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Low-sodium Chaya Leaf Seasoning Powder with Potassium Chloride Substitution: Nutritional, Antioxidant, and Microbial Quality Assessment

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ABSTRACT

This study investigates the development of a low-sodium seasoning powder using Chaya (*Cnidoscolus chayamansa*), popularly known as Mexican spinach, by substituting sodium chloride (NaCl) with potassium chloride (KCl) at various ratios. The antioxidant capabilities of dried Chaya leaves, dried at 60°C for five hours, were tested using 2,2-Diphenyl-1-picrylhydrazyl (DPPH), Ferric reducing antioxidant power (FRAP), and 2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic) acid (ABTS) techniques, demonstrating excellent free radical scavenging activity and making it suitable for low sodium seasoning compositions. The substitution of 25% KCl was the most favored option, as it effectively balanced flavor and health advantages without causing noticeable changes in appearance, color, and aroma. This recipe successfully reduced the sodium content to 1171 mg/100 g while maintaining Chaya's original nutritional values, which include 23.57 g/100 g of protein, 4.77 g/100 g of fats, and 54.12 g/100 g of carbohydrates, as well as dietary fibers. Additionally, the formulation demonstrated physicochemical stability, as indicated by an ash content of 14.00 g/100 g, moisture content of 3.51 g/100g, and a total energy of 353.69 kcal/100 g. The safety of this new seasoning is validated by its microbiological quality, which

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is indicated by a total bacterial count of 2.6×10^4 cfu/g and the absence of mold and yeast. This emphasizes the potential of the seasoning to promote healthy dietary choices by reducing sodium intake without affecting sensory appeal.

Keywords: Antioxidant activity, Chaya leaf, KCl, low-sodium seasoning, nutrients

INTRODUCTION

The increasing occurrence of hypertension and cardiovascular diseases (CVDs), significant global health issues, is closely linked to the use of large amounts of dietary sodium. Although much evidence connects salt intake to higher risks of hypertension and CVDs, attempts to address these health concerns through dietary changes encounter substantial obstacles (Kario et al., 2024). In response, the World Health Organization (WHO) has set an ambitious target to lower global salt consumption by 30% by 2025, a strategy intended to mitigate the prevalence of chronic health issues (Rybicka et al., 2022). Despite these clear objectives, developing palatable low-sodium food alternatives remains a formidable challenge, often compromised by the difficulty of maintaining the desirable taste and flavor profiles that consumers demand. Recent efforts have predominantly focused on replacing sodium chloride (NaCl) with other salts, such as potassium chloride (KCl), which can maintain ionic strength and enhance flavors without the adverse health effects of high sodium levels. Research by He et al. (2021) has shown that achieving up to a 30% reduction in sodium without significantly affecting taste perception, establishing a practical threshold for sodium reduction in food products is possible. Furthermore, innovative approaches have explored incorporating natural ingredients with inherent health benefits.

For example, Kingwascharapong et al. (2024) have studied the substitution of sodium with potassium and calcium salts in snack foods, reducing sodium levels and enhancing the mineral contents, which are beneficial for cardiovascular health. Likewise, the utilization of herbal and plant-based ingredients, such as Chaya (*Cnidoscolus chayamansa*), commonly known as Mexican spinach, offers the dual benefits of reducing sodium while enriching the nutritional and antioxidant properties of food products (Loarca-Piña et al., 2010). Despite these advancements, replacing sodium chloride with alternative salts often fails to adequately satisfy health benefits and consumer taste preferences (Kingwascharapong et al., 2024). Moreover, the potential of integrating underexplored natural ingredients with favorable health attributes into seasoning powders remains largely untapped. Chaya, for instance, is highly nutritious but seldom used in culinary product development (Hutasingh et al., 2023). This research aims to bridge these gaps by examining the use of potassium chloride as a substitute for sodium chloride and incorporating Chaya leaves into the formulation of a low-sodium seasoning powder. This study seeks to meet WHO's salt reduction targets and enhance dietary options' palatability and health benefits, thereby addressing the dual challenge of reducing sodium intake and enriching food products with health-promoting ingredients. Through this approach, the study contributes to the expanding field of food science and public health nutrition, exploring Chaya's potential to broaden the array of ingredients available for creating healthier dietary choices.

MATERIALS AND METHODS

Preparation of Chaya Leaf Powders

Fresh Chaya leaf (*C. chayamansa*) samples were collected from Mueang Surat Thani District, Surat Thani Province, and brought to the Food Innovation and Management Laboratory, King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Chumphon Province. The samples were washed with clean water and blanched in boiling water for 2 min. After that, the Chaya samples were dried at 60°C for 5 h. The dried samples were ground using a grinder (MX-T2G National, Japan) and then sieved through an 80-mesh sieve (with a diameter of 0.1 mm) to obtain a uniformly sized powder. The Chaya leaf powder was then packed into plastic bags and vacuum-sealed before being stored in a freezer (-20°C) for no more than two months before the samples were analyzed and used to develop seasoning powder from Chaya leaf powders.

Antioxidant Activity of Chaya Leaf Powder

Preparation of Ethanolic Chaya Leaf Powder Extract

Chaya leaf powder (10 g) was mixed with 350 mL of 60% (v/v) ethanol (Lab-Scan, Thailand). The mixture was stirred for 3 h, followed by filtering (Buamard & Benjakul, 2019). The supernatant, referred to as 'Chaya leaf extract,' was placed in an amber bottle, capped tightly and kept in a cold condition during analyses.

Analyses

DPPH Radical Scavenging Activity (DPPH-RA). The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) activity of an extract from Chaya leaf powder was examined according to the method described by Tagrida and Benjakul (2021). A diluted sample (0.3 ml) was mixed with 2.7 ml of 0.15 mM DPPH in methanol (Lab-Scan, Bangkok, Thailand), shaken and incubated for 60 min at 25°C in the dark. The decrease in optical density (OD) at 517 nm using spectrophotometer (VIS-7235, Rayleigh, Beijing, China) monitored the DPPH reduction.

ABTS Radical Scavenging Activity (ABTS-RA). 2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic) acid (ABTS) radical scavenging activity of extract from Chaya leaf powder was determined according to the method described by Karnjanapratum and Benjakul (2015). A diluted sample (150 µL) was mixed with ABTS solution (2850 µL) and incubated for 1 h at room temperature in the dark. Absorbance 734 nm was read with spectrophotometer. Blank was prepared using distilled water instead of a sample.

Ferric-reducing Antioxidant Power (FRAP). The FRAP of an extract from Chaya leaf powder was determined following the method of Benjakul et al. (2012). The sample solution (150 µL) was mixed with 2.85 mL of working FRAP reagent, and the mixture was incubated in the dark at room temperature for 30 min. The absorbance at 593 nm was read using spectrophotometer.

Production of Chaya Seasoning Powder Using Potassium Chloride (KCl) to Replace Sodium Chloride (NaCl)

The seasoning powder formula used in the research obtained from the preliminary results of our research team (data not shown) was used as the standard formula (salt; NaCl 22.7 g, sugar 26.6 g, Chaya leaf powder 30.7 g, fish powder 16.0 g, pepper powder 2.0 g, and garlic powder 2.0 g) to study the suitable ratios for substituting KCl for NaCl at replacement levels of 0, 25, 50, 75, and 100 percent, resulting in five experiments (Table 1), each replicated three times, as shown in Table 1. Then, considering the appearance of the produced seasoning powder before and after dissolving it in hot water, sensory evaluation, proximate composition, color values, moisture content, water activity, and pH values of the product were determined. The nutrition values of the best recipe were also determined.

Table 1
The percentage of potassium chloride used to replace sodium chloride in Chaya leaf seasoning powder

Salts (%)	Formulas				
	1	2	3	4	5
NaCl	100	75	50	25	0
KCl	0	25	50	75	100

Sensory Evaluation

Samples were prepared as soup by boiling 20 g of Chaya leaf seasoning powder in 1 L of boiling water for 3 min. Then, 30 mL of the soup were placed into heat-resistant plastic cups with tight-fitting lids and kept in a temperature-controlled cabinet at 70°C, awaiting sensory evaluation by 60 untrained panelists. The evaluation assessed the sensory characteristics of aroma, taste, saltiness, sweetness, bitterness, and overall liking using a 9-point hedonic scale, with scores ranging from 1 (disliked extremely) to 9 (liked extremely). The sample with the highest acceptance score was selected to test the other parameters.

Proximate Composition Determination

The amounts of moisture, ash, fat, protein, and dietary fiber in the Chaya leaf seasoning powder samples were analyzed according to the standard methods of Association of Official Analytical Chemists (AOAC) 2011. The carbohydrate content was determined by subtracting the other components in the Chaya leaf powder samples. Sodium content was also determined according to the AOAC 2012.

Color Values Determination

The color values of the Chaya leaf seasoning powder samples were measured using a colorimeter (HunterLab's Color Flex EZ ®, USA) and reported in terms of L* (lightness), a* (redness/greenness), and b* (yellowness/blueness). Furthermore, the entire color difference, denoted as ΔE*, was computed utilizing the subsequent equation 1:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2} + (\Delta b^*)^2 \quad [1]$$

Where ΔL*, Δa*, and Δb* denote the disparities between the color characteristics of the specimen and the white reference standard (L* = 93.63, a* = −0.94, and b* = 0.40).

Water Activity (A_w)

The low-sodium seasoning powder sample from Chaya leaf was analyzed for water activity (A_w) using an AquaLab Series 3 water quality meter (USA). A sample of the seasoning powder, weighing approximately 1 g, was placed into the measurement cell of the water activity meter. The sample was evaluated in triplicate and performed at room temperature.

pH Determination

The pH values of various Chaya leaf seasoning powder formulas were analyzed using a pH meter (Euteon Instruments, Singapore). The powder was dissolved in hot water before analysis.

Nutritional Values and Microbial Quality Determination

Moisture, protein, total fat, total carbohydrate, ash and sodium content were determined according to the AOAC 2012. Total sugar (Kongkaew et al., 2014), cholesterol content was determined using AOAC Official Method 994.10 (direct saponification-gas chromatographic method), total energy (Calorie calculation), total bacteria was analyzed following AOAC Official Method 966.23 (Aerobic Plate Count at 35°C, 21st ed 2019), Mold and Yeast counts were determined according to AOAC Official Method 997.02 (Yeast and Mold Counts in Foods, Dry Rehydratable Film Method, 19th ed 2012) were also determined.

Statistical Analysis

The experiment was conducted in triplicate for each factor studied. The data variance was analyzed using Analysis of Variance (ANOVA) to compare the differences between the factors studied with Duncan's Multiple Range Test. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) statistical software (SPSS 10.0 for Windows, SPSS Inc., Chicago, USA) at a 95% confidence level.

RESULTS AND DISCUSSION

Antioxidant Capacity

The antioxidant activities of fresh and dried Chaya leaves at a temperature of 60°C for 5 h, measured by DPPH, FRAP, and ABTS assays, are shown in Table 2. The antioxidant properties in Chaya leaves, which were dried, demonstrated a substantial increase in antioxidant capabilities, particularly as observed through the DPPH, FRAP, and ABTS assays. The DPPH radical scavenging activity of dried leaves increased significantly from 35.96 ± 1.29 µmol Trolox equivalent (TE)/g in fresh specimens to 654.23 ± 5.53 µmol TE/g. Similarly, the ABTS and FRAP values showed a significant increase from 86.28 ± 1.11 and 29.64 ± 0.86 µmol TE/g to 1465.94 ± 16.73 and 425.77 ± 6.48 µmol TE/g, respectively. The significant increase in antioxidant capacity after drying indicates the important function of the drying process in not only concentrating natural bioactive components but also potentially creating new antioxidant substances. The increase in value highlights the importance of incorporating dried Chaya leaves into the diet due to their strong ability to fight oxidative stress. Chaya is an excellent ingredient for health-enhancing food items like low-sodium spice powders. Adding Chaya to these products could reduce sodium consumption and enhance the nutritional composition by adding powerful antioxidant qualities (Carlsen et al., 2010; Pandey & Rizvi, 2009). These findings correspond with previous research, confirming the important role of natural antioxidants in preventing chronic diseases and promoting overall health. Therefore, incorporating dried Chaya leaves into food products and nutraceuticals is a commendable strategy for improving health outcomes by increasing antioxidant intake.

Table 2
The antioxidant activity of fresh and dried chaya using the DPPH$^{\bullet}$, ABTS$^{+\bullet}$, and FRAP assays after exposure to 60°C for 5 h

Analytical methods	Samples	
	Fresh Chaya leaf	Dried Chaya leaf
DPPH radical scavenging activity (µmol TE/g sample)	35.96 ± 1.29^{b}	654.23 ± 5.53^{a}
ABTS radical scavenging activity (µmol TE/g sample)	86.28 ± 1.11^{b}	1465.94 ± 16.73^{a}
FRAP (µmol TE/g sample)	29.64 ± 0.86^{b}	425.77 ± 6.48^{a}

Note. * Mean ± SD (n=3). Different letters in the same row indicate significant differences (p<0.05)

Sensory Attributes

The sensory evaluation of the seasoning powders with various levels of KCl substitution is shown in Table 3. The results showed a marked preference for the 25% KCl substitution level, attaining an overall acceptability rating of 6.25 ± 0.22. The decrease in consumer acceptance at KCl levels above 25% can be attributed to reduced saltiness and some consumers' potential detection of a bitter metallic taste. This dual impact highlights the importance of balancing KCl substitution to maintain flavor and consumer satisfaction. This finding signifies a willingness among consumers to accept moderate sodium reductions if the sensory quality is maintained, suggesting KCl as a feasible NaCl alternative without compromising taste, appearance, aroma, or flavor. Such sensory acceptance is crucial for the success of healthier food options in the market, as Drewnowski and Rehm (2014) highlighted. Additionally, insights from Grimes et al. (2009) and Sarmugam et al. (2013) underscore the influence of consumer awareness and socio-demographic factors on dietary choices, emphasizing the need for educational strategies to enhance acceptance of low-sodium products.

Furthermore, the study reveals the minimal impact of KCl substitution on the sensory attributes of the seasoning powders, indicating that Chaya's distinct qualities, combined with KCl, can effectively maintain or enhance the product's appeal. It aligns with the understanding that comprehensive consumer education and targeted communication strategies, based on accurate salt knowledge and correcting misconceptions, could facilitate broader acceptance of such health-oriented innovations.

Table 3
Sensory properties of Chaya leaf seasoning powder with a low sodium content that replaces sodium chloride with various potassium chloride recipes

Likeness scores	Percentage of sodium chloride replaced by potassium chloride				
	Control	25%	50%	75%	100%
Appearance	$7.43{\pm}1.07^{*a}$	$7.52{\pm}1.06^{a}$	$7.47{\pm}1.03^{a}$	$7.22{\pm}1.90^{a}$	$7.08{\pm}2.04^{a}$
Color	$7.62{\pm}1.02^{a}$	$7.68{\pm}1.20^{a}$	$7.68{\pm}1.00^{a}$	$7.45{\pm}1.71^{a}$	$7.38{\pm}1.85^{a}$
Odor	$6.67{\pm}1.27^{a}$	$6.95{\pm}1.17^{a}$	$6.77{\pm}1.06^{a}$	$6.60{\pm}1.02^{a}$	$6.57{\pm}0.85^{a}$
Saltiness	$6.95{\pm}1.12^{a}$	$6.83{\pm}1.01^{a}$	$5.57{\pm}1.16^{b}$	$5.47{\pm}1.92^{b}$	$5.17{\pm}1.00^{b}$
Umami	$7.12{\pm}1.00^{a}$	$7.35{\pm}0.17^{a}$	$5.63{\pm}1.08^{b}$	$5.47{\pm}1.84^{b}$	$5.17{\pm}1.10^{b}$
Overall	$6.87{\pm}1.10^{a}$	$6.25{\pm}0.22^{a}$	$5.47{\pm}1.00^{b}$	$5.50{\pm}1.72^{b}$	$5.00{\pm}1.07^{b}$

Note. *Value mean ± standard deviation (n=60). Different superscripts within the same row indicate significant differences (p<0.05)

Sodium Reduction

The salt content of seasoning powder from Chaya leaf with various levels of KCl substitution is depicted in Table 4. The findings indicated that the salt level was reduced proportionately to the rise of KCl in the incorporated seasoning (p<0.05). A compelling link between consumer acceptance and the health benefits of reduced sodium intake was previously reported. The sensory evaluation highlighting a preference for the 25% KCl substitution level, with an overall acceptability rating of 6.25 ± 0.22, demonstrates that moderate sodium reduction is feasible and well-received when the sensory quality of the seasoning powder is preserved. Without compromising taste, appearance, aroma, or flavor, this preference for a lower sodium option mirrors the critical public health need to reduce sodium consumption, as substantial sodium reduction to 0.30 ± 0.23 mg NaCl/g in the 100% KCl substitution sample directly addresses the risks associated with high sodium intake, such as hypertension and cardiovascular diseases (Aburto et al., 2013; He et al., 2021).

Table 4
The salt content of seasoning powder from Chaya leaves with low sodium that replaces sodium chloride with potassium chloride at various contents

Potassium chloride (%)	Sodium chloride content (mg NaCl/g sample)
0%	189.00 ± 0.02*[a]
25%	141.00 ± 0.10[b]
50%	69.00 ± 0.48[c]
75%	46.00 ± 0.16[d]
100%	0.30 ± 0.23[e]

Note. *Values mean ± standard deviation (n=3). Different superscripts within the same column indicate significant differences (p<0.05)

The willingness among consumers to embrace such moderate sodium reductions, underscored by the maintained sensory appeal of the KCl-substituted seasoning powder, suggested that KCl served as a practical NaCl substitute. It aligns with Drewnowski and Rehm's (2014) emphasis on the importance of sensory acceptance for the success of healthier food products and is supported by studies exploring the impact of consumer knowledge and socio-demographic factors on dietary choices (Grimes et al., 2009; Sarmugam et al., 2013). The minimal impact of KCl substitution on the sensory attributes of the seasoning powders, particularly when combined with Chaya's unique qualities, not only maintains but potentially enhances the product's appeal, offering a healthier alternative that does not sacrifice flavor for sodium reduction.

This strategic approach to developing low-sodium seasoning options, which balance sensory quality with significant health benefits, contributes to broader public health efforts to mitigate diet-related risks by providing a viable solution for reducing sodium intake. By ensuring the sensory quality of reduced-sodium products, we encourage wider consumer acceptance, supporting the goal of lowering the incidence of hypertension and cardiovascular diseases linked to excessive sodium consumption.

Chemical Compositions

The chemical component of seasoning powder from Chaya leaves with low sodium that replaced sodium chloride with potassium chloride at a rate of 25% is illustrated in Table 5. The seasoning powder had a high content of carbohydrates (42.50% ± 1.23%), protein (25.83% ± 0.91%), ash (25.16% ± 0.39%) and fiber (17.01% ± 0.78%) contents. Including

Chaya leaf powder in the development of seasoning powders provided a low-sodium alternative and significantly enhanced the nutritional profile of the products. Chaya, known for its superior nutrient density compared to conventional leafy vegetables, is rich in essential minerals like calcium, iron, potassium, and vitamins such as vitamin C and β-carotene, alongside notable levels of protein, fat, ash, carbohydrates, and dietary fiber (Kuti & Kuti, 1999). These findings emphasized the nutritional benefits of incorporating Chaya into seasoning powders. They supported the global initiative to recognize the value of neglected and underutilized species in improving food and nutritional security. This strategic integration of Chaya into food products reaffirms its multifaceted benefits, supporting efforts to diversify diets with underutilized plants for improved health outcomes.

Table 5
Chemical components of seasoning powder from Chaya leaves with low sodium that replace sodium chloride with potassium chloride at a rate of 25%

Protein (%)	Lipid (%)	Ash (%)	Carbohydrate (%)	Fiber (%)
$25.83 \pm 0.91^{*b}$	5.24 ± 0.30^{d}	25.16 ± 0.39^{b}	42.50 ± 1.23^{a}	17.01 ± 0.78^{c}

Note. *Value mean ± standard deviation (n=3). Different superscripts within the same row indicate significant differences (p<0.05)

Moisture Content, Water Activity (A_w), and pH

The moisture content, water activity and pH of the selected formulation (25% KCl substitution) are shown in Table 6. The selected formulation had a moisture content of 3.4 ± 0.05%, water activity (A_w) of 0.43 ± 0.01, and pH of 6.45 ± 0.1, suggesting the enhanced stability and safety for the practical use of the low-sodium seasoning powder in various culinary applications. Recent studies highlight the critical role of these physicochemical properties in food preservation. For instance, low water activity significantly reduces the risk of microbial growth by limiting water availability necessary for microbial metabolism, thus contributing to the product's safety and extended shelf-life (Beuchat, 1983; Erkmen & Bozoglu, 2016). Furthermore, the pH level within this range can effectively suppress the growth of spoilage-causing microorganisms, ensuring the product's longevity (Smith et al., 2010).

Incorporating ingredients like Chaya (*C. chayamansa*) and using KCl as a sodium substitute exemplify innovative approaches to creating nutritious products that meet

Table 6
Moisture content, water activity (A_w) and pH of seasoning powder from Chaya leaves with low sodium that replaces sodium chloride with potassium chloride at a rate of 25%

Recipe	Moisture (%)	Water activity (A_w)	pH
25% Substituted	3.4 ⊥ 0.05*	0.43 ⊥ 0.01	6.45 ⊥ 0.1

Note. *Value mean ± standard deviation (n=3) health-conscious consumers' needs (Ramírez et al., 2021). The seasoning powder's physicochemical stability suggests its utility in the food industry. It provides a viable ingredient for manufacturing products consistent with sodium reduction public health initiatives to address diet-related health concerns, such as hypertension and cardiovascular disease.

Color Values

The color value of seasoning powder derived from Chaya leaves, which has a reduced sodium content by replacing sodium chloride with potassium chloride at a ratio of 25%, is presented in Table 7. Color analysis revealed minimal changes in the color attributes of the seasoning powder with KCl substitution, maintaining its visual appeal. Preservation of color is crucial for consumer acceptance, as visual cues play a significant role in food choice (Spence et al., 2016). The ability to retain color attributes while reducing sodium content further supports the feasibility of KCl substitution in producing visually appealing, healthier food products.

Table 7
Color values of seasoning powder from Chaya leaves with low sodium that replaces sodium chloride with potassium chloride at a rate of 25%

Recipe	Color values			
	L*	a*	b*	ΔE*
25% Substituted	40.89 ± 0.41*	-5.89 ± 0.07	18.95 ± 0.26	5.40 ± 0.17

Note. *Mean ±, Standard deviation (*n*=3)

Nutritional Values and Microbial Quality

The seasoning powder contains a high amount of protein (25.57 g per 100 g) due to fish meat in the Chaya leaf seasoning powder. This combination resulted in a higher protein level than that of many plant-based products on their own, hence improving the nutritional composition of the powder. Inosine from fish protein and glutamate from Chaya leaf work together to improve the umami flavor in foods seasoned with this low-sodium powder, making the sensory experience more enjoyable. The study by Hutasingh et al. (2024) revealed the substantial influence of drying techniques on the aromatic attributes and umami constituents of Chaya leaves. This research establishes the foundation for understanding how these factors contribute to the seasoning powder's high protein content and its ability to enhance umami taste.

The carbohydrate content of 54.12 g/100 g and fat content of 4.77 g/100 g in the low-sodium seasoning powder contribute to its substantial energy source of 353.69 Kcal/100 g. These nutritional values, indicative of a nutritionally dense product, suggest that while the seasoning powder is nutritious, it should be consumed in moderation within a balanced diet to avoid excessive caloric intake. The presence of fish meat in the seasoning blend, which is known for its high protein and essential amino acids content, further complements the powder's nutritional profile by enhancing the overall taste and mouthfeel of the food products it seasons (Kingwascharapong et al., 2023). Moreover, the incorporation of Chaya leaf not only adds to the product's nutritional value by providing dietary fibers but also enriches it with glutamate, a natural umami-enhancing compound, synergistically working with inosine present in the fish meat to enhance the umami flavor, a key aspect in the acceptability of low-sodium food products (Kingwascharapong et al., 2023).

The study highlights the sodium content as a key aspect, which has been lowered to 1171 mg/100 g. However, it is important to consume it cautiously to adhere to global dietary guidelines for reducing sodium intake. Minimizing the risks connected with high blood pressure and cardiovascular illnesses is crucial. This decrease is crucial, emphasizing the difficulty of balancing taste preferences and health concerns in developing low-sodium food products. The salt content of the powder was significantly reduced to 698.33 mg/100 g, suggesting a possible approach for attaining large sodium reduction without negatively affecting the sensory characteristics. In a study conducted by Kingwascharapong et al. (2023), the researchers examined the replacement of NaCl with alternative salts such as KCl and calcium chloride ($CaCl_2$) in smoked green mussel products. The study highlighted the importance of choosing and using sodium substitutes carefully to maintain the quality of the product while reducing its sodium content. This research supports the ongoing efforts to develop healthier food choices.

The low-sodium seasoning powder has a minimal cholesterol content of 2.13 mg/100 g, corresponding to dietary standards that recommend reducing cholesterol intake. This highlights the product's positive impact on heart health. The Chaya leaf reduced sodium seasoning powder is a valuable addition to the food sector due to its unique characteristics and extensive nutritional advantages. It provides a healthier alternative to traditional seasoning solutions. The study conducted by Cicero et al. (2020) examines the effects of commonly used seasonings and cooking fats on arterial stiffness and blood lipid patterns in a sample of individuals from a rural population. The findings of this research highlight the importance of selecting healthier fats to enhance lipid profiles and potentially lower the risk of cardiovascular disease. This seasoning powder suits consumers who want to reduce their sodium and cholesterol intake without affecting taste or quality. It maintains the original nutritional properties of Chaya and guarantees food safety through careful control of microbiological purity.

Furthermore, evaluating the microbial quality of the newly developed low-sodium seasoning powder demonstrates remarkable compliance with food safety regulations, as no mold or yeast was found, and the overall bacterial count was 2.6×10^4 cfu/g. This result indicates adhering to strict manufacturing standards and the product's durability. The lack of mold and yeast, as emphasized in our research, aligns with the results of Odamtten et al. (2018), who investigated the microbiological content and potential toxicity of imported spice powders in the Ghanaian market, emphasizing the significance of ensuring microbial safety in food items. Through rigorous microbiological quality control measures, our low-sodium seasoning powder provides a dependable component for culinary purposes. It is safer for consumers who want to decrease sodium consumption without sacrificing food safety or sensory satisfaction.

CONCLUSION

Chaya leaf-based seasoning powder effectively reduced sodium levels by replacing NaCl with KCl without compromising taste. A 25% substitution of KCl was found to optimally balance health benefits with consumer satisfaction, significantly reducing the sodium content and demonstrating KCl's efficacy as a sodium substitute. The seasoning powder exhibited a low cholesterol level of 2.13 mg/100g. It maintained a balanced nutrient profile, consisting of 23.57 g/100g protein, 54.12 g/100g carbohydrates, and 4.77 g/100g fats while ensuring excellent microbiological safety. Additionally, the high antioxidant activity of Chaya leaves enhanced the nutritional value of the seasoning powder, suggesting the potential for a longer shelf life. These findings underscore the feasibility of introducing low-sodium seasoning options that do not sacrifice flavor for health, supporting broader public health efforts to reduce dietary sodium intake.

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