemon enriched Coconut Chia Seeds Ladoo were developed using different proportions of chia seeds, jaggery, almonds, coconut flakes, oats, lemon zest/juice, vanilla extract, ghee and water (Table 1).

Table 1: Formulation of Lemon enriched Coconut Chia Seeds Ladoo with T_1, T_2 and T_3 Variations

Ingredients	T_1 Sample	T_2 Sample	T_3 Sample
Chia seeds (g)	10 g	15 g	20 g
Jaggery (g)	5 g	5 g	10 g
Oats (g)	5 g	5 g	5 g
Almonds (g)	5 g	10 g	5 g
Salt (tsp)	1 tsp	1 tsp	1 tsp
Lemon (tsp)	1 tsp	1 tsp	1 tsp
Vanilla extract (tsp)	1 tsp	1 tsp	1 tsp
Coconut flakes (g)	10g	5 g	15 g
Water (ml)	100 ml	100 ml	100 ml
Ghee (tsp)	1 tsp	2 tsp	3tsp

Note: tsp= table spoon

2.3 Sensory Evaluation

A 7-point hedonic scale (1 = Dislike extremely to 7 = Like extremely) was used to evaluate color, texture, flavor, taste, aroma and overall acceptability by 15 semi-trained panelists.

2.4 Nutritional and Mineral Analysis of Lemon enriched Coconut Chia Seeds Ladoo

The proximate composition including moisture, protein, fat, fiber, carbohydrate and ash was determined using AOAC (2023) [1] standard methods. Mineral content (Calcium, Potassium, Magnesium, Iron, Zinc) was analyzed using flame photometry and atomic absorption spectrophotometry per AOAC methods (AOAC 2023; Methods 972.29, 967.22, 985.35, 985.29, 985.28) [1].

2.5 Vitamin and Antioxidant Analysis of Lemon enriched Coconut Chia Seeds Ladoo

Vitamin C, D, and E were assessed using AOAC-approved methods (986.35, 985.29, 2011.14). Antioxidant activity was measured using DPPH, ABTS, and FRAP assays (AOAC 999.07).

2.6 Shelf life and microbial stability of Lemon enriched Coconut Chia Seeds Ladoo

Shelf life and microbial stability were assessed at 0, 15, and 30 days. Parameters included Total Viable Count, Yeast & Mold count and E. coli presence using AOAC methods (990.12, 997.02, 991.14).

3. Statistical Analysis

Data were analyzed using one-way ANOVA to determine statistically significant differences ($p<0.05$) among samples during storage and between formulations for various parameters using SPSS software.

4. Results and Discussion

4.1 sensory evaluation of Lemon enriched Coconut Chia Seeds Ladoo

The sensory evaluation of Lemon Coconut Chia Seeds Ladoo formulations (T_1, T_2, and T_3) was conducted using a 7-point hedonic scale to assess colour, texture, flavour, taste, aroma, and overall acceptability (Table 2). Among the three samples, T_3 received the highest overall acceptability score (6.48 ± 0.38), indicating a strong consumer preference. T_3 also scored highest in texture (6.29 ± 0.47) and was equally rated for taste and aroma (6.47 ± 0.51), which can be attributed to its higher coconut (15 g) and ghee content (3 tsp), both of which contribute to improved mouthfeel and flavor release. T_1, while rated slightly higher in colour (6.41 ± 0.87), had the lowest texture score (6.00 ± 0.50), drier texture likely due to lower ghee content. T_2 showed balanced scores across all attributes but did not outperform as T_3 in any category. The incorporation of lemon zest and juice provided a refreshing citrus note, enhancing the flavour and aroma scores across all samples, consistent with findings from González-Molina *et al.* (2010) [3] and Kawakami *et al.* (2010) [4], who emphasized the sensory and antioxidant benefits of citrus ingredients. Overall, the results indicate that increasing the chia seed and coconut content, balanced with adequate ghee and jaggery, can significantly enhance sensory appeal and consumer acceptability in functional snack products.

Table 2: Sensory Attributes of Lemon enriched Coconut Chia Seeds Ladoo (T_1, T_2 and T_3)

Sample	Colour	Texture	Flavour	Taste	Aroma	Overall Acceptability
T_1	6.41 ± 0.87	6.00 ± 0.50	6.06 ± 0.66	6.47 ± 0.51	6.47 ± 0.51	6.23 ± 0.47
T_2	6.18 ± 0.64	6.24 ± 0.44	6.35 ± 0.61	6.18 ± 0.39	6.18 ± 0.39	6.24 ± 0.41
T_3	6.24 ± 0.44	6.29 ± 0.47	6.35 ± 0.49	6.47 ± 0.51	6.47 ± 0.51	6.48 ± 0.38

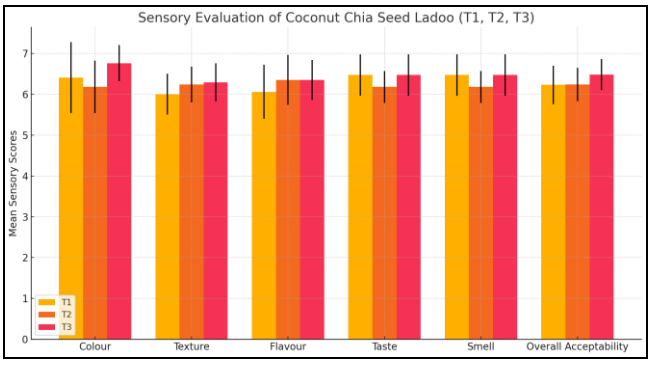

Fig 1: Sensory Attributes of Lemon enriched Coconut Chia Seeds Ladoo

4.2 Nutritional evaluation of Lemon enriched Coconut Chia Seeds Ladoo

The nutritional composition of the optimized sample T_3 Lemon Coconut Chia Seeds Ladoo is presented in Table 3. The Ladoo provided a substantial energy value of 490.6 Kcal/100g, primarily attributed to its high carbohydrate (51.8 g/100g) and fat content (28.6 g/100g). The high carbohydrate value is a result of natural sugars from jaggery and complex carbohydrates from oats and chia seeds, offering sustained energy release suitable for use as an energy-dense snack. The fat content, largely derived from coconut and ghee, includes medium-chain triglycerides, which have been shown to support energy metabolism and are less likely to be stored as body fat (Morton, 1987) [7]. The protein content (6.5 g/100g), while moderate, contributes to the product's overall nutritional balance with chia seeds and almonds acting as key protein sources, this study was compared with mixed seed laddu protein content 4% (Ashwini and Anil, 2024) where our study found slightly higher protein content.

The ladoo also exhibited a commendable dietary fiber content (14 g/100g), primarily from chia seeds, coconut, and oats, aligning with recommendations for fiber-rich functional foods aimed at improving digestive health and satiety (Curhan *et al*., 1999; USDA, 2020) [2, 9]. The moisture content was 11.6%, indicating relatively low water activity, which supports longer shelf stability. The ash content (1.5%) reflects the presence of essential minerals, discussed further in the mineral analysis section. Overall, the nutritional profile of T_3 suggests that the product is well-suited as a functional, plant-based snack offering a balanced combination of macronutrients and bioactive components. Its composition aligns with consumer trends toward clean-label, nutrient-dense alternatives to conventional sweets and processed snacks (González-Molina *et al*., 2010; AOAC, 2023) [3, 1].

Table 3: Nutritional Evaluation of lemon enriched coconut chia seed Ladoo (T_3)

Test Parameter	Unit	Results
Energy	K/cal	490.6
Carbohydrates	g/100g	51.8
Protein	g/100g	6.5
Fat	g/100g	28.6
Fibre	g/100g	14
Moisture	%	11.6
Ash	%	1.5

4.3 Mineral analysis of lemon enriched coconut chia seed Ladoo (T_3)

The mineral composition of the optimized Lemon Coconut Chia Seeds Ladoo (T_3) is summarized in Table 4. The product exhibited a high potassium content (480 mg/100g), which plays a crucial role in maintaining electrolyte balance, nerve function, and muscle contractions. This is largely attributed to the presence of chia seeds, coconut, and lemon, which are naturally rich in potassium (USDA, 2020; AOAC, 2023) [9, 1]. The magnesium content (75 mg/100g) further enhances the ladoo's value as a functional food, given magnesium's role in energy metabolism, neuromuscular transmission, and bone health (AOAC Method 967.22; Morton, 1987) [7]. This ladoo provided 4.5 mg/100g of iron, contributing to the prevention of iron-deficiency anemia. The calcium content (140 mg/100g) supports bone strength and metabolic activities and the zinc level (1.2 mg/100g) contributes to immune function and wound healing (Curhan *et al*., 1999; González-Molina *et al*., 2010) [2, 3]. These mineral levels reflect the nutritional richness of the selected natural ingredients, such as almonds, chia seeds and lemon, which suggest that regular consumption of this ladoo may contribute to meeting the daily mineral requirements, particularly in plant-based diets.

Table 4: Mineral analysis of lemon enriched coconut chia seed Ladoo (T_3)

Test Parameter	Unit	Results	Method
Potassium	mg/100gm	480g	AOAC 972.29
Magnesium	mg/100gm	75g	AOAC 967.22
Iron	mg/100gm	4.5g	AOAC 985.35
Calcium	mg/100gm	140g	AOAC 985.29
Zinc	mg/100gm	1.2g	AOAC 985.28

4.4 Vitamin analysis of lemon enriched coconut chia seed Ladoo (T_3)

The vitamin composition of the Lemon Coconut Chia Seeds Ladoo (T_3), as shown in Table 5, demonstrates its potential as a functional food with antioxidant and immune-supportive properties. The product contained 1.4 µg/100g of Vitamin E, a fat-soluble antioxidant essential for protecting cellular structures against oxidative stress and supporting skin health and immune function. This is primarily attributed to the inclusion of almonds and chia seeds, which are natural sources of Vitamin E (USDA, 2020; Morton, 1987) [9, 7]. Additionally, the Ladoo provided 3.5 mg/100g of Vitamin C, derived mainly from lemon zest and juice. Vitamin C is crucial for collagen synthesis, enhancing iron absorption, and reinforcing immune defense mechanisms (González-Molina *et al*., 2010) [3]. Although the Vitamin D content was relatively low (0.5 µg/100g), its presence is notable, as plant-based foods Show minimal contribution this nutrient; it may be attributed to trace amounts from ghee. Overall, the combined vitamin profile highlights the nutritional significance of the Ladoo, supporting its application as a health-promoting snack, particularly beneficial in vegetarian or predominantly plant-based diets.

Table 5: Vitamin analysis of lemon enriched coconut chia seed Ladoo (T_3)

Test Parameter	Unit	Results	Test Method
Vitamin E	µg/100g	1.4	AOAC 986.35
Vitamin C	mg/100g	3.5	AOAC 985.29
Vitamin D	µg/100g	0.5	AOAC 2011.14

4.5 Antioxidant analysis of lemon enriched coconut chia seed Ladoo (T_3)

The antioxidant potential of the Lemon enriched Coconut Chia Seeds Ladoo (T_3) was evaluated using three standard assays DPPH, ABTS and FRAP as shown in Table 6. The highest activity was observed in the ABTS assay (120.5 mg/100g), followed by FRAP (90 mg/100g) and DPPH (80.6 mg/100g), indicating a robust free radical scavenging capacity. This strong antioxidant activity can be attributed to the presence of polyphenols, flavonoids and ascorbic acid from lemon zest and juice, as well as tocopherols and other

bio-actives present in chia seeds, almonds and coconut (González-Molina *et al*., 2010; Kawakami *et al*., 2010) [3, 4]. The use of natural ingredients rich in phytochemicals contributes to the reduction of oxidative stress, supporting claims of functional and therapeutic benefits. These findings are consistent with previous research on citrus and seed-based products, which highlight their role in enhancing antioxidant status and preventing chronic diseases (Sun, 2007; Komori *et al*., 1995) [8, 5]. Overall, the antioxidant activity of the ladoo underscores its potential as a health-promoting functional food suitable for regular consumption.

Table 6: Antioxidant Activity of lemon enriched coconut chia seed Ladoo

Antioxidant Activity	Units	Result	Test Method
DPPH	mg/100gm	80.6	AOAC 999.07
ABTS	mg/100g	120.5	AOAC 999.07
FRAP	mg/100gm	90	AOAC 999.07

4.6 Shelf life and microbial stability of Lemon enriched Coconut Chia Seeds Ladoo (T_3)

The microbial evaluation of the Lemon Coconut Chia Seeds Ladoo (T_3), as presented in Table 7, confirms its excellent microbiological quality and shelf stability over a 30-day period under both ambient and refrigerated conditions. The Total Viable Count (TVC) was found to be <10 CFU/ml, significantly below the permissible limit of 1×10^6 CFU/ml, indicating minimal microbial load. Similarly, Yeasts and Molds were also recorded at <10 CFU/ml, suggesting the product is resistant to fungal contamination, likely due to low moisture content (11.6%) and the presence of antimicrobial compounds in lemon and coconut (Morton, 1987; González-Molina *et al*., 2010) [7, 3]. Pathogenic microorganisms such as E. coli**,** coliforms and Salmonella were absent in all tested samples, aligning with the microbiological safety standards established by AOAC methods and food safety guidelines (AOAC, 2023) [1]. These results support the product's hygienic preparation, effective moisture control and suitability for short- to medium-term storage without preservatives. These findings affirm the Ladoo's microbial stability and safety.

Table 7: Shelf life and microbial stability of Lemon enriched Coconut Chia Seeds Ladoo

Test Parameter	Unit	Results	Limits	Test Method
Total Viable Count	CFU/ml	<10	1×10^6	AOAC 990.12
Yeasts & Molds	CFU/ml	<10	1×10^6	AOAC 997.02
E. coli	CFU/25ml	Absent	Absent/25g	AOAC 991.14
Coliform Count	CFU/ml	Absent	Absent/25g	AOAC 991.14
Salmonella	CFU/25ml	Absent	Absent/25g	AOAC 2013.10

5. Conclusion

The study successfully formulated and evaluated a novel functional food product, Lemon enriched Coconut Chia Seeds Ladoo**,** which showed excellent nutritional composition, high antioxidant activity, favorable sensory acceptability and microbial stability over 30 days. T_3 sample showed as the optimal formulation as per sensory evaluations. This product has significant potential as a health-promoting snack alternative suitable for a wide range of consumers, especially those seeking plant-based, nutrient-dense foods.

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