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Article

The Effect of Ginger (*Zingiber officinale*) Extract Addition on The Characteristics of Chayote (*Sechium edule (Jacq.) Sw.*) Syrup

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Abstract. This study aimed to evaluate the effect of adding ginger (*Zingiber officinale*) extract on the physical, chemical, microbiological, and sensory properties of chayote (*Sechium edule*) syrup, a potential functional drink developed from local agricultural produce. The research was designed using a Completely Randomized Design (CRD) with five levels of ginger extract addition (0%, 10%, 20%, 30%, and 40%) and three replications. Data were analyzed using Analysis of Variance (ANOVA), and Duncan's New Multiple Range Test (DNMRT) at a 5% significance level was applied when significant differences were detected. The results showed that increasing the concentration of ginger extract significantly improved syrup viscosity (up to 1568.67 cP), phenol content (up to 45.65 mg GAE/g), and antioxidant activity (up to 46.03%), while reducing TPC to 2.7×10^2 CFU/g. The most preferred formulation was at 30% ginger extract addition, yielding a product with desirable sensory qualities and balanced composition. Color analysis using °Hue showed a shift towards deeper yellow tones, although this was not statistically significant. High viscosity contributes to better texture and product stability, while elevated phenol and antioxidant content enhance the health-promoting potential of the syrup. These attributes are essential in designing functional beverages. This study contributes to the development of functional drinks using local agricultural commodities and introduces a novel combination of chayote juice and ginger extract as a promising formulation.

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1. Introduction

Indonesia is an agricultural country rich in various natural resources from agriculture. Horticultural plants are one of Indonesia's natural resources that play an important role in various aspects including food and health. One of the horticultural plants is chayote. Chayote (*Sechium edule* (Jacq.) Sw.) is a type of pumpkin that comes from the Cucurbitaceae family. This fruit can be easily found on the market at an affordable price because its cultivation is not complicated. Generally, people consume chayote by processing it into vegetables by boiling, steaming, or stir-frying.

Chayote is included in the category of vegetables and fleshy fruits due to its high water content, which ranges between 87% and 95%, making it perishable and prone to microbial spoilage if not properly handled [1]. The dietary fiber in chayote is comparable to other vegetables, and its low-fat content makes it suitable for healthy diets. Methanol extracts of chayote shoots have been shown to contain high levels of calcium and iron, along with the highest concentrations of flavonoids and β-carotene, and exhibit strong antioxidant activity [2]. Chayote contains flavonoids, phenolic compounds, vitamin C, and carotenoids. Shariff et al. (2023) reported that the upper shoot tier exhibited the highest antioxidant activity (IC_{50} = 245.12 µg/ml), while the lower tier recorded the highest total phenolic content (355.66 mg GAE/g), indicating the richness of bioactives such as flavones and flavonols [3]. In addition, chayote is rich in essential minerals and amino acids. Protein isolates from chayote seeds obtained through ultrasound-assisted extraction have been reported to exhibit a balanced amino acid profile, with high essential amino acid content (315.63 mg/g protein), strong protein digestibility (80.3%), and significant α-amylase inhibitory activity (74% at 100 µg/mL) [4]. Among six plant fractions tested, chayote shoots were found to contain the highest levels of phenolics, flavonoids, and ascorbic acid, and demonstrated the strongest antioxidant activity [5]. However, most existing literature focuses on nutritional content without exploring advanced processing into functional beverages.

The commonly known benefits of chayote include its antidiabetic effects. Chayote juice has been reported to significantly preserve pancreatic islet structure and insulin levels, lower blood glucose, and suppress pro-inflammatory and apoptotic markers in diabetic mice [6]. Despite being widely consumed as a vegetable, chayote has yet to be widely developed into value-added products such as functional syrup. Spray-dried chayote juice encapsulated with gum arabic has been shown to retain its total flavonoid content and bioactivity for up to 293 days under optimal storage conditions [7]. However, studies integrating both sensory acceptability and bioactivity enhancement of chayote-based drinks remain rare and represent an urgent research gap for developing marketable, locally based functional food innovations.

According to SNI 01-3544-2013, syrup is a beverage product made from a mixture of water and sugar with a sugar solution content of at least 65% with or without other food ingredients and/or food additives permitted in accordance with applicable regulations [8]. Generally, syrup is in the form of a thick solution so it needs to be diluted first before being consumed. In making syrup, sugar functions as a sweetener, preservative, and thickener as well as a source of energy that is easily digested and absorbed by the body. Sugar improves palatability and increases the shelf life of herbal syrups by acting as a natural preservative and thickening agent [9].

A functional beverage formulation using lemongrass, ginger, and black tea identified lime juice as an effective additional flavoring agent, capable of enhancing both palatability and α-glucosidase inhibitory activity [10]. The addition of lime juice in the study aimed to reduce the bland taste and unpleasant aroma of the chayote syrup produced. In this study, to reduce the bland taste and unpleasant aroma of chayote syrup, researchers chose to add ginger which has a spicy taste and distinctive aroma. The pungent flavor of ginger is mainly attributed to 6-gingerol and 6-shogaol, compounds whose concentrations can be significantly influenced by drying and extraction methods such as freeze-drying or microwave-assisted drying, which retain aroma and phenolic content effectively [11].

Most previous studies on chayote syrup have focused on citrus-based flavoring agents such as lime juice, with limited consideration for their functional or preservative effects. In contrast, ginger has both sensory and bioactive advantages, yet its potential specifically in syrup formulations with chayote has not been studied. Most studies used lime juice to improve chayote syrup palatability. However, none have evaluated ginger extract addition for its flavor, antioxidant, and microbiological effects in syrup form. This study addresses that gap by evaluating ginger extract as an alternative enhancer based on recent evidence that ginger extract improves phenolic content, antioxidant activity, and sensory quality in syrup systems [12].

The novelty of this study lies in combining two bioactive-rich local ingredients—ginger and chayote—into a functional syrup, a formulation not yet explored in current literature, despite both components showing independent health-promoting properties. Herbal syrups with ginger extract offer multifunctional roles such as anti-inflammatory, antimicrobial, and digestive benefits, in addition to enhancing flavor [13]. Compared to international research on functional beverages using herbal or tropical fruit extracts—such as hibiscus-infused syrups, turmeric beverages, and berry-based nutraceutical drinks—the use of chayote and ginger in syrup form is underexplored. This positions the present study as a meaningful contribution within global efforts to diversify health-oriented drinks from underutilized crops.

Ginger contains natural antioxidants, namely phenolic compounds in the form of flavonoids, cinnamic acid derivatives, coumarins, tocopherols, and organic acids. These phytochemicals, such as gingerols and shogaols, have been shown to exert strong antioxidant effects and modulate biological processes related to inflammation, cardiovascular diseases, and oxidative stress [14]. Furthermore, ginger extract contains flavonoid compounds with a total phenolic content that significantly contributes to radical scavenging activity, especially in beverage formulations [9]. These properties position ginger not only as a flavor enhancer but also as a promising functional component that can complement chayote's nutritional potential. This aligns the study within the growing field of functional food development through the combination of local plant-based ingredients. By integrating ingredients that are widely cultivated but underutilized in the health food sector, this study also highlights the intersection of food science and public health nutrition in local contexts.

Researchers conducted a preliminary study to see the effect of adding ginger extract to chayote syrup. The experiment was conducted using treatments of 0%, 10%, 20%, 30%, 40%, and 50% addition of ginger extract based on the total weight of chayote juice used. From the results of the preliminary study that has been conducted, it was obtained that the addition of ginger extract affects the color, aroma, and taste. Syrup with 0% treatment has a yellow color, a pungent aroma of chayote, and a sweet taste with a little taste of chayote. Syrup with 10–50% treatment has a brownish yellow color, there is a ginger aroma, a sweet taste and there is a spicy taste typical of ginger. In this treatment, the color of the syrup gets darker and the spicy taste of ginger increases along with the increasing percentage of ginger extract addition. However, for the treatment of adding 50% ginger extract, the spicy taste produced is quite strong so that it is less acceptable. This aligns with findings showing that increasing ginger concentration in syrup reduces sweetness but enhances aroma, antioxidant content, and acceptability up to a certain threshold [9].

Specifically, this study evaluates the effect of ginger extract addition on various parameters, including: (1) physical properties (viscosity, °Hue); (2) chemical composition (pH, total acid, total sugar, total phenol, and antioxidant activity); (3) microbiological stability (Total Plate Count); and (4) sensory quality (color, aroma, and taste). In line with previous research on ginger-enriched syrups, these parameters have shown to be responsive to ginger extract concentration, particularly total phenolic content and microbiological stability [9]. These comprehensive assessments aim to determine the optimal formulation and demonstrate the feasibility of developing functional beverages from local agricultural commodities.

Based on the description above, the percentage of ginger extract addition that will be used in making chayote syrup in this study is 0%, 10%, 20%, 30%, and 40%. The purpose of this study was to determine the effect of adding ginger extract on the characteristics of chayote syrup and to determine the best concentration of ginger extract addition on the characteristics of the resulting chayote syrup. Specifically, the study examines physical parameters (viscosity, °Hue), chemical properties (pH, total acid, total sugar, total phenol, antioxidant activity), microbiological quality (Total Plate Count), and organoleptic attributes (color, aroma, and taste) to comprehensively assess the impact of ginger extract.

2. Method

2.1 Place and Time

This research was conducted in the Laboratory of Chemistry, Biochemistry of Agricultural Products and Food Nutrition, Laboratory of Technology and Engineering of Agricultural Product Processes, Laboratory of Microbiology and Biotechnology of Food and Agricultural Products, Laboratory of Total Quality Control, and Central Instrumentation Laboratory, Faculty of Agricultural Technology, Andalas University, Padang City, West Sumatra. The research was conducted from April to May 2024.

2.2 Materials and tools

The raw materials used in the syrup making research were chayote (category not too ripe, not defective, and not rotten), elephant ginger (fresh, dry, not defective, and not rotten), granulated sugar, citric acid (Gajah brand), and CMC obtained from Pasar Raya Padang. The materials used in the analysis were standard buffer solution, distilled water, 4 N HCl, 4 N NaOH, 3% acetic acid, *luff schoorl* solution, 25% H_2SO_4, 20% KI, 0.1 N thiosulfate solution, 1% starch indicator, PP indicator, 0.1 N NaOH, methanol, DPPH solution, gallic acid solution, folin-ciocalteu reagent, 5% Na_2CO_3, PCA media, physiological salt, and so on.

The tools used in making syrup are knives, cutting boards, filter cloths, digital scales, blenders, pans, spoons, stirring spoons, gas stoves, tongs, funnels, strainers, and syrup bottles. The tools used for analysis are colorimeters (Hunterlab colorFlex EZ Spectrophotometer), viscometers (B-One Viscometer with Model BMV 102 M), refractometers, vortexes (Thermo Scientific LP Vortex Mixer), stormer cups, droppers, pH meters, measuring flasks, measuring cups, beakers, test tubes, Erlenmeyers, filter paper, ultrasonic baths (Ultrasonic Cleaner Elma S300H), test tubes, UV-Vis spectrophotometers (Shimadzu UV-1800 UV-Vis Spectrophotometer), cuvettes, autoclaves (Hirayama HVE-50 Autoclave), colony counters (AS ONE Colony Counter ACK-3), sterile petri dishes, tissues, and so on. All instruments were calibrated according to manufacturer guidelines prior to use. Microbiological tests including Total Plate Count were performed in triplicates to ensure data reliability and repeatability.

2.3 Research Design

The experimental design used in this study was a Completely Randomized Design (CRD) with 5 treatments and 3 replications. The treatments were as follows: Treatment A: 0% ginger extract Treatment B: 10% ginger extract, Treatment C: 20% ginger extract, Treatment D: 30% ginger extract, Treatment E: 40% ginger extract

Statistical analysis was conducted using Analysis of Variance (ANOVA) with a significance level of 5%. Differences among means were further tested using Duncan's New Multiple Range Test (DNMRT). All computations were performed using SPSS version 25 (IBM, USA), following a method similar to Sayuti et al. (2023), where a CRD was employed with four treatment types, analyzed using ANOVA and DNMRT at 5% to evaluate physical and chemical characteristics in food formulations [15]. Likewise, Larasati et al. (2021) implemented CRD with ANOVA and DMRT in aquatic feed trials to assess treatment effects on growth and feed utilization [16].

2.4 Research Implementation

2.4.1 Formulation Determination

The syrup formulation was adapted with modifications from a previously established method [17], and further refined based on results from preliminary research. The formulation used in the syrup can be seen in Table 1.

Table 1. Formulation for Making Chayote Syrup with the Addition of Ginger Extract

Ingredient	A (0%)	B (10%)	C (20%)	D (30%)	E (40%)
Chayote juice (g)	200	200	200	200	200
Ginger extract (g)	0	100	100	100	100
Sugar (g)	750	750	750	750	750
Citric acid (g)	0.6	0.6	0.6	0.6	0.6
CMC (g)	0.6	0.6	0.6	0.6	0.6

Note: The percentage of ginger extract addition is based on the total water weight (100 g) used in the extract preparation.

2.4.2 Preparation of Chayote Juice

The preparation of chayote juice was carried out by cutting the chayote into two parts. The two halves were rubbed together to remove the sap inside the chayote. Then, the skin of the chayote was peeled. The chayote was washed to remove sap and other impurities. After that, the chayote was chopped into smaller pieces. The chopped chayote was then blended using a blender with added water (juice-to-water ratio: 4:1). The blended mixture was then filtered using filter cloth to obtain the chayote juice.

2.4.3 Preparation of Ginger Extract

The ginger extract was prepared by sorting the ginger to be used. The skin of the ginger was peeled and the unusable parts were removed. The peeled ginger was washed to remove soil and other impurities. Then, the ginger was chopped into smaller pieces. Next, 10 g, 20 g, 30 g, and 40 g of ginger were weighed according to treatments (0%, 10%, 20%, 30%, and 40%). The ginger was then crushed using a blender with 100 ml of water per treatment. The crushed mixture was then heated until boiling. After boiling, the mixture was filtered to obtain the ginger extract *(Modified from [18]).*

2.4.4 Syrup Preparation *(Modified from [19])*

The preparation of chayote syrup was done by preparing 200 g of chayote juice and 100 g of ginger extract according to treatment (0%, 10%, 20%, 30%, and 40%) and mixing them in a cooking pot. Then, 750 g of granulated sugar and 0.6 g of CMC were added and stirred until well mixed. The mixture was then heated for ±15 minutes until boiling, to ensure the sugar was fully dissolved and thickened. After that, 0.6 g of citric acid was added 3 minutes before the cooking process ended. The heating was then stopped and the syrup was poured into pre-sterilized glass bottles. The bottles were sealed tightly and the syrup was stored at room temperature *(Modified from [19]).*

2.4.5 Observations

Observations were conducted on the chayote juice and ginger extract for parameters including pH, total acid, total phenol, and antioxidant activity. Observations on the syrup included analysis of color, viscosity test, pH, total acid, total sugar content, total dissolved solids, total phenol, antioxidant activity, total plate count, and organoleptic test.

To enhance clarity and reproducibility, the complete experimental workflow is outlined in the following flowchart. It depicts the sequential stages of the study, including raw material preparation, ginger extract concentration treatments, syrup formulation, controlled processing conditions, analytical evaluations (physical, chemical, and microbiological), organoleptic assessment using semi-trained panelists, and statistical data analysis.

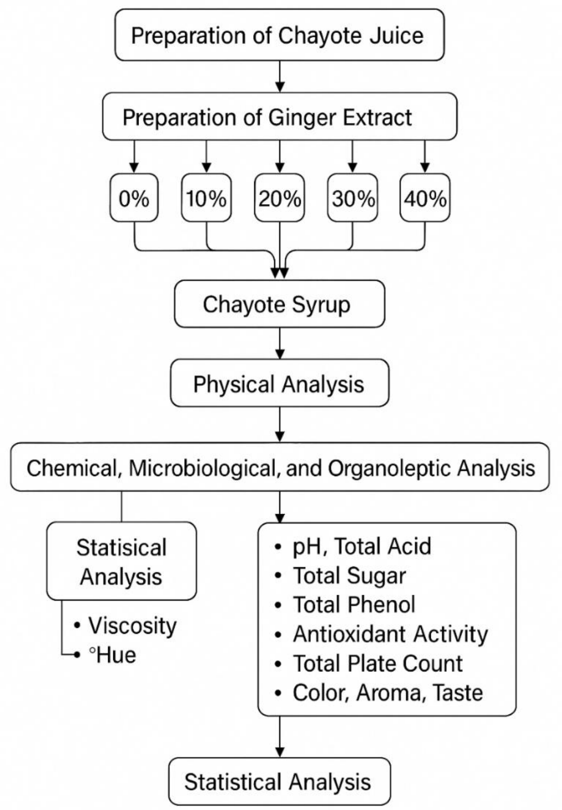

Figure 1. Experimental workflow of chayote syrup production with varying concentrations of ginger extract and subsequent analyses.

3. Results and Discussion

3.1 Raw Material Analysis

The analysis conducted on the raw materials of chayote juice and ginger includes pH, total acid, total phenol, and antioxidant activity. The analysis results of the raw materials are shown in Table 2.

Table 2. Raw Material Analysis Results

Analysis Component	Chayote Juice (Mean ± SD)	Ginger (Mean ± SD)
pH	6.71 ± 0.12	6.52 ± 0.13
Total acid (%)	0.1749 ± 0.0002	0.2620 ± 0.0004
Total phenol (mg GAE/g)	121.59 ± 1.81	234.93 ± 1.96
Antioxidant activity (%)	43.38 ± 1.29	67.52 ± 0.84

Note: The values are the mean of 3 replications.

Based on Table 2, the pH value of chayote juice was 6.71. This value is close to that reported in recent studies on chayote juice used in functional foods, which typically range between 6.0–6.7 [20]. The pH value of the ginger sample was 6.52, which is within the range found in functional beverages containing ginger [21].

The total acid content of chayote juice was 0.1749%, while that of ginger was 0.2620%. Total acidity for both juices falls within expected ranges reported in studies using fresh or microfluidized extracts [7],[22]. Variability in acidity is commonly due to juice concentration and water addition.

The total phenol content of chayote juice was 121.59 mg GAE/g, while that of ginger was 234.94 mg GAE/g. This aligns with values found using optimized extraction for chayote and ginger, which report ranges of 120–160 mg GAE/g and 200–250 mg GAE/g respectively [22-24] Phenolic content is influenced by cultivar, maturity, and extraction method.

The antioxidant activity of chayote juice was 43.38%, which corresponds well with findings reporting 36–45% DPPH inhibition in aqueous chayote extracts [3]. Antioxidant components include flavonoids, polyphenols, carotenoids, and vitamin C [25].

The antioxidant activity of ginger was 67.52%, consistent with data from recent studies on red and emprit ginger, reporting 60–80% antioxidant activity depending on extraction type [26-27]. This is attributed to phenolics like gingerol and shogaol, which show strong radical scavenging properties.

3.2 Physical Analysis of Syrup

3.2.1 Color Analysis

Hue value is a component that determines the color used. The results of the color analysis of chayote syrup with the addition of ginger extract can be seen in Table 3.

Table 3. Color Analysis of Chayote Syrup with Ginger Extract Addition

Treatment (Ginger Extract)	Hue Value (°Hue) ± SD	Color
E (40%)	96.92 ± 6.35	Yellow
D (30%)	98.13 ± 6.34	Yellow
C (20%)	99.88 ± 4.98	Yellow
B (10%)	101.91 ± 7.32	Yellow
A (0%)	104.82 ± 6.45	Yellow

CV = 1.26%

Chayote syrup with the addition of ginger extract resulted in a pale yellow to yellow-brown color. The syrup color produced is influenced by the color of ginger, where the color of ginger is affected by oleoresin, which is a color-giving component in ginger. Ginger oleoresin has been reported to contain bright yellow to dark brown pigments and is rich in phytochemicals that influence color intensity [28].

Additional studies confirm that ultrasonication enhances the yellow hue and solubility of ginger oleoresin in aqueous food systems, giving it a stronger color expression [29]. In addition, the color change is caused by caramelization reaction. Caramel addition has been shown to enhance syrup color and improve visual acceptance among consumers without compromising safety [30]. The syrup color can be seen in the image below.

Figure 2. Chayote Syrup with Ginger Extract Addition

3.2.2 Viscosity Test

The results of the viscosity test on chayote syrup with ginger extract addition can be seen in Table 4.

Table 4. Viscosity of Chayote Syrup with Ginger Extract Addition

Treatment (Ginger Extract)	Viscosity (cP) ± SD
A (0%)	1031.33 ± 13.32[a]
B (10%)	1259.33 ± 12.22[b]
C (20%)	1398.00 ± 13.11[c]
D (30%)	1488.00 ± 7.21[d]
E (40%)	1568.67 ± 25.79[e]

CV = 0.23%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the analysis of variance (ANOVA), it shows that the treatment of ginger extract addition significantly affects ($p<0.05$) the viscosity of the syrup. The average viscosity value of the syrup ranges from 1031.33–1568.67 cP. The highest average value was obtained in treatment E (40% ginger extract addition) with a value of 1568.67 cP, while the lowest average value was obtained in treatment A (0% ginger extract addition) with a value of 1031.33 cP.

The increase in syrup viscosity is directly proportional and related to the increase in total sugar content. Higher sugar concentrations have been found to significantly increase the viscosity, soluble solids, and refractive index of fruit syrups [31]. This is due to the binding of water molecules by sugar, which results in a thicker syrup texture [32]. In addition to sugar, viscosity is also affected by the starch content present in ginger. Ginger starch, rich in amylose and amylopectin, contributes to viscosity and gel formation upon heating, owing to its gelatinization and thickening properties, particularly under thermal processing conditions [33-34]. Moreover, increasing the proportion of ginger extract in syrup has been shown to further enhance viscosity, attributed to the high polysaccharide and bioactive compound content present in ginger [9].

3.3 Chemical Analysis of Syrup

3.3.1 pH Value

The average results of pH testing of chayote syrup with ginger extract addition can be seen in Table 5.

Table 5. pH Values of Chayote Syrup with Ginger Extract Addition

Treatment	pH Value ± SD
A (0%)	4.33 ± 0.11[a]
B (10%)	4.51 ± 0.25[ab]
C (20%)	4.68 ± 0.20[abc]
D (30%)	4.79 ± 0.21[bc]
E (40%)	4.98 ± 0.23[c]

CV = 0.87%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the results of analysis of variance (ANOVA), it shows that the treatment of ginger extract addition significantly affects ($p<0.05$) the pH value of syrup. The average pH values ranged from 4.33–4.98. The highest average was obtained in treatment E (ginger extract 40%) with a value of 4.98. The lowest average was obtained in treatment A (ginger extract 0%) with a value of 4.33.

The pH value of the resulting syrup increased with the increasing amount of ginger extract added. The addition of ginger extract has been shown to significantly affect the pH value of coconut sap syrup, where higher concentrations result in a slight pH increase due to reduced acidity [9]. This finding is further supported by studies indicating that ginger extract suppresses acid production during *Streptococcus* metabolism, thereby contributing to a rise in pH [35]. Moreover, evidence from oral care formulations demonstrates that toothpaste containing giant ginger extract can elevate salivary pH, reinforcing the alkalizing potential of ginger [36].

3.3.2 Total Acid

The results of total acid analysis of chayote syrup with ginger extract addition can be seen in Table 6.

Table 6. Total Acid Values of Chayote Syrup with Ginger Extract Addition

Treatment	Total Acid (%) ± SD
E (40%)	0.0871 ± 0.0001[d]
D (30%)	0.0874 ± 0.0001[d]
C (20%)	0.1163 ± 0.0050[bc]
B (10%)	0.1454 ± 0.0052[ab]
A (0%)	0.1746 ± 0.0006[a]

CV = 5.19%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the results of analysis of variance (ANOVA), it shows that the treatment of ginger extract addition significantly affects ($p<0.05$) the total acid of syrup. The total acid values ranged from 0.0871–0.1746%. The highest average value was obtained in treatment A (ginger extract 0%) with 0.1746%. The lowest average value was obtained in treatment E (ginger extract 40%) with 0.0871%.

The total acid content of chayote syrup was observed to decrease with increasing concentrations of ginger extract. This reduction may be attributed to the presence of phenolic homolog compounds in ginger, which are classified as weak acids. During thermal processing, gingerol—known for its instability under heat—is converted into shogaol, potentially altering the acid profile of the extract [37]. Additionally, the inherent acidity of chayote juice may also play a role in this trend. It has been reported that higher levels of total phenols and antioxidant activity are associated with a reduction in the total acid content of food products [38].

3.3.3 Total Soluble Solids

The results of total soluble solids analysis of chayote syrup with the addition of ginger extract can be seen in Table 7.

Table 7. Total Soluble Solids of Chayote Syrup with Ginger Extract Addition

Treatment	Total Soluble Solids (°Brix) ± SD
A (0%)	70.00 ± 1.00
B (10%)	70.17 ± 0.76
C (20%)	70.33 ± 1.44
D (30%)	70.50 ± 1.00
E (40%)	71.00 ± 1.00

CV = 0.27%

Based on the analysis of variance (ANOVA), it shows that the treatment of ginger extract addition has no significant effect ($p>0.05$) on the total soluble solids of syrup. The total soluble solids values ranged from 70.00–71.00°Brix. The highest average value was obtained in treatment E (ginger extract 40%) with 71.00°Brix. The lowest average value was obtained in treatment A (ginger extract 0%) with 70.00°Brix.

The total soluble solids of the syrup increased with the increasing addition of ginger extract. This is due to the sugar content in the ginger extract added. This is influenced by the starch content in ginger, which can dissolve in water. The total soluble solids in the syrup increase with higher concentrations of ginger extract, likely due to the contribution of carbohydrates and other soluble constituents such as vitamins and organic acids [39]. Moreover, thermal processing techniques such as heating or drying enhance the dissolution of these compounds, further contributing to the rise in total soluble solids [40].

3.3.4 Total Sugar

The total sugar analysis results of chayote syrup can be seen in Table 8.

Table 8. Total Sugar Content of Chayote Syrup with Ginger Extract Addition

Treatment	Total Sugar Content (%) ± SD
A (0%)	70.03 ± 0.75^{a}
B (10%)	71.23 ± 0.40^{b}
C (20%)	72.15 ± 0.67^{c}
D (30%)	73.73 ± 0.52^{d}
E (40%)	74.80 ± 0.77^{e}

CV = 0.18%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the analysis of variance (ANOVA), it shows that the treatment of ginger extract addition significantly affects ($p<0.05$) the total sugar of syrup. The total sugar content of chayote syrup with ginger extract addition ranged from 70.03–74.80%. The highest average was obtained in treatment E (ginger extract 40%) at 74.80%, and the lowest in treatment A (ginger extract 0%) at 70.03%.

To further illustrate the compositional changes in chayote syrup due to ginger extract enrichment, the following graph presents the trend in total sugar content as a function of ginger extract concentration.

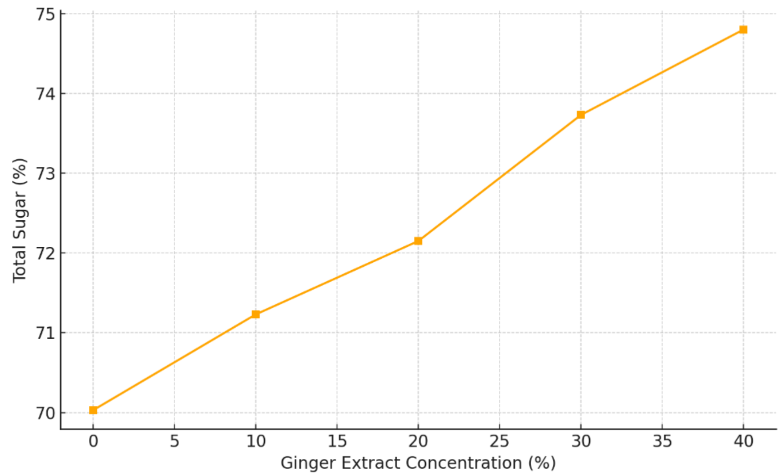

Figure 3. *Effect of ginger extract concentration on total sugar content (%).*

As shown in Figure X, the total sugar content of chayote syrup increases gradually with the addition of ginger extract, rising from 70.03% at 0% to 74.80% at 40%. This trend is likely due to two factors: first, the intrinsic soluble carbohydrates contributed by the ginger extract, and second, concentration effects during thermal processing which promote water evaporation and sugar enrichment.

While the increase is relatively moderate, it contributes to the overall sweetness and viscosity of the syrup, which are critical to sensory acceptability. From a functional formulation standpoint, the rise in sugar content must be balanced with health considerations, particularly in the development of beverages aimed at wellness-conscious consumers. These findings are consistent with prior observations in botanical syrup enrichment studies [9,41].

The analysis results of total sugar showed that the more ginger extract was added, the higher the total sugar content in the syrup. This is because ginger contains carbohydrates and sugar. Red ginger powder has been reported to contain considerable amounts of glucose, which contributes to its sweetening capacity in syrup formulations [42]. The observed increase in total sugar content serves as an indicator of the syrup's perceived sweetness. This sweet profile is primarily attributed to the presence of glucose, fructose, and sucrose—key components of both reducing and non-reducing sugars [43]. In accordance with SNI 01-3544-2013, which requires a minimum total sugar content of 65% in syrup products, the chayote syrup developed in this study—with total sugar values ranging from 70.03% to 74.80%—successfully meets the national standard [8].

3.3.5 Total Phenol

The total phenol analysis results of chayote syrup with ginger extract addition can be seen in Table 9.

Table 9. Total Phenol Content of Chayote Syrup with Ginger Extract Addition

Treatment	Total Phenol (mg GAE/g) ± SD
A (0%)	26.81 ± 2.39[a]
B (10%)	32.90 ± 1.96[b]
C (20%)	35.94 ± 1.76[c]
D (30%)	39.42 ± 2.06[d]
E (40%)	45.65 ± 2.61[e]

CV = 1.27%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the results of analysis of variance (ANOVA), it shows that the treatment of ginger extract addition significantly affects ($p<0.05$) the total phenol content. The total phenol content of chayote syrup with ginger extract addition ranged from 26.81–45.65 mg GAE/g. The highest value was obtained in treatment E (ginger extract 40%) at 45.65 mg GAE/g, and the lowest was in treatment A (ginger extract 0%) at 26.81 mg GAE/g. To visually clarify the effect of increasing ginger extract concentration on key functional components of chayote syrup, the following graphs illustrate the trends in total phenol and total sugar content across treatments.

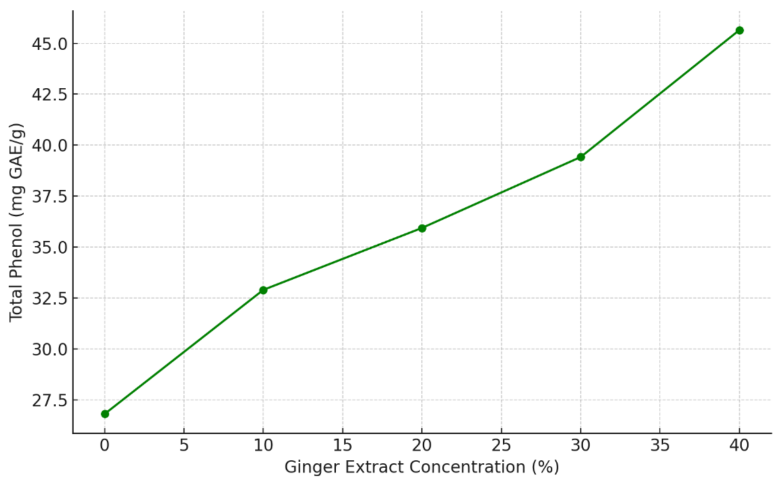

Figure 4. Effect of ginger extract concentration on total phenol content (mg GAE/g).

As shown in Figure X, there is a clear upward trend in total phenol content with increasing ginger extract concentration. This increase—from 26.81 mg GAE/g at 0% to 45.65 mg GAE/g at 40%—is attributable to the high polyphenolic content of ginger. The bioactive compounds such as gingerol, shogaol, and zingerone are known to contribute to antioxidant activity, reinforcing the formulation's potential as a functional beverage. His trend aligns with similar findings by [9] and [42], who observed enhanced phenolic profiles in plant-enriched syrups.

The total phenol content produced in chayote syrup increased with the increasing addition of ginger extract. The increase in total phenol is caused by the phenolic compounds contained in ginger. These phenolic compounds include gingerol and shogaol. Phenolic compounds in ginger act as antioxidants and play a role in capturing free radicals. The increase in phenol content is attributed to the disruption of cell walls during thermal processing, which facilitates the release of phenolic compounds such as gingerol and shogaol [44].

3.3.6 Antioxidant Activity

The results of antioxidant activity analysis of chayote syrup with ginger extract addition can be seen in Table 10.

Table 10. Antioxidant Activity of Chayote Syrup with Ginger Extract Addition

Treatment	Antioxidant Activity (%) ± SD
A (0%)	35.75 ± 0.84[a]
B (10%)	38.79 ± 0.70[b]
C (20%)	40.81 ± 0.97[c]
D (30%)	43.54 ± 0.86[d]
E (40%)	46.03 ± 0.93[e]

CV = 0.43%

Note: Numbers in the same column followed by different lowercase letters indicate significant differences at the 5% level of Duncan's New Multiple Range Test (DNMRT).

Based on the results of analysis of variance (ANOVA), it shows that the treatment of ginger extract addition had a significant effect ($p<0.05$) on the antioxidant activity of the syrup. The antioxidant activity values ranged from 35.75% to 46.03%. The highest average value was obtained in treatment E (40% ginger extract) with 46.03%, while the lowest average value was obtained in treatment A (0% ginger extract) with 35.75%. To highlight the functional impact of ginger extract on antioxidant potential, the following graph illustrates the relationship between ginger extract concentration and antioxidant activity in chayote syrup formulations.

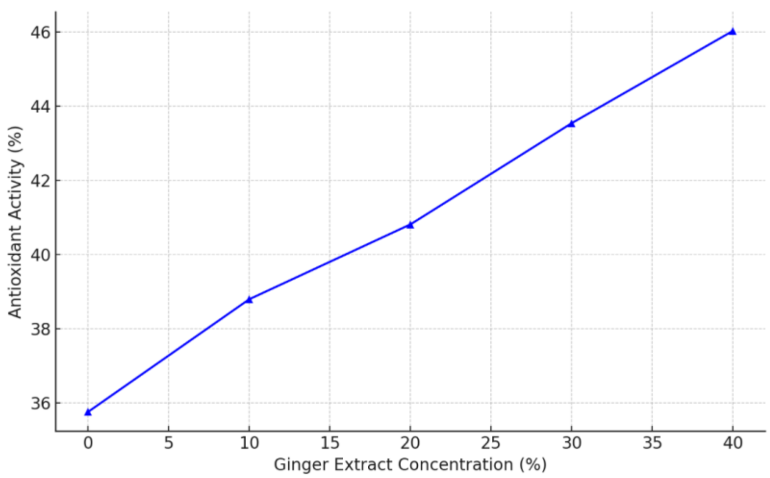

Figure 5. Effect of ginger extract concentration on antioxidant activity (% DPPH inhibition).

As shown in Figure X, the antioxidant activity of the syrup exhibits a consistent upward trend as the concentration of ginger extract increases. The activity rises from 35.75% at 0% to 46.03% at 40% ginger concentration. This enhancement is attributed to the presence of bioactive compounds in ginger—particularly gingerol, shogaol, and zingerone—which are well-documented for their radical-scavenging properties.

The increase in antioxidant activity with higher ginger levels reinforces the role of ginger not only as a flavoring agent but also as a functional enhancer. The observed increase in antioxidant activity with higher ginger concentrations highlights ginger's dual function as both a flavoring agent and a functional enhancer. This trend is consistent with previous findings that reported enhanced antioxidant capacity in beverages fortified with plant-derived polyphenols [44, 45].

This result supports the potential of this formulation as a functional drink, particularly appealing to health-conscious consumers looking for naturally sourced antioxidants. From the analysis results, it can be seen that the antioxidant activity of chayote syrup increased with the addition of ginger extract. This increase in antioxidant activity is due to the higher antioxidant activity in ginger extract (67.52%) compared to chayote juice (43.38%) at a concentration of 1,000 ppm. Phenolic compounds are known to act as antioxidants due to their ability to donate hydrogen atoms, which makes them effective in scavenging free radicals and inhibiting lipid oxidation [46]. The phenolic compounds found in ginger include gingerol and shogaol, which are concentrated in the ginger oleoresin that significantly contribute to antioxidant activity. Non-volatile active compounds, such as gingerol and shogaol in ginger, have strong antioxidant properties and also contain vitamin E [47]. The antioxidant activity of chayote juice may also originate from the phenolic compounds in chayote, which contribute to antioxidant properties [44].

3.4 Microbiological Analysis

3.4.1 Total Plate Count

The results of total plate count analysis of chayote syrup with the addition of ginger extract can be seen in Table 11.

Table 11. Total Plate Count Analysis Results of Chayote Syrup with Ginger Extract Addition

Treatment	Total Plate Count (CFU/g)
A (0%)	3.4×10^2
B (10%)	3.2×10^2
C (20%)	2.9×10^2
D (30%)	2.8×10^2
E (40%)	2.7×10^2

Based on the results of microbiological analysis, it can be seen that the total microbes present in chayote syrup with ginger extract addition ranged from 2.7×10^2 to 3.4×10^2 CFU/g. The highest average value was found in treatment A (0% ginger extract) with a total plate count of 3.4×10^2 CFU/g. The lowest average value was found in treatment E (40% ginger extract) with a total plate count of 2.7×10^2 CFU/g. The total plate count value obtained in chayote syrup with ginger extract addition has met the standard requirements of SNI (2013), which is a maximum of 5×10^2 CFU/g [8].

From the total plate count analysis results, it was found that the more ginger extract was added, the lower the total plate count value of the resulting syrup. This is due to the content of secondary metabolites in ginger, including essential oils, flavonoids, oleoresin, alkaloids, tannins, and phenolic compounds such as 6-gingerol and 6-shogaol, which exhibit strong antibacterial activity and can disrupt microbial membranes [48-50]. Phenolic compounds also possess antioxidant and antimicrobial properties. Their lipophilic nature facilitates penetration and damage to microbial membranes, leading to cell lysis and growth inhibition [51]. Additionally, the high sugar content in syrup also plays a role in microbial inhibition by reducing water activity, making it difficult for bacteria to grow [52].

3.5 Organoleptic Test

3.5.1 Color

The organoleptic test results of the color of chayote syrup with ginger extract addition can be seen in Table 12.

Table 12. Organoleptic Test Results of Chayote Syrup Color with Ginger Extract Addition

Treatment	**Color Score ± SD**
E (40%)	3.60 ± 0.96
C (20%)	3.72 ± 0.68
B (10%)	3.80 ± 0.76
D (30%)	3.90 ± 0.76
A (0%)	3.88 ± 0.93

CV = 4.39%

Note: Score 1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, 5 = strongly like

Based on the results of analysis of variance, it can be seen that the addition of ginger extract in making chayote syrup had no significant effect (p>0.05) on the organoleptic value of the resulting color. The organoleptic color scores of chayote syrup with ginger extract addition ranged from 3.60–3.90. The highest average score was obtained from treatment D (ginger extract 30%) with a value of 3.90 (like). The lowest average score was obtained from treatment E (ginger extract 40%) with a value of 3.60 (like). Treatment A (0% ginger extract) had a color score of 3.88 ± 0.93. From the panelists' assessment, it can be seen that treatment E (ginger extract 40%) when diluted was pale yellow and cloudy.

Chayote syrup with ginger extract addition produced a pale yellow to yellowish-brown color. The pale yellow to brownish-yellow color in the syrup was caused by the oleoresin content in ginger, which has a bright yellow to dark brown tone [9]. In addition, the color change was due to a caramelization reaction which enhances visual appeal [53].

3.5.2 Aroma

The results of the organoleptic test for the aroma of chayote syrup with the addition of ginger extract can be seen in Table 13.

Table 13. Organoleptic Aroma Values of Chayote Syrup with Ginger Extract Addition

Treatment	Aroma Score ± SD
B (10%)	3.12 ± 0.83[a]
A (0%)	3.20 ± 1.00[a]
C (20%)	3.44 ± 0.77[b]
D (30%)	3.60 ± 0.71[b]
E (40%)	3.80 ± 0.96[c]

CV = 5.01%

Note: Score 1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, 5 = strongly like.

Based on the results of analysis of variance, it can be seen that the addition of ginger extract in the making of chayote syrup significantly affected (p<0.05) the organoleptic value of the resulting aroma. The average organoleptic aroma value of chayote syrup with ginger extract addition ranged from 3.12–3.80. The highest average value was obtained in treatment E (40% ginger extract addition) with a value of 3.80 (like). The lowest average value was obtained in treatment B (10% ginger extract addition) with a value of 3.12 (neutral).

The resulting chayote syrup has little aroma. However, the addition of ginger extract affects the aroma of chayote syrup, resulting in a stronger aroma. This is due to the aromatic content in ginger which comes from essential oils derived from ginger rhizome. Ginger is known for its aromatic compounds such as zingiberene and zingerone, which significantly enhance the aroma in food and beverage applications [54]. Further, sensory studies confirmed that ginger extract increased aroma perception and was preferred by panelists at higher concentrations [12].

3.5.3 Taste

The results of the organoleptic test for the taste of chayote syrup with the addition of ginger extract can be seen in Table 14.

Table 14. Organoleptic Taste Values of Chayote Syrup with Ginger Extract Addition

Treatment	Taste Score ± SD
B (10%)	3.04 ± 1.10[a]
A (0%)	3.24 ± 1.12[ab]
C (20%)	3.56 ± 0.82[bc]
E (40%)	3.84 ± 1.11[c]
D (30%)	3.96 ± 0.98[c]

CV = 5.89%

Note: Score 1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, 5 = strongly like. Different letters indicate significant differences at 5% Duncan's New Multiple Range Test (DNMRT).

Based on the results of analysis of variance, it can be seen that the addition of ginger extract in the making of chayote syrup significantly affected ($p<0.05$) the organoleptic value of taste. The average organoleptic taste value ranged from 3.04–3.96. The highest average value was obtained in treatment D (30% ginger extract addition) with a value of 3.96 (like). The lowest average value was obtained in treatment B (10% ginger extract addition) with a value of 3.04 (neutral).

Chayote syrup with ginger extract has a spicy taste and contains a characteristic ginger taste. The sweet taste comes from sucrose (table sugar) added during the making of syrup. The spicy taste comes from the ginger extract. This spicy taste is caused by phenolic compounds such as gingerol and shogaol contained in ginger oleoresin. Ginger oleoresin contains flavoring compounds that give a pungent taste (zingerone) and aroma such as gingerol and shogaol [55]. Panelist evaluations indicated that the highest preference was given to treatment D, which contained 30% ginger extract. This formulation was favored due to its balanced sweet and spicy flavor profile, which enhanced overall acceptability. Similar findings have been reported, where increasing the concentration of ginger extract was shown to improve taste preference in functional beverages [12].

3.5.4 Recapitulation of Organoleptic Values

The results of the recapitulation of organoleptic values of chayote syrup with the addition of ginger extract can be seen in Figure 2.

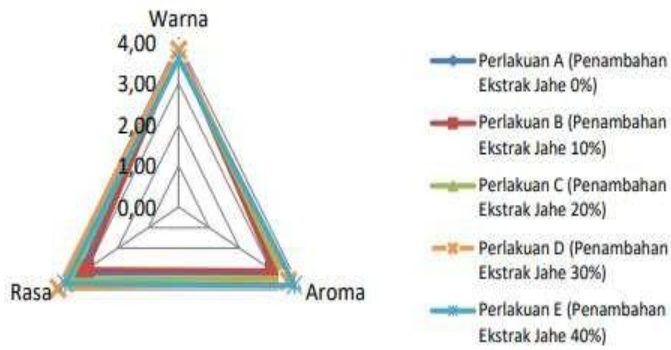

Figure 6. Recapitulation of organoleptic values of chayote syrup

Based on the recapitulation chart of the organoleptic values, it can be concluded that the best treatment is treatment D (30% ginger extract addition) with an average organoleptic test value of color 3.80 (like), aroma 3.60 (like), and taste 3.96 (like).

3.6 Potential for Commercialization and Industrial Application

The findings of this study indicate that chayote syrup enriched with ginger extract offers significant potential for commercialization within the functional food and beverage sector. The formulation not only meets national syrup quality standards (SNI 01-3544-2013) with respect to sugar content, microbial load, and organoleptic acceptability, but also demonstrates enhanced antioxidant activity and phenolic content with increasing ginger concentration [8]. These attributes align with current functional beverage development trends, where the incorporation of ginger extract is proven to increase antioxidant activity, phenolic compounds, and consumer preference in health drinks [56,57].

From an industrial perspective, the high viscosity and microbial stability of the syrup—achieved without synthetic preservatives—enhance product shelf life and safety, which are essential for scaling up production and distribution in retail or ready-to-drink formats. The antioxidant-rich composition and microbial stability reflect characteristics found in successful formulations of ginger-based drinks, which have demonstrated shelf stability and bioactivity even without synthetic additives [42,58]. The use of locally sourced raw materials, such as chayote and ginger, further supports the sustainability and economic viability of this innovation, particularly in regions with abundant agricultural output.

In addition, the product offers differentiation in the functional drink market, which is increasingly competitive and consumer-driven. The combination of indigenous ingredients and measurable health benefits could attract niche markets both domestically and for export, aligning with global trends in natural health beverages and clean-label food products**.** This differentiation is supported by findings that ginger extract beverages exhibit high antioxidant activity and consumer sensory preference, particularly in formulations with 20–35% ginger concentrations [45].

This innovation also opens opportunities for small- to medium-scale food industries and cooperatives to develop value-added agricultural products, contributing to rural entrepreneurship and local food sovereignty. Moreover, the formulation could be further adapted for industrial applications such as syrup concentrates, culinary sauces, or nutraceutical preparations, with appropriate modifications to viscosity, acidity, and flavor balance based on market requirements.

4 Conclusion

The study demonstrated that the addition of ginger extract significantly influenced the quality characteristics of chayote syrup, particularly in terms of viscosity, pH, total acid, total sugar, total phenol, antioxidant activity, and organoleptic attributes such as aroma and taste. Among the tested formulations, the syrup with 30% ginger extract addition (treatment D) yielded the best overall results, showing a viscosity of 1488.00 cP, pH of 4.79, total sugar content of 73.73%, phenolic content of 39.42

mg GAE/g, and antioxidant activity of 43.54%, with acceptable microbial safety (2.8×10^2 CFU/g) and high panelist preference.

These findings suggest that a 30% ginger extract formulation offers an optimal balance between sensory acceptability and functional benefits, supporting the potential of chayote-ginger syrup as a locally sourced, plant-based functional beverage. The integration of ginger extract enhances both the nutritional profile and consumer appeal, positioning this product as a viable candidate for further development in the health-focused beverage industry. Based on the research that has been conducted, the author suggests that future researchers conduct studies on the analysis of volatile and non-volatile compounds in syrup using GC-MS, and determine shelf life as well as the effect of storage on organoleptic values and the nutritional content of syrup.

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