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DEVELOPMENT AND EVALUATION OF VALUE-ADDED PRODUCTS USING PEPPER LEAVES

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ABSTRACT

Pepper leaves are an underutilized plant resource with nutritional and functional potential, yet their use in value-added food products remains limited. The present study was undertaken to develop and evaluate three food products incorporating pepper leaves: tea powder, spread and soup mix. Pepper leaves were processed into powder and incorporated at different levels into the selected formulations. Four treatments, including a control, were prepared for each product category and subjected to sensory evaluation using a nine-point hedonic scale. A trained/selected panel of ten judges evaluated appearance, colour, flavour, texture, taste and overall acceptability after a preliminary taste-sensitivity screening. The most acceptable products were T2 tea powder, SP1 spread and S3 soup mix. T2 consisted of 40% pepper leaf powder, 40% green tea powder and 20% cinnamon powder; SP1 consisted of 20% fresh pepper leaves, 70% cream cheese, 10% olive oil, 3% salt, 5% lemon juice and 2% pepper powder; and S3 consisted of 20% pepper leaf powder, 50% corn flour, 10% dried carrot flakes, 5% dried garlic, 5% pepper powder and 10% salt. Nutrient analysis showed that T2 contained 370 µg vitamin A, 52 mg vitamin C and 6.8 mg iron per 100 g, while SP1 contained 200 µg vitamin A, 31 mg vitamin C and 3.4 mg iron, and S3 contained 430 µg vitamin A, 75 mg vitamin C and 6.2 mg iron. Total antioxidant activity was reported as 415, 280 and 500 µg AAE/g for T2, SP1 and S3, respectively. Storage evaluation showed a gradual reduction in sensory scores accompanied by an increase in microbial counts, while the developed products remained considerably lower in reported production cost than the selected commercial comparators. The study demonstrates the feasibility of utilizing pepper leaves in convenient, acceptable and economically promising food products and provides a basis for further product optimization and commercialization.

Keywords: Pepper leaves; value addition; functional food; sensory evaluation; antioxidant activity; shelf life; food product development

1. INTRODUCTION

The increasing demand for sustainable, nutritious and convenient foods has encouraged researchers to explore plant resources that remain underutilized in conventional food systems. Agricultural residues and underused plant parts can provide an opportunity for value addition when they possess acceptable sensory characteristics and useful nutritional or bioactive properties. Pepper leaves represent one such resource. Although pepper fruits are widely recognized as food and spice commodities, leaves receive comparatively little attention in modern product development.

The source study describes pepper leaves as containing vitamins, minerals, dietary fibre and phytochemicals such as phenolics, flavonoids, carotenoids and alkaloid-related compounds. The literature reviewed in the original study associates these constituents with antioxidant, antimicrobial and anti-inflammatory activity, although many of these observations are based on extracts or experimental models rather than direct clinical outcomes. This distinction is important when discussing functional-food potential: the presence of bioactive compounds supports further investigation but does not by itself establish therapeutic efficacy.

Black pepper (Piper nigrum L.) is particularly important in the context of Kerala and the Western Ghats. The original document notes that black pepper is traditionally recognized as an economically important spice and that its phytochemical profile has stimulated interest in food, nutraceutical and pharmaceutical applications. The leaves, however, remain comparatively underutilized. Their incorporation into food products could therefore contribute to better utilization of plant biomass while providing additional product formats for consumers.

Value addition can also improve the economic usefulness of agricultural materials by converting raw or underused resources into products with improved convenience, sensory appeal, storage characteristics and marketability. The literature reviewed in the source emphasizes that consumer acceptance is central to the success of value-added foods, making sensory evaluation an essential stage in product standardization. The present study consequently combined product development with sensory evaluation, nutrient analysis, antioxidant analysis, storage evaluation, microbial assessment and cost analysis.

The study is particularly relevant because the developed products represent three different modes of consumption. Tea powder provides a beverage format, spread provides a semi-solid convenience food, and soup mix provides a dry instant preparation. These formats demonstrate how the same underutilized ingredient can be incorporated into products with different sensory and functional characteristics.

2. REVIEW OF LITERATURE

2.1 Nutritional and Functional Potential of Pepper Leaves

The literature reviewed in the source document reports that pepper leaves contain vitamins A, C and E and minerals including calcium, iron, magnesium, phosphorus and potassium. Dietary fibre further contributes to their nutritional relevance. The source also reports the presence of phenolic compounds, flavonoids, carotenoids and other phytochemicals that can contribute to antioxidant activity. The exact composition can vary with species, cultivar, maturity, cultivation conditions, processing and extraction method.

The antioxidant potential of pepper leaves has been linked to compounds capable of scavenging reactive species and reducing oxidative processes in experimental systems. The source review cites work on phenolic acids, flavonoids and carotenoids and describes their possible contribution to antioxidant defence. Such evidence supports the exploration of pepper leaves as functional food ingredients, while the present study provides product-level antioxidant measurements rather than attempting to establish disease-preventive effects.

2.2 Traditional and Biological Relevance

Pepper plants have a long history of culinary and traditional medicinal use. Black pepper is associated with piperine, while Capsicum species contain capsaicinoids. The original literature review describes antioxidant, antimicrobial and anti-inflammatory activities reported for pepper-derived extracts. It also discusses possible gastrointestinal and metabolic effects reported in experimental research. These observations provide a scientific rationale for investigating pepper leaves as a food ingredient, but the developed products in this study should be considered foods rather than therapeutic preparations.

2.3 Value Addition and Consumer Acceptance

Value addition transforms agricultural materials into products with greater convenience, market appeal and potentially improved storage characteristics. The original review emphasizes that successful value addition requires attention to sensory quality, processing, packaging, safety, cost and consumer preferences. Sensory testing therefore serves as a bridge between laboratory formulation and practical product acceptance. A product with nutritional advantages but poor flavour, texture or appearance is unlikely to achieve sustained consumer acceptance.

2.4 Research Gap and Rationale

The source document identifies the limited commercial utilization of pepper leaves as a gap. Most attention has traditionally been directed toward pepper fruits and their extracts. The present study addresses this gap by developing three consumer-oriented products and comparing formulations containing different proportions of pepper leaf material. The study also extends beyond sensory evaluation by examining nutrients, antioxidant activity, storage quality and cost, thereby providing a broader product-development perspective.

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3. OBJECTIVES

- To develop value-added food products using pepper leaves.
- To standardize different formulations of pepper leaf tea powder, spread and soup mix.
- To evaluate the sensory characteristics of the developed formulations and identify the most acceptable products.
- To determine selected nutrient contents of the most acceptable products.
- To assess the total antioxidant activity of the selected products.
- To examine changes in sensory quality and microbial load during storage.
- To estimate the production cost of the selected products and compare it with similar commercial products.
- To create awareness about the potential utilization of pepper leaves through product popularization.

4. MATERIALS AND METHODS

4.1 Study Design

The study followed a product-development and evaluation design. Fresh pepper leaves were collected, cleaned and processed into powder for selected applications. Three product categories were developed, each with a control and three variations. Sensory evaluation was then used to identify one preferred formulation from each category. The selected products were subjected to laboratory nutrient and antioxidant analysis, storage evaluation, microbial analysis and cost assessment.

4.2 Collection and Processing of Pepper Leaves

Fresh, healthy and pest-free pepper leaves were collected from home gardens and smallholder farms in Marutha, Malappuram district, Kerala. The leaves were sorted to remove damaged or discoloured material and washed thoroughly. The source document describes blanching as an optional processing step intended to preserve colour, reduce microbial load and inactivate enzymes. After draining and cooling, the leaves were dried until sufficiently moisture-free, ground into a fine powder and sieved to obtain a relatively uniform particle size. The resulting powder was stored in airtight, moisture-resistant containers.

This processing sequence was important because the subsequent products differed in their raw-material requirement. Tea powder and soup mix used dried pepper leaf powder, whereas the selected spread used fresh pepper leaves that were blanched, cooled and blended into a paste. The source document emphasizes hygienic handling and appropriate packaging to maintain product quality.

4.3 Product Development

4.3.1 Pepper Leaf Tea Powder

The tea powder was developed by blending pepper leaf powder with green tea powder and cinnamon powder. Four formulations were prepared: T0 as the control and T1, T2 and T3 as the pepper-leaf formulations. The standardized compositions were T0 = 0:80:20, T1 = 60:20:20, T2 = 40:40:20 and T3 = 20:60:20 for pepper leaf powder, green tea powder and cinnamon powder, respectively. The ingredients were blended thoroughly to obtain a homogeneous powder and packed in airtight, food-grade, moisture-resistant containers.

Treatment	Pepper leaf powder (g)	Green tea powder (g)	Cinnamon powder (g)
T0 (Control)	0	80	20
T1	60	20	20
T2	40	40	20
T3	20	60	20

4.3.2 Pepper Leaf Spread

The spread was prepared using fresh pepper leaves, cream cheese, olive oil, salt, lemon juice and pepper powder. The leaves were washed, briefly blanched, cooled and blended into a fine paste. The paste was mixed with the remaining ingredients until a smooth

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and uniform consistency was obtained. The control contained no pepper leaves, while SP1, SP2 and SP3 incorporated different levels of fresh leaves.

Treatment	Pepper leaves (g)	Cream cheese (g)	Olive oil (g)	Salt (g)	Lemon juice (g)	Pepper powder (g)
SP0 (Control)	0	80	10	3	5	2
SP1	20	70	10	3	5	2
SP2	10	75	10	3	5	2
SP3	30	65	10	3	5	2

4.3.3 Pepper Leaf Soup Mix

The soup mix was formulated from pepper leaf powder, corn flour, dried carrot flakes, dried garlic, pepper powder and salt. The ingredients were mixed thoroughly to achieve a homogeneous dry blend. For consumption, the mix was dissolved in boiling water and cooked until a smooth consistency was obtained. The study used S0 as the control and S1–S3 as the experimental formulations. The formulation selected for further analysis was S3, consisting of 20% pepper leaf powder, 50% corn flour, 10% dried carrot flakes, 5% dried garlic, 5% pepper powder and 10% salt.

Selected formulation	Pepper leaf powder	Corn flour	Carrot flakes	Dried garlic	Pepper powder	Salt
S3	20%	50%	10%	5%	5%	10%

4.4 Sensory Evaluation

A preliminary taste-sensitivity test was conducted among 50 students from different departments of KAHM Unity Women's College, Manjeri. The test used solutions representing basic tastes and was used to identify sensitive panel members. Ten members were subsequently selected as judges for product evaluation. The sensory evaluation used a nine-point hedonic scale ranging from 9 = like extremely to 1 = dislike extremely. The attributes assessed were appearance, colour, flavour, texture, taste and overall acceptability.

Four formulations in each product category were evaluated. Mean scores were calculated for each sensory attribute and mean rank scores were used to compare preferences. Kendall's coefficient of concordance (W) was used to assess agreement among rankings. The source reports significance at the 5% level, with *** representing highly significant values, ** significant values and NS non-significant values.

4.5 Nutrient Analysis

The most acceptable tea powder, spread and soup mix were analysed for vitamin A, vitamin C and iron. The source document states that the analyses were conducted at STS Lab, Coimbatore, using the FSSAI Manual of Methods of Analysis of Foods and APHA 3500 Ca B (23rd edition). The reported values are presented on a 100-g product basis in the original study.

4.6 Antioxidant Analysis

Total antioxidant activity of the selected products was assessed at STS Lab, Coimbatore using a UV–Visible spectrophotometric method. The reported results are expressed as µg AAE/g. These values represent antioxidant activity measured by the analytical method used and should not be interpreted as direct measures of clinical health effects.

4.7 Storage and Microbial Analysis

Selected products were packed in airtight containers and stored under the conditions described in the source study. Sensory evaluation was performed during storage, and microbial analysis was conducted initially and after the specified storage period. Ten judges participated in the storage-related sensory evaluation. Microbial analysis followed the FSSAI Manual of Methods of Analysis of Foods (Microbiological Analysis), 2015, according to the source document.

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4.8 Cost Analysis and Product Popularization

Production cost was calculated for 100 g of each selected product using ingredient costs and the cost-plus approach described in the original study. The developed products were compared with selected commercial products. Product popularization was conducted among students of KAHM Unity Women's College, Manjeri through a lecture and distribution of pamphlets containing ingredients, preparation methods, nutrient information and health-related information.

5. RESULTS AND DISCUSSION

5.1 Sensory Evaluation of Pepper Leaf Tea Powder

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T0	8.4 (2.85)	8.4 (3.05)	8.2 (3.10)	8.3 (2.85)	8.1 (2.95)	8.3 (3.00)
T1	7.9 (2.00)	7.5 (1.75)	7.1 (1.55)	8.0 (2.55)	7.3 (1.75)	7.8 (2.15)
T2	8.7 (3.25)	8.8 (3.60)	8.3 (3.35)	8.2 (2.85)	8.4 (3.25)	8.4 (3.10)
T3	7.8 (1.90)	7.2 (1.60)	7.4 (2.00)	7.4 (1.75)	7.5 (2.05)	7.5 (1.75)

T2 showed the strongest overall sensory performance among the experimental tea formulations. Its highest attribute score was colour (8.8), followed by appearance (8.7) and taste (8.4). The source data report Kendall's W values of 0.375 for appearance, 0.712 for colour, 0.545 for flavour, 0.228 for texture, 0.373 for taste and 0.336 for overall acceptability. Colour and flavour were reported as highly significant at the 5% level, whereas the remaining attributes were reported as non-significant.

The results indicate that an intermediate level of pepper leaf powder was more acceptable than the higher incorporation level used in T1. The combination in T2 may have provided a more balanced sensory profile between the pepper leaf ingredient, green tea and cinnamon. The lower overall score of T3 suggests that reducing green tea and increasing the relative dominance of the pepper leaf ingredient may not necessarily improve consumer preference.

5.2 Sensory Evaluation of Pepper Leaf Spread

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
SP0	8.4 (3.00)	8.1 (2.80)	8.2 (2.90)	8.2 (2.85)	8.0 (2.70)	8.1
SP1	8.5 (3.20)	8.6 (3.30)	8.5 (3.25)	8.4 (3.35)	8.7 (3.60)	8.5 (3.10)
SP2	7.4 (1.45)	7.6 (1.55)	7.8 (1.90)	7.3 (1.70)	7.4 (1.65)	7.6 (2.00)
SP3	7.9 (2.35)	7.2 (1.70)	6.7 (1.75)	7.2 (1.75)	7.2 (1.70)	—

SP1 was the most acceptable spread formulation. It recorded the highest mean scores for appearance (8.5), colour (8.6), flavour (8.5), texture (8.4) and taste (8.7), and an overall acceptability score of 8.5. The source document reports that SP1 also had the highest mean rank scores across most attributes. In contrast, SP2 showed the lowest overall acceptability among the formulations for which a complete overall score was reported.

The spread results suggest that 20% fresh pepper leaves provided a favourable balance between the green character of the leaves and the creamy base. Increasing the leaf level to 30% in SP3 was associated with lower flavour and texture scores, indicating that stronger leaf character may reduce sensory appeal in this formulation.

5.3 Sensory Evaluation of Pepper Leaf Soup Mix

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
S0	8.5	8.4	8.3	8.4	8.5	8.4
S1	7.7	7.5	7.7	7.6	7.3	7.7
S2	8.0	7.3	7.3	7.4	7.6	7.2
S3	8.7	8.6	8.6	8.6	8.7	8.6

S3 achieved the highest mean score for every reported sensory attribute and therefore was selected for further analysis. Its overall acceptability score was 8.6. The source document also reports high mean rank scores for S3, particularly for flavour, texture and taste. The result indicates that the 20% pepper leaf powder formulation provided a favourable balance between the leaf ingredient and the corn-flour-based soup matrix.

The lower scores for S1 and S2 indicate that increasing the proportion of pepper leaf powder beyond the selected level did not necessarily improve sensory acceptance. This supports the need for systematic formulation trials when developing foods from underutilized ingredients.

5.4 Selection of the Most Acceptable Products

Product	Selected treatment	Composition	Overall score
Tea powder	T2	40% pepper leaf powder + 40% green tea powder + 20% cinnamon	8.4
Spread	SP1	20% fresh pepper leaves + 70% cream cheese + 10% olive oil + 3% salt + 5% lemon juice + 2% pepper powder	8.5
Soup mix	S3	20% pepper leaf powder + 50% corn flour + 10% carrot flakes + 5% dried garlic + 5% pepper powder + 10% salt	8.6

The three selected products represented different consumption formats and demonstrated high sensory scores. The selection process was based on the combined performance of appearance, colour, flavour, texture, taste and overall acceptability rather than on a single sensory attribute.

5.5 Nutrient Composition of Selected Products

Product	Vitamin A (µg/100 g)	Vitamin C (mg/100 g)	Iron (mg/100 g)
Tea powder (T2)	370	52	6.8
Spread (SP1)	200	31	3.4
Soup mix (S3)	430	75	6.2

The selected products showed measurable levels of the three analysed nutrients. S3 recorded the highest reported vitamin A and vitamin C values, while T2 recorded the highest iron value. Across the three products, vitamin A ranged from 200 to 430 µg/100 g, vitamin C from 31 to 75 mg/100 g, and iron from 3.4 to 6.8 mg/100 g. These values reflect the complete formulations and should not be interpreted as the nutrient composition of pepper leaves alone.

The nutrient profile is relevant to value addition because pepper leaves are being used as a component in foods that already have different nutritional matrices. The soup mix, for example, combines pepper leaf powder with corn flour, carrot flakes and other ingredients, while the spread contains cream cheese and olive oil. Thus, product formulation influences the final nutrient concentration.

5.6 Antioxidant Activity

Selected product	Total antioxidant activity (µg AAE/g)	Relative observation
Tea powder (T2)	415	Intermediate among the three
Spread (SP1)	280	Lowest among the three
Soup mix (S3)	500	Highest among the three

S3 recorded the highest antioxidant activity at 500 µg AAE/g, followed by T2 at 415 µg AAE/g and SP1 at 280 µg AAE/g. The difference among products may reflect differences in pepper leaf content, ingredient composition and processing. Because the analysis was performed on the finished products, the measured activity represents the combined matrix rather than an isolated pepper-leaf extract.

The antioxidant findings are broadly consistent with the literature review in the source document, which identifies phenolics, flavonoids and carotenoids as contributors to antioxidant potential in pepper leaves. Nevertheless, antioxidant assay values should be presented as analytical measurements and not as evidence of disease prevention or treatment.

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5.7 Storage Stability: Sensory Changes in Tea Powder

Attribute	Initial	1 month	2 months	Kendall's W
Appearance	8.7	8.0	7.8	0.346***
Colour	8.8	7.7	7.5	0.554***
Flavour	8.3	7.7	7.3	0.678***
Texture	8.2	7.6	7.3	0.532***
Taste	8.4	8.2	8.0	0.523***
Overall acceptability	8.4	7.7	7.2	—

The sensory scores of T2 tea powder declined progressively during storage. Overall acceptability decreased from 8.4 initially to 7.7 after one month and 7.2 after two months. Colour declined from 8.8 to 7.5, flavour from 8.3 to 7.3 and texture from 8.2 to 7.3. The source reports significant/highly significant Kendall's W values for several attributes, indicating increasing agreement among judges in the observed direction of change.

5.8 Storage Stability: Pepper Leaf Spread

Attribute	Initial	1 month	Kendall's W
Appearance	8.5	7.3	0.800***
Colour	8.6	7.2	0.900***
Flavour	8.5	7.0	0.700***
Texture	8.4	8.0	0.129 NS
Taste	8.7	7.1	1.000***
Overall acceptability	8.5	7.3	0.800***

The spread showed a marked decline in most sensory attributes during the one-month storage period. Overall acceptability decreased from 8.5 to 7.3. The largest decline was observed in flavour, from 8.5 to 7.0, and taste, from 8.7 to 7.1. Texture showed a smaller reduction, from 8.4 to 8.0, and the source reports a non-significant Kendall's W for texture. The results indicate that the spread was more storage-sensitive than the dry tea powder and soup mix.

5.9 Storage Stability: Pepper Leaf Soup Mix

Attribute	Initial	1 month	2 months	Kendall's W
Appearance	8.7	8.5	7.9	0.346***
Colour	8.6	8.1	7.6	0.554***
Flavour	8.6	8.1	7.4	0.678***
Texture	8.6	8.0	7.5	0.532***
Taste	8.7	8.3	7.5	0.523***
Overall acceptability	8.6	8.2	7.9	0.479**

S3 retained comparatively high sensory scores over two months. Overall acceptability decreased from 8.6 initially to 8.2 after one month and 7.9 after two months. Appearance declined from 8.7 to 7.9, while flavour declined from 8.6 to 7.4. Despite these changes, the product remained relatively well accepted at the end of the reported observation period.

5.10 Microbial Analysis

Product	Initial total microbial count	Final reported count	Storage period assessed
Tea powder	7×10^1 CFU/g	10×10^1 CFU/g	2 months
Spread	12×10^1 CFU/g	16×10^1 CFU/g	1 month
Soup mix	3×10^1 CFU/g	7×10^1 CFU/g	2 months

Microbial counts increased during storage for all three products. Tea powder increased from 7×10^1 to 10×10^1 CFU/g, spread from 12×10^1 to 16×10^1 CFU/g, and soup mix from 3×10^1 to 7×10^1 CFU/g. The source document compares these values with a stated threshold of 10^6 CFU/g and concludes that the products remained within the cited criterion during the tested period. However, because food safety depends on the specific product category, organism, test method and applicable regulatory standard, these results should be regarded as study-specific observations rather than a universal commercial shelf-life claim.

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5.11 Cost Analysis

Commercial comparator	Commercial cost (₹/100 g)	Developed product	Developed cost (₹/100 g)	Reported saving (₹)
Green tea powder	350	Pepper leaf tea powder	150	200
Nutella spread	320	Pepper leaf spread	180	140
Knorr soup mix	165	Pepper leaf soup mix	50	115

The cost analysis demonstrates a clear economic advantage for the developed formulations under the costing assumptions used in the original study. The tea powder cost ₹150/100 g compared with ₹350/100 g for the selected commercial green tea comparator. The spread cost ₹180/100 g compared with ₹320/100 g for the commercial spread comparator, and the soup mix cost ₹50/100 g compared with ₹165/100 g for the commercial soup comparator. The corresponding reported differences were ₹200, ₹140 and ₹115 per 100 g.

The cost advantage is particularly notable for the soup mix, which had the lowest reported production cost. Since the study used ingredient-based costing and a cost-plus approach, commercial-scale feasibility would additionally require packaging, labour, utilities, transport, quality control, licensing and marketing costs to be incorporated into a full business model.

5.12 Product Popularization

The developed products were popularized among students at KAHM Unity Women's College, Manjeri. A lecture was used to explain the nutritional characteristics and potential benefits of pepper leaves, while pamphlets were distributed containing ingredients, preparation methods, nutrient information and health-related information. The source document reports that participants showed interest in the products and their ease of preparation. This component is relevant because awareness is an important factor in increasing the utilization of underused food resources.

6. OVERALL DISCUSSION

The findings demonstrate that pepper leaves can be incorporated successfully into different food matrices when the level of incorporation is optimized. The sensory results show a consistent pattern: the selected formulations were not those with the highest possible pepper-leaf proportion. Instead, moderate incorporation produced the strongest consumer-oriented scores. This suggests that balancing the characteristic flavour, colour and texture of pepper leaves with familiar ingredients is important for product acceptance.

Among the three products, S3 showed the highest overall sensory score and antioxidant activity, while T2 showed the highest reported iron value. SP1 provided a convenient spread format and also demonstrated strong initial sensory acceptance. The products therefore illustrate complementary opportunities for value addition rather than a single superior product.

Storage findings showed that sensory quality decreased with time. The dry products—tea powder and soup mix—were evaluated for two months, while the spread was evaluated for one month. The spread showed a relatively larger sensory decline, which is consistent with its semi-solid, higher-moisture nature, although the study did not perform a full physicochemical moisture or water-activity analysis. Therefore, future research should investigate moisture migration, water activity, packaging atmosphere and temperature as determinants of storage stability.

The microbial results showed increasing counts over storage but values below the criterion cited in the original study. For commercialization, however, additional tests should be considered, including yeast and mould, specified pathogens where relevant, moisture content, water activity, rancidity/oxidative stability and packaging integrity. A validated shelf-life study under controlled conditions would strengthen the evidence for market claims.

From an economic perspective, the products showed lower reported costs than the selected commercial comparators. This is especially relevant for local value addition because pepper leaves can be sourced as an underutilized plant material. Small-scale processing, women's self-help groups and local food enterprises could potentially explore the products, subject to food-safety requirements, standardization and market testing.

7. CONCLUSION

The study successfully developed three value-added food products using pepper leaves: tea powder, spread and soup mix. Sensory evaluation identified T2, SP1 and S3 as the most acceptable formulations. The selected products contained measurable levels of vitamin A, vitamin C and iron and showed antioxidant activity. The soup mix recorded the highest antioxidant activity and overall sensory score, while the tea powder recorded the highest reported iron content. Storage evaluation demonstrated gradual reductions in sensory scores and increases in microbial counts, emphasizing the importance of appropriate packaging and storage conditions. The developed products were also less expensive than the selected commercial comparators under the costing method used in the study.

The overall findings support the potential of pepper leaves as an underutilized ingredient for food product development. The work provides a practical foundation for further research on optimization, consumer acceptance, safety, packaging, shelf-life validation and commercialization.

8. LIMITATIONS OF THE STUDY

- The study evaluated only three product categories and selected formulations.
- Only selected nutrients (vitamin A, vitamin C and iron) were reported; a complete proximate and mineral profile was not included in the article.
- Antioxidant activity was assessed using one analytical approach and does not establish clinical health effects.
- Storage evaluation was limited to the periods reported in the source study, with the spread evaluated for a shorter period than the dry products.
- The microbial analysis reported total microbial counts rather than a comprehensive pathogen-specific safety profile.
- Consumer acceptance was assessed using a selected sensory panel rather than a large representative market sample.
- Commercial feasibility requires additional costing for packaging, labour, utilities, transport, regulatory compliance and marketing.

9. RECOMMENDATIONS FOR FUTURE RESEARCH

- Conduct six-month or longer controlled shelf-life studies with moisture, water activity, peroxide value, yeast and mould and relevant pathogen testing.
- Compare different drying methods and determine their effects on colour, nutrient retention and antioxidant activity.
- Evaluate different pepper species/cultivars and maturity stages to identify the most suitable raw material.
- Undertake proximate composition, mineral, fibre and phytochemical profiling of both pepper leaf powder and finished products.
- Conduct larger consumer acceptance studies covering different age groups and consumer segments.
- Study packaging options such as vacuum, moisture-barrier and modified-atmosphere packaging for dry products.
- Develop standardized commercial processing protocols and pilot-scale production models.
- Evaluate the market potential, willingness to pay, packaging preferences and purchase intention for pepper-leaf products.
- Explore commercialization through local enterprises and women’s self-help groups.

10. DECLARATIONS

Funding: The source document does not report a specific external research grant. The authors should confirm the final funding statement before submission.

Conflict of interest: The source document does not provide a conflict-of-interest statement. The authors should confirm and insert the appropriate declaration.

Ethical considerations: The source document describes sensory evaluation involving student panelists. The authors should insert the appropriate institutional/ethical statement applicable to the original study before submission.

Data availability: The underlying sensory score sheets and laboratory reports are contained in the original project documentation. Supporting raw data can be made available by the authors where appropriate.

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