

PRESERVING PINEAPPLE JUICE NATURALLY: IMPACTS ON SHELF LIFE AND NUTRIENTS OF SELECTED GHANAIAN PINEAPPLE (*ANNAS COMOSUS*) JUICES

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Abstract: Pineapple (*Ananas comosus*) is a widely consumed tropical fruit, but its high perishability limits its shelf life. This study assessed the juice yield and the effects of natural preservatives (rosemary and clove) on the quality of three pineapple varieties (Smooth Cayenne, Sugarloaf, and MD2). A 3 × 3 Factorial Completely Randomized Design was used, with variety and preservative as factors, each at three levels. Smooth Cayenne had the highest juice yield (700 mL). Sugarloaf juice preserved with rosemary had the highest crude fiber, fat, carbohydrate, protein, and ash, while the unpreserved Sugarloaf variety had the highest crude moisture content. On day ten, the highest pH (5.43) was recorded in juice from the MD2 variety with no preservative, while the lowest pH (5.15) was observed in MD2 juice preserved with rosemary. The highest Total Soluble Solids (TSS) value (14.01 °Brix) was found in MD2 juice treated with clove, while the lowest TSS (0.91 °Brix) was observed in Sugarloaf and Smooth Cayenne juices preserved with rosemary. The Smooth Cayenne variety with rosemary exhibited the highest Total Titratable Acidity (TTA) on day one (0.00078), and still had the highest on day ten (0.00077) without preservatives, while the lowest TTA values (0.00043 and 0.00042) were recorded in Sugarloaf juice preserved with clove on days one and ten respectively. Vitamin C content was highest in Smooth Cayenne juice with no preservative (25.24 mg/100 mL on day one and 21.72 mg/100 mL on day ten), while the lowest vitamin C levels were found in MD2 juice 5.28 mg/100 mL both with no preservative (day one) and with rosemary-clove mix (day ten). Mineral analysis revealed no statistically significant differences in copper, potassium, phosphorus, and zinc content for both juices tested as day one samples, however a statistical difference was observed on day ten among all four minerals due to the effects of preservatives. Specifically, the highest concentration of copper (5.48 mg/L), was found in MD2 samples preserved with clove, whereas the lowest (3.20 mg/L) was identified as MD2 samples preserved with no preservative. In addition, iron concentrations were highest at 31.28 mg/L in Sugarloaf samples preserved with rosemary, while the lowest (9.49 mg/L) was determined in MD2 samples preserved with no preservative. Manganese concentrations were greatest (14.83 mg/100 mL) in MD2 samples preserved with no preservative. The highest levels of potassium were observed in Smooth Cayenne samples preserved with clove. Phosphorus was found to be at its highest level in MD2 samples preserved with clove. Finally, zinc was also found to be highest in MD2 samples preserved with clove and lowest in Sugarloaf samples preserved with clove. Sensory evaluation of the samples demonstrated that neither rosemary nor clove resulted in an unacceptable deterioration of the sensory attributes of the juice or nutritional degradation. Therefore this study demonstrates the feasibility of using natural preservatives to extend the shelf-life of pineapple juice while maintaining its quality.

Keywords: Extract Carbohydrate, Sugar Loaf, Smooth Cayenne, MD2, Pineapple.

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Introduction

The pineapple (*Ananas comosus*), as a global tropical fruit is commercially important worldwide because of its many health promoting properties, and in Ghana, for its commercial importance. In Ghana there are four major varieties of pineapple that are grown, namely: Sugarloaf, Smooth Cayenne, MD2 and Queen Victoria, which have different physical and chemical attributes which affect

how well they can be processed (Pandhare et al., 2018). The growth in demand for pineapple juice is indicative of a growing trend of fruit juice consumption in Ghana and other areas of the globe; demand for pineapple juice grew from \$17 million in 2014 to \$84.56 million in 2024 (NEPAD; Kleemann, 2016). However, although pineapple juice has a significant potential market, the highly perishable nature of pineapple juice makes production difficult after the fruit has been

harvested. High water content (81.2-86.2%), and sugar (13-19%) levels make pineapple juice susceptible to microbial spoilage, and nutrient degradation. Because traditional preservation methods often include synthetic preservatives which cause health concerns, consumers look for natural alternatives to preserve their food.

Rosemary (*Salvia rosmarinus*) and Clove (*Syzygium aromaticum*) have been reported to have potential natural preservative qualities through antimicrobial, and antioxidant activity (Veenstra & Johnson, 2021; Ashwini et al., 2023). Little research has been done to find out whether or not those preservatives work on different types of pineapples that are produced in Ghana. Furthermore, there is a lack of knowledge regarding the preservation of pineapple juice with the use of rosemary and clove, in particular, as it pertains to juice yield, nutrient retention and the mineral stability of pineapple juice over time. As such, this study will investigate the effects of rosemary and clove on the juice yield and quality characteristics of the three most commonly grown pineapple varieties in Ghana; Smooth Cayenne, Sugarloaf, and MD2. In addition, the study will evaluate: (i) the juice yield potential of the three varieties of pineapple; (ii) the effects of rosemary and clove extracts on the proximate composition of pineapple juice (moisture, protein, fat, fibre, ash, and nitrogen-free extract); (iii) the effects of rosemary and clove on the chemical properties of pineapple juice (pH, total soluble solids (TSS), total titratable acidity (TTA), and vitamin C); and (iv) the effects of rosemary and clove on the mineral content of pineapple juice (potassium, phosphorus, iron, zinc, copper, and manganese) during storage.

Through understanding the responses of the three varieties of pineapple to natural preservatives, this research will assist in developing strategies for the value addition of pineapple, and also provide guidance for the development of healthy and stable pineapple juice products for both domestic and foreign markets.

Materials and Methods

Location of the Study

This research was conducted in the Department of Horticulture laboratory of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi.

List of Materials Used

The materials used in the study included: Three varieties of pineapple (Smooth Cayenne, Sugarloaf, and MD2) - fifty (50) of full ripe (¾-Full Ripe) of each variety, totaling one hundred and fifty (150) pineapple fruits. Also, clove oil, Rosemary Oil, stainless knife, minMAX juicer, dispenser, refractometer, thermometer, holding bottles, plastic containers, gas burner, Camry weighing scale, ice chest, pH meter, distilled water, beakers, measuring cylinder, conical flask, spatula, pipette, burette, chopping board, and indicators and refrigerator.

Source and Selection of Sample

Full ripe, uniform size and maturity pineapple fruits were sourced from ACOPPS and AMOPPA Cooperative Organic Producers and Exporters Society Limited, a local farm located in the Central Region of Ghana. A total of thirty (30) pineapples were sourced for use in this study, ten (10) of each variety. Two natural preservatives, that is, Clove Oil (manufactured by Hemani International KEPZ, Karachi-Pakistan; manufactured under license from Hemani Herbal LLC, Longwood, FL32750, USA; Batch Number: 30CL20/21; Manufactured: August 2020; Expiration date: July 2024) and Rosemary Oil (manufactured by Hemani International KEPZ, Karachi-Pakistan; manufactured under license from Hemani Herbal LLC, Longwood, FL32750, USA; Batch Number: 30RM20/21; Manufactured: July 2020; Expiration date: June 2024) were purchased from a local essential oils and powder shop at Ahodwo-Kumasi in the Ashanti Region of Ghana. Collection of plant material used in this study was done according to the relevant local and national guidelines and regulations.



Plate 1: Clove Oil



Plate 2: Rosemary Oil

Experimental Design

The experimental design used in this study is a completely randomized factorial design as it had three factors (varieties of pineapples; preservatives) at three levels each. Replication of the Experimental Design. The experimental design used in this study was conducted three times to provide an overall mean for the three varieties of pineapples.

Variety of Pineapple and Preservatives

There were three types of varieties of pineapples used namely Smooth Cayenne, Sugarloaf, and MD2. As well as three types of preservatives used in this study which are Clove Oil, Rosemary Oil and No Preservative or Control.

Processing of Pineapple Juice/Pineapple Fruits Preparation

The fruits were peeled by removing the crown, skin and base using a sharp stainless-steel knife. The peeled fruits were cut into smaller pieces weighing about 200g each (using Camry scales). The fruit pieces were then juiced using a MinMAX Juicer (MNJ-1299, England).

Treatment of Juice with Preservatives

A total of three replications of 1 Litre each of the juice obtained from the pineapple fruits were treated with 0.1mL of either of the preservatives (Clove Oil, Rosemary Oil and Control) and mixed. Each of the treatment was bottled and then pasteurized at 62°C for 20 minutes to form the experimental sample. The experimental samples were then stored in refrigerator at 7°C for 10 days.

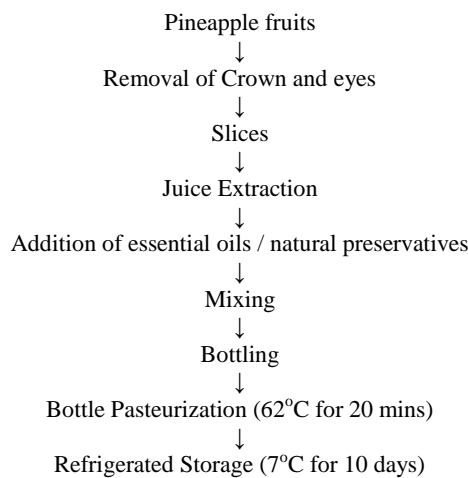


Fig. 1: Flow sheet for the preparation of the pineapple juice



Plate 3: Sliced Pineapple Fruit Weighed before Juicing



Plate 4: Juice Yield Obtained from Smooth Cayenne



Plate 5: Juice Yield Obtained from Sugarloaf



Plate 6: Juice Yield Obtained from MD2



Plate 7: Samples of Pineapple Fruit Juice

Proximate Analysis

Crude Fat

Crude fat was determined by the Soxhlet extraction method using Petroleum Ether b.p. 40-60°C as the solvent. (Appendix A)

Crude Fibre

The crude fibre was found by using 1.25% Sulphuric Acid Solution and 1.25% Sodium Hydroxide Solution for fibre determination. (Appendix B)

Ash Content

Two grams of each sample were placed into pre-tared porcelain crucibles and placed in a Muffle Furnace at 550°C for 4 hours. After they had cooled in a Desiccator, their residues were weighed and expressed as Ash Content as a % of the Original Sample.

Ash Content

Two grams of each sample were placed into pre-tared porcelain crucibles and placed in a Muffle Furnace at 550°C for 4 hours. After they had cooled in a Desiccator, their residues were weighed and expressed as Ash Content as a % of the Original Sample.

Moisture Content

Moisture content was determined by drying a 5 gram sample at 105°C until a constant weight was achieved. (Appendix C)

Protein Content

Crude Protein was determined using the Kjeldahl method. (Appendix D)

Nitrogen-Free Extract (NFE)

Carbohydrate (Nitrogen-Free Extract, NFE) by difference method (Appendix E).

Chemical Analysis

Total Soluble Solids (TSS)

AOAC (2012) Method (Appendix F)

Total Titratable Acidity (TTA)

A 10 ml sample was added to distilled water and phenolphthalein indicator. The sample was then titrated with 0.1 N NaOH until a persistent pink end point was observed. (Appendix G)

pH Determination

pH was measured using a digital pH meter which had been calibrated with buffer solutions. (Appendix H)

Vitamin C (Ascorbic Acid)

Vitamin C content was determined by redox titration. (Appendix I)

Mineral Analysis

The Mineral Composition was analyzed using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) (Varian 720-ES). Samples were analyzed in triplicate according to Okem et al. (2014).

Data Collection and Statistical Analysis

Questionnaire for Data Collection

Twenty pineapple juice producing companies located in four selected regions of Ghana completed a structured questionnaire to provide information on the following; company details, fruit procurement, processing, preservatives used, packaging, sales, and storage. Interviews and personal observations were conducted to obtain additional data including; pineapple varieties used, juice yield obtained, and preservatives applied during production.

Statistical Analysis Collected data were analyzed using the Analysis of Variance (ANOVA) procedure available in STATISTIX version 10.0. Tukey’s Honest Significant Difference (HSD) Test was employed to compare means of treatments that differed significantly based on ANOVA results. Significance was accepted when $P \leq 0.01$

Effect of Preservatives on Chemical Properties of Juice Prepared From Three Varieties of Pineapple on Days One and Ten

Table 1: Effect of Preservatives on pH of Pineapple Juice (Day 1 and Day 10) n-150

Preservatives	Varieties	Day 1	Day 10
Rosemary	MD2	5.48 ^a	5.15 ^c
	Sugarloaf	5.70 ^a	5.35 ^{ab}
	Smooth Cayenne	5.57 ^a	5.32 ^{ab}
Cloves	MD2	5.51 ^a	5.30 ^b
	Sugarloaf	5.72 ^a	5.34 ^{ab}
	Smooth Cayenne	5.62 ^a	5.32 ^{ab}
Control	MD2	5.48 ^a	5.43 ^a
	Sugarloaf	5.68 ^a	5.29 ^b
	Smooth Cayenne	5.42 ^a	5.23 ^{bc}
Mean pH	MD2	5.49 ^a	5.29 ^a
	Sugarloaf	5.70 ^a	5.33 ^a
	Smooth Cayenne	5.54 ^a	5.29 ^a

*two means of the same column with a line with a different letter significantly differ (p = 0.01). **HSD (0.01):**Day 1: Varieties = 0.149, Preservatives = 0.149, Interaction = 0.335. Day 10: Varieties = 0.052, Preservatives = 0.052, Interaction = 0.116

Consequences of pineapple Juice on pH (Day 1 and Day 10)

On Day 1, no significant differences were observed among the preservatives, varieties, or their interaction (p > 0.01), as indicated in Table 1 above indicating all treatments maintained similar pH levels (~5.4 to 5.7). By Day 10, however, a significant interaction effect between preservative type and pineapple variety was observed (p < 0.01). Notably: The MD2 juice with rosemary had

the lowest pH (5.15c), suggesting greater acidification over storage. Conversely, the MD2 control (no preservative) retained the highest pH (5.43a), indicating less change over time. Among varieties, Smooth Cayenne and Sugarloaf maintained more stable pH across treatments compared to MD2. While initial pH levels were consistent, preservative–variety combinations influenced pH stability over storage, with rosemary in MD2 contributing to greater acid development.

Table 2: Consequence of Preservatives on Total Soluble Solids (TSS) (Day 1 and Day 10), n=158

Preservatives	MD2 (Day 1)	Sugarloaf (Day 1)	Smooth Cayenne (Day 1)	MD2 (Day 10)	Sugarloaf (Day 10)	Smooth Cayenne (Day 10)
Rosemary	12.46 ^b	9.01 ^d	9.01 ^d	12.46 ^a	8.13 ^e	11.56 ^c
Cloves	14.01 ^a	10.14 ^c	10.14 ^c	11.13 ^d	9.50 ^f	11.03 ^d
Control	13.34 ^{ab}	12.31 ^b	10.36 ^e	12.23 ^b	9.70 ^e	11.43 ^c
Day	MD2	Sugarloaf		Smooth Cayenne		
Day 1	13.26 ^a	10.45 ^b		9.81 ^c		
Day 10	11.94 ^a	9.11 ^c		11.34 ^b		

*Any two means in the same column followed by different letters differ significantly (p=0.01) Any two means in the same column followed by different letters differ significantly (p=0.01) **HSD (0.01): Day 1:** Varieties = 0.530, Preservatives = 0.530, Interaction = 1.191. **Day 10:** Varieties = 0.079, Preservatives = 0.079, Interaction = 0.178

With reference to Table 2 above, Total Soluble Solids (TSS) content of pineapple juice showed significant interaction effects between variety and preservative treatment on both Day 1 and Day 10. On the first day, the highest TSS was observed in MD2 juice treated with Cloves (14.01). The lowest TSS was found in Sugarloaf and Smooth Cayenne treated with Rosemary (9.01). Overall, MD2 variety consistently recorded the highest TSS (13.26), followed by Sugarloaf and Smooth Cayenne. While on the 10 day MD2 treated with Rosemary retained the highest TSS (12.46), showing good stability over time. The lowest TSS (8.13) was found in Sugarloaf treated with Rosemary, indicating

significant degradation. While TSS decreased slightly across most samples from Day 1 to Day 10, Smooth Cayenne preserved with natural additives (Cloves and Rosemary) showed notable improvement in TSS over time. The effect of preservatives was variety-dependent, as the same preservative influenced TSS differently across varieties. The MD2 variety consistently performed best under all preservative treatments, suggesting its suitability for juice production with better TSS retention. Rosemary had varying effects it enhanced TSS in MD2 but significantly reduced it in Sugarloaf.

Table 3: Effect of Preservatives on Total Titratable Acidity (TTA) (Day 1 and Day 10), n=150

Preservatives	MD2 (Day 1)	Sugarloaf (Day 1)	Smooth Cayenne (Day 1)	Mean (Day 1)	MD2 (Day 10)	Sugarloaf (Day 10)	Smooth Cayenne (Day 10)	Mean (Day 10)
Rosemary	0.00055 ^f	0.00046 ^h	0.00078 ^a	0.00060 ^b	0.00060 ^{cd}	0.00046 ^e	0.00046 ^e	0.00051 ^c
Cloves	0.00065 ^d	0.00043 ⁱ	0.00075 ^b	0.00061 ^a	0.00059 ^d	0.00042 ^f	0.00074 ^b	0.00058 ^b
Control	0.00064 ^e	0.00049 ^g	0.00074 ^c	0.00062 ^a	0.00061 ^c	0.00047 ^e	0.00077 ^a	0.00062 ^a
Mean	0.00061 ^b	0.00046 ^c	0.00076 ^a		0.00060 ^b	0.00045 ^c	0.00065 ^a	

*Any two means in the same column followed by different letters differ significantly (p=0.01)

Significant interaction effects (p < 0.01) were observed between pineapple variety and preservative type on both Day 1 and Day 10, (see Table 3) indicating that the effect of each preservative on TTA depends on the variety of pineapple used. On Day 1, the highest TTA (0.00078) was observed in Smooth Cayenne preserved with rosemary, while the lowest (0.00043) occurred in Sugarloaf preserved with cloves. This suggests rosemary had a stronger acid-preserving effect in Smooth Cayenne than in other varieties. On Day 10, the highest TTA (0.00077) was again found in Smooth Cayenne without preservatives, while the lowest

(0.00042) was recorded in Sugarloaf preserved with cloves. This shows that Smooth Cayenne retains acidity better, especially without preservatives, while clove-treated Sugarloaf loses more acidity over time. Among preservatives, cloves and the control (no preservative) maintained higher TTA than rosemary across both days, especially in Smooth Cayenne. Variety-wise, Smooth Cayenne consistently exhibited the highest TTA values across treatments and days, indicating a naturally higher acid content or better acid retention.

Table 4: Effect of Preservatives on Vitamin C (Day 1 and Day 10), n=150

Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
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Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary (D ₁)	7.04 ^e	10.27 ^{cd}	19.08 ^b	12.13 ^b
Cloves (D ₁)	11.15 ^c	9.10 ^d	17.90 ^b	12.72 ^b
Control (D ₁)	5.28 ^e	10.56 ^{cd}	25.24 ^a	13.69 ^a
Rosemary (D ₁₀)	6.45 ^f	10.27 ^d	17.02 ^b	11.25 ^b
Cloves (D ₁₀)	7.33 ^{e^f}	9.10 ^{de}	17.31 ^b	11.25 ^b
Control (D ₁₀)	13.50 ^c	10.56 ^d	21.72 ^a	15.26 ^a

*Any two means in the same column followed by different letters differ significantly (p=0.01)

There was a significant interaction ($p < 0.01$) between preservatives and pineapple varieties on both Day 1 and Day 10, indicating that Vitamin C retention varied depending on both variety and preservative used. Smooth Cayenne consistently retained the highest Vitamin C content across all treatments and days, with the peak (25.24 mg/100ml) observed on Day 1 under the control (no preservative), followed by 21.72 mg/100ml on Day 10 under control. MD2 juice generally recorded the lowest Vitamin C levels, particularly when preserved with rosemary on both days. Preservative-wise, control samples (no preservative) outperformed others in Vitamin C retention across all varieties, suggesting possible degradation of Vitamin C due to the antioxidant activity of rosemary and cloves. Overall, Vitamin C declined slightly from

Day 1 to Day 10, but the decline was less pronounced in Smooth Cayenne and clove-preserved juices, implying better retention over time as indicated in Table 4.

Effect of Preservatives on Mineral Composition of Juice Prepared From Three Varieties of Pineapple on Day One and Ten

Effect of preservatives on copper of juice prepared from three varieties of pineapple on day one

Analysis of Variance (ANOVA) showed that there were no significant differences ($p > 0.01$) between the interaction of preservatives and variety for copper on day one as well as the individual effects (Table 5).

Table 5: Effect of preservatives on copper of juice prepared from three varieties of pineapple on day one, n=150

Varieties				
Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary	4.52 ^{a*}	5.38 ^a	5.01 ^a	5.01 ^a
Cloves	5.63 ^a	5.18 ^a	4.04 ^a	5.01 ^a
Control	3.03 ^a	4.30 ^a	3.34 ^a	3.56 ^b
Means	4.34 ^a	5.01 ^a	4.12 ^a	

HSD (0.01): Varieties=1.33, Preservatives=1.33, Interaction=3.00

*Any two means in the same column followed by different letters differ significantly (p=0.01)

Effect of preservatives on copper of juice prepared from three varieties of pineapple on day ten

Analysis of Variance (ANOVA) showed a significant difference ($p < 0.01$) between the interaction of preservatives and variety for copper content at day ten (Figure 1). The highest Copper content (5.48) was recorded by juice made from the MD2 variety and preserved with Cloves and the least (3.20) was juice made from the MD2 variety but with no preservative.

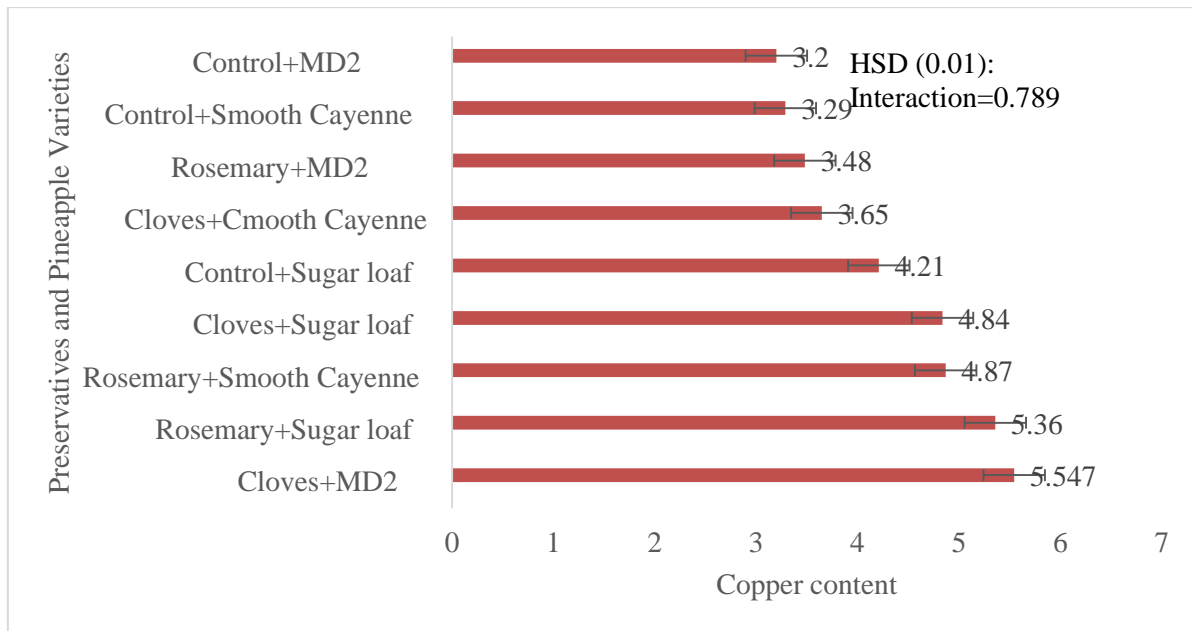


Figure 1: Effect of preservatives and varieties of pineapple on copper of juice prepared from three varieties of pineapple on day ten

Table 6: Effect of preservatives on Iron content of juice prepared from three varieties of pineapple on day one to 10, n=150

Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary (D₁)	14.50 ^{cd}	44.80 ^a	20.70 ^{bcd}	26.66 ^a
Cloves (D₁)	13.03 ^{cd}	31.00 ^{a^b}	22.03 ^{bcd}	22.02 ^{ab}
Control (D₁)	11.06 ^d	26.43 ^{bc}	17.01 ^{bcd}	18.15 ^b
Rosemary (D₁₀)	16.32 ^{bcd}	31.28 ^a	14.24 ^{cd}	20.61 ^a
Cloves (D₁₀)	13.57 ^d	29.91 ^a	17.71 ^{bc}	20.40 ^a
Control (D₁₀)	9.49 ^e	18.05 ^b	16.18 ^d	14.57 ^b

*Any two means in the same column followed by different letters differ significantly (p=0.01)

A significant interaction effect ($p < 0.01$) was observed between pineapple variety and preservative treatment on both Day 1 and Day 10, indicating that iron content varied based on the combination of these factors. Sugarloaf variety consistently showed the highest iron content, especially on Day 1 under rosemary treatment (44.80 mg/100ml) and on Day 10 with rosemary (31.28 mg/100ml) and cloves (29.91 mg/100ml). MD2 variety recorded the lowest iron values, particularly under control conditions on Day 10 (9.49 mg/100ml). Preservative-wise, rosemary and cloves significantly enhanced iron retention, particularly in Sugarloaf and Smooth Cayenne varieties. On Day

10, a slight decline in iron content was observed across all varieties and treatments compared to Day 1, indicating some mineral loss over time (Table 6).

Effect of preservatives on Potassium content of juice prepared from three varieties of pineapple at day one

Analysis of Variance (ANOVA) showed that there were no significant differences ($p > 0.01$) between the interaction of preservatives and variety for Potassium content on day one as well as the individual effects (Table 7).

Table 7: Effect of preservatives on Potassium of juice prepared from three varieties of pineapple on day one

Varieties				
Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary	1.61 ^{a*}	1.33 ^a	1.80 ^a	1.58 ^a
Cloves	1.37 ^a	1.27 ^a	1.59 ^a	1.41 ^a
Control	1.06 ^a	1.39 ^a	1.25 ^a	1.23 ^a
Means	1.35 ^a	1.33 ^a	1.55 ^a	

HSD (0.01): Varieties=0.373, Preservatives=0.373, Interaction=0.838

*Any two means in the same column followed by different letters differ significantly (p=0.01)

Effect of preservatives on Potassium content of juice prepared from three varieties of pineapple on day ten

Analysis of Variance (ANOVA) showed a significant difference ($p < 0.01$) between the interaction of preservatives and

variety for Potassium content at day ten (Figure 2). The highest Potassium content (1.83) was recorded as juice made from the Smooth Cayenne variety and preserved with Cloves and the least (1.08) was juice made from the Smooth Cayenne variety but with no preservative.

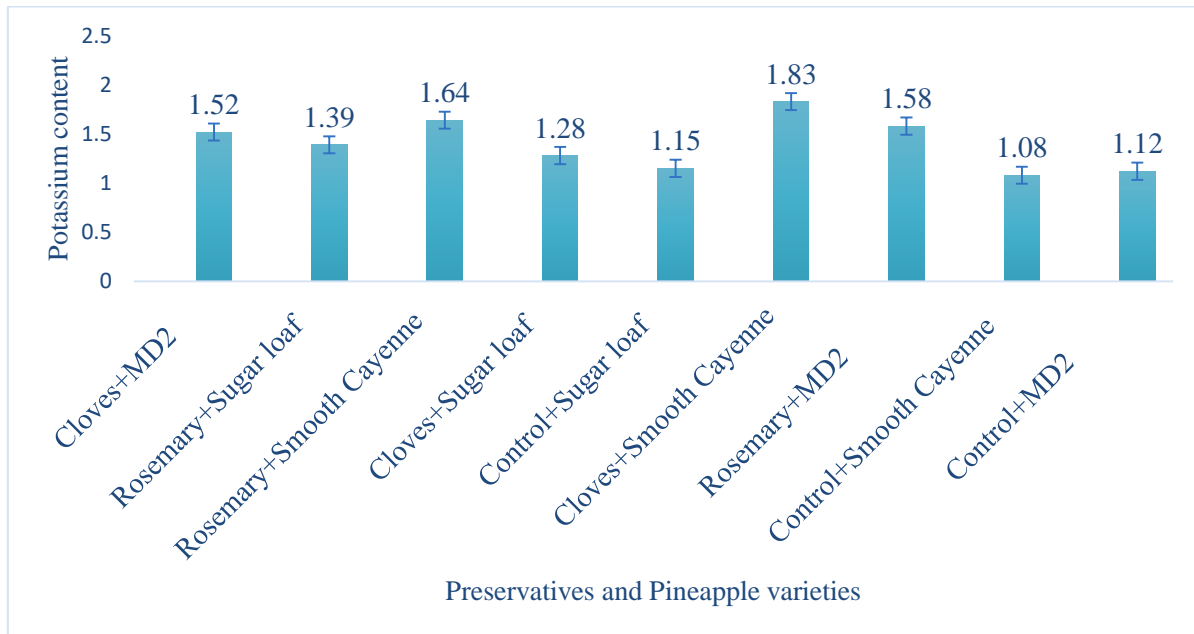


Figure 2: Effect of preservatives on Potassium content of juice prepared from three varieties of pineapple on day ten

Table 8: Effect of preservatives on Manganese content of Juice Prepared from three varieties of pineapple on Day One to TEN. n=150

Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary (Day 1)	12.01 ^{bc}	7.35 ^c	10.10 ^{bc}	9.81 ^a
Cloves (Day 1)	15.49 ^{ab}	8.09 ^c	8.05 ^c	10.54 ^a
Control (Day 1)	18.94 ^a	8.71 ^c	8.88 ^c	12.18 ^a
Rosemary (Day 10)	10.79 ^{bc}	7.00 ^{ef}	9.53 ^{cd}	9.11 ^b
Cloves (Day 10)	11.97 ^b	8.48 ^{de}	10.23 ^{bcd}	10.23 ^a
Control (Day 10)	14.83 ^a	7.55 ^{ef}	5.86 ^f	9.41 ^{ab}

*Any two means in the same column followed by different letters differ significantly ($p=0.01$)

Significant interaction effects were observed between preservatives and varieties on both Day 1 and Day 10 ($p < 0.01$). The MD2 variety consistently recorded the highest manganese content across all treatments and days. Highest Mn (18.94 mg/100ml) was in MD2 with no preservative on Day 1. The lowest Mn levels were observed in Smooth Cayenne with control preservative on Day 10 (5.86 mg/100ml). Preservative effect: On Day 1, control yielded slightly higher Mn means overall. On Day 10, cloves generally preserved Mn better across varieties than rosemary or control. A reduction in manganese content over

storage time (Day 1 to Day 10) was noted in most treatments, indicating time-dependent mineral loss(see Table 8)

Effect of preservatives on Phosphorus content of juice prepared from three varieties of pineapple at day one

Analysis of Variance (ANOVA) showed that there were no significant differences ($p > 0.01$) between the interaction of preservatives and variety for Phosphorus content at day one as well as the individual effects (Table 9).

Table 9: Effect of preservatives on Phosphorus of juice prepared from three varieties of pineapple at day one

Varieties				
Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary	0.30 ^{a*}	0.18 ^a	0.20 ^a	0.22 ^a
Cloves	0.40 ^a	0.20 ^a	0.18 ^a	0.25 ^a
Control	0.20 ^a	0.16 ^a	0.16 ^a	0.17 ^a
Means	0.30 ^a	0.18 ^a	0.18 ^a	

HSD (0.01): Varieties=0.125, Preservatives=0.125, Interaction=0.282

*Any two means in the same column followed by different letters differ significantly (p=0.01)

Effect of preservatives on Phosphorus of juice prepared from three varieties of pineapple on day ten.

Analysis of Variance (ANOVA) showed a significant difference (p<0.01) between the interaction of preservatives and variety for

Phosphorus content at day ten (Figure 3). The highest Phosphorus content (0.49) was recorded by juice made from MD2 variety and preserved with Cloves and the least (0.14) was juice made from Sugarloaf without preservatives.

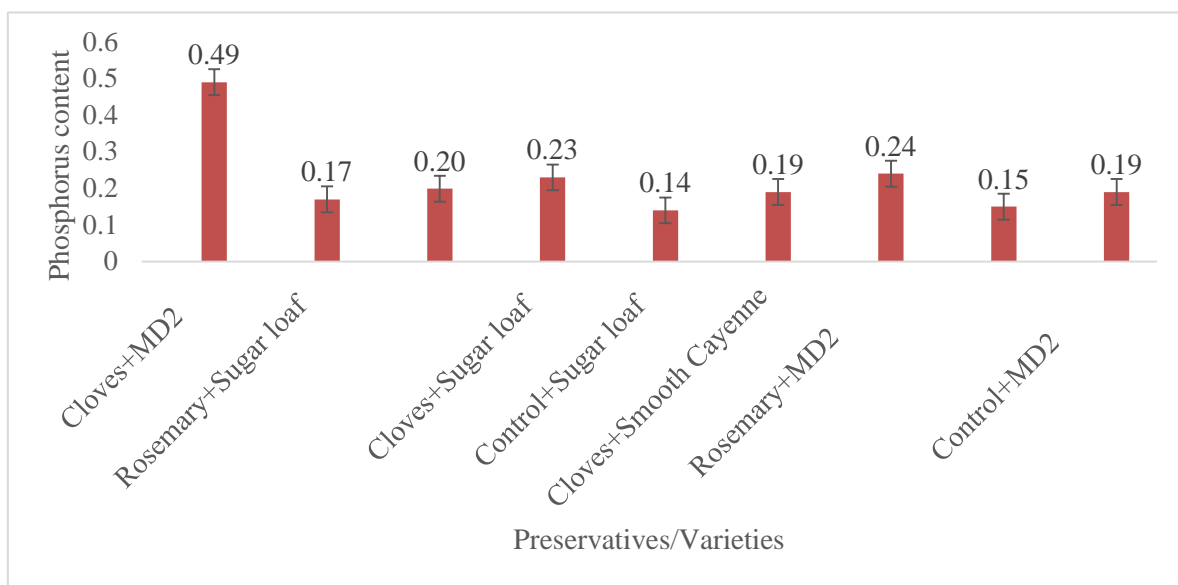


Figure 3: Effect of preservatives on Phosphorus content of juice prepared from three varieties of pineapple on day ten

Table 10: Effect of preservatives on Zinc content of juice prepared from three varieties of pineapple at day one to Ten

Preservatives	MD2	Sugarloaf	Smooth Cayenne	Means
Rosemary (D ₁)	9.86 ^a	3.68 ^a	6.50 ^a	6.68 ^a
Cloves (D ₁)	11.12 ^a	5.82 ^a	8.10 ^a	8.34 ^a
Control (D ₁)	7.81 ^a	9.01 ^a	6.27 ^a	7.68 ^a
Rosemary (D ₁₀)	8.27 ^{bc}	4.09 ^f	5.70 ^e	6.02 ^b
Cloves (D ₁₀)	11.45 ^a	4.14 ^f	7.11 ^{cd}	7.57 ^a
Control (D ₁₀)	6.87 ^d	8.47 ^b	7.01 ^{cd}	7.45 ^a

Significant interaction effects were observed between preservative treatments and pineapple varieties on both Day 1 and Day 10 (p < 0.01). Copper content varied significantly by variety and preservative: Cloves consistently preserved the highest copper content in MD2 across both days (11.12 and 11.45 mg/100ml). Sugarloaf generally had the lowest Cu values, particularly with rosemary and cloves on Day 10. On Day 1, control treatment in

Sugarloaf had unexpectedly high Cu (9.01 mg/100ml), indicating possible varietal influence or enzyme interactions. On Day 10, a slight reduction in Cu content was observed in most treatments except MD2 with cloves, suggesting preservative stability over time. MD2 consistently retained more copper than the other varieties, indicating a strong varietal influence on mineral retention (See Table 10).

Discussion

Effect of Preservatives on Chemical Properties of Juice Prepared From Three Varieties of Pineapple

PH Dynamics and Interaction Effects

The pH values recorded in this study exceeded the typical range (2.51–3.91) reported by Mehta et al. (2019), likely due to the harvest stage and ripeness of the fruit. Elevated pH in MD2 juice without preservatives (5.43) compared to the lowest pH (5.15) in rosemary-treated MD2 juice on day ten suggests rosemary's role in slowing down respiration and organic acid degradation through its antioxidative components like carnosic acid and rosmarinic acid (Nieto et al., 2018; Parada & Aguilera, 2007). The non-significant interaction on day one could be due to the buffering capacity of pineapple juice shortly after extraction.

Total Soluble Solids (TSS) and Antioxidant Preservation

The highest TSS recorded in MD2 juice treated with clove extract (14.01) aligns with clove's polyphenolic content, especially eugenol, which has antimicrobial and antioxidant properties that potentially suppress sugar degradation (Kamatou et al., 2012; Parveen et al., 2018). Conversely, rosemary consistently showed the lowest TSS across all varieties, possibly due to its inhibition of enzymatic activities involved in sugar hydrolysis. This suggests rosemary limits sugar release by stabilizing cellular structures (Zhou et al., 2016).

Sugar Accumulation and Ripening Stage

Sugar concentration is a maturity marker, and the unexpected lower values in Sugarloaf may reflect earlier harvesting. Sugar content increases during the later ripening stages due to the breakdown of starch and complex carbohydrates (Nunes et al., 2014; Ripoll et al., 2016), reinforcing the importance of uniform ripeness at harvest.

Titrateable Acidity (TTA) as an Indicator of Maturity

Smooth Cayenne's consistently higher TTA may result from its genotype and slower postharvest acid metabolism. Rosemary-treated samples retained more acid, confirming prior findings that natural antioxidants delay organic acid breakdown during storage (Falleh et al., 2009). Organic acids like citric acid are key indicators of fruit freshness, and their reduction signals metabolic activity and ripening progression.

Vitamin C Retention and Oxidative Losses

Vitamin C degradation was clearly time-dependent. Clove and rosemary preserved some ascorbic acid, but the general decline across all samples emphasizes vitamin C's vulnerability to oxidation (Lee & Kader, 2000). Smooth Cayenne's superior retention supports genotypic differences in antioxidant capacity and cellular structure integrity (Sakanaka et al., 2005).

Mineral Composition and Preservative Influence

Iron: Higher iron levels in rosemary- and clove-treated samples reflect the iron-binding and stabilizing capacity of polyphenols, as these compounds can chelate metal ions and reduce their oxidation (McClements, 2019). Additionally, vitamin C in pineapple enhances iron bioavailability, consistent with synergistic absorption effects (Hurrell & Egli, 2010). **Copper:** Elevated copper in clove-treated MD2 samples may result from

eugenol-induced leaching, as phenolic compounds have been shown to interact with and mobilize metals in solution (Siddiqui et al., 2017). **Potassium:** Clove treatment in Smooth Cayenne led to the highest potassium content, possibly due to improved membrane permeability or release during softening, a process enhanced by antimicrobial preservatives (Anwar et al., 2020). **Manganese:** The highest manganese content in MD2 without preservatives suggests oxidative or enzymatic loss when preservatives are present, as polyphenols may chelate and bind trace metals (Rodríguez-Roque et al., 2015). **Phosphorus:** Clove-treated MD2 juice had the highest phosphorus levels, potentially enhanced by natural phosphorus in the spice or reduced leaching under antioxidant protection (Olowokudejo et al., 2008). **Zinc:** MD2 juice treated with cloves retained the most zinc, reflecting enhanced mineral stability in the presence of polyphenolic compounds, which reduce degradation and binding losses (Gómez-García et al., 2021).

This study had several limitations that may have influenced the interpretation of results. The short 10-day observation period, while sufficient for early post-processing changes, may be inadequate for assessing long-term preservative efficacy or modeling nutrient degradation kinetics over time. Additionally, a potentially limited sample size could reduce the statistical power of the analysis, increasing the likelihood of Type II errors and obscuring meaningful differences between treatments. The study also did not specify the exact concentrations of rosemary and clove extracts used, which is critical given the natural variability in phytochemical potency that can affect preservative performance. Moreover, the absence of detailed environmental parameters such as light exposure, relative humidity, and potential fluctuations in storage temperature limits the ability to fully attribute observed changes to the treatments alone. Lastly, juice processing techniques, including mechanical handling and any thermal treatments applied, may have introduced confounding effects on the vitamin and mineral composition, complicating the isolation of preservative impacts.

Conclusion

This study evaluated the effects of natural preservatives rosemary and clove on the nutritional and sensory quality of pineapple juice produced from three varieties: Sugarloaf, MD2, and Smooth Cayenne. The proximate composition analysis showed that juice from the Sugarloaf variety preserved with rosemary had the highest crude fiber, fat, nitrogen-free extract (NFE), protein, and ash contents. Conversely, the Sugarloaf variety without any preservatives retained the highest moisture content across both day one and day ten. Juice prepared from the MD2 variety and preserved with rosemary exhibited the highest total soluble solids (TSS), suggesting enhanced sweetness and potential for better flavor retention. In contrast, the Smooth Cayenne variety preserved with clove recorded the highest vitamin C content, reflecting strong antioxidant retention.

Although copper, potassium, phosphorus, and zinc levels were not significantly influenced by the interaction of preservatives and pineapple varieties on day one, notable differences emerged by day ten, indicating time-dependent mineral dynamics. Both rosemary and clove were effective in preserving the sensory and nutritional qualities of pineapple juice over the short storage period without introducing off-flavors or compromising consumer acceptability.

Based on these findings, the use of MD2 pineapple preserved with rosemary is recommended for processors seeking to optimize TSS stability and sweetness in juice products. Similarly, Smooth Cayenne preserved with clove may be preferred for retaining higher vitamin C levels. These recommendations, however, should be interpreted in the context of the specific processing and storage conditions used in this study. Future research should extend beyond the 10-day storage period to assess microbial stability, sensory acceptance, and the economic feasibility of using rosemary and clove as natural preservatives. Additional studies could also explore the application of these natural preservatives in juice derived from other tropical fruits, such as mango varieties including Keitt and Kent.

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Author contributions

E. T K., R.K.N: Contributed to conceptualization, investigation, formal analysis, and data collection. Also involved in reviewing and editing the manuscript

R.K.N., E. M. R, P. A: Led the conceptualization, investigation, formal analysis, data collection, and data analysis. Additionally, contributed to writing the original draft and participated in the review and editing process.

M.A.A, J.T.B., E. N. A., M. A., A.C.A: Contributed to conceptualization, methodology, and supervision.

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Declarations

Ethics approval and consent to participate

This study was approved, and ethical clearance was obtained from the Kwame Nkrumah University of Science and Technology, (KNUST), Department of Horticulture

Consent for publication

All authors consent to publication.

Competing interests

The authors declare no competing interests.

Data Availability

Not Applicable

SUPPLEMENTARY MATERIALS : Methods use to determine the Physicochemical and Mineral Quality.

1. Appendix A: Crude Fat

A 2 g dried sample was placed in an extraction thimble and inserted into the Soxhlet apparatus. A pre-weighed solvent flask was attached, and 150-200 mL of petroleum ether was added. Extraction was conducted for 2-3 hours, after which the solvent was evaporated at 105°C for 30 minutes. The remaining fat was weighed to determine the percentage of crude fat in the sample.

2. Appendix B: Crude Fibre

A 2 g fat-free dried sample was digested in 200 mL of hot sulphuric acid and boiled for 30 minutes under reflux. The sample was filtered, washed, and further digested in 200 mL of boiling sodium hydroxide solution for another 30 minutes. The residue was filtered, washed with 95% ethanol, dried at 105°C, weighed, and then ashed at 550°C for 30 minutes. The crude fibre content was calculated based on weight loss.

3. Appendix C: Moisture content

The percentage of moisture was calculated using the formula:

Moisture content (%) = $\frac{\text{Fresh sample weight} - \text{Dry sample weight}}{\text{Fresh sample weight}} \times 100$

4. Appendix D: Protein Content

A 2 g sample was digested in a Kjeldahl flask using H₂SO₄ and a Kjeldahl catalyst (Selenium, CuSO₄, Na₂SO₄ mixture) until a clear digest was obtained. The digest was diluted, and 10 mL aliquots were distilled with 40% NaOH, collecting the distillate in 4% boric acid. The ammonia content was determined by titration with 0.1 N HCl. The percentage of nitrogen was calculated using:

$\%N = \frac{14(A - B)N \times 100}{1000 \times 0.2}$

where A and B are titration volumes of the sample and blank, respectively. Crude protein content was derived using the factor 6.25 (Total Nitrogen × 6.25).

5. Appendix E: Nitrogen-Free Extract (NFE)

The carbohydrate content was calculated by subtraction

$\%NFE = 100 - (\%CP + \%CF + \%Ash + \%EE)$

where CP = Crude Protein, CF = Crude Fiber, Ash = Total Ash, EE = Ether Extract.

6. Appendix F: Total Soluble Solids (TSS)

A 4 g sample was dried in a metal dish at 100°C for 21 hours, then cooled and reweighed. Drying was repeated until the weight change was minimal. TSS was calculated as:

$\%TSS = \frac{\text{Final Sample Weight} - \text{Initial Sample Weight}}{\text{Sample Weight}} \times 100$

7. Appendix G: Total Titratable Acidity (TTA)

TTA was calculated using:

$\%TTA = \frac{0.1M \text{ NaOH} \times \text{Volume of NaOH (L)} \times 90.08 \times 100}{\text{Sample Weight}}$

8. Appendix H: pH Determination

The Nernst equation was used to convert millivolt readings to pH values:

$$E = E^{\circ} - \frac{RT}{zF} \ln Q$$

Where E is reduction potential, E° is standard potential, R is the gas constant, T is the temperature (K), z is ion charge, F is the Faraday constant, and Q is the reaction quotient.

9. Appendix I: Vitamin C (Ascorbic Acid)

A 20 mL sample was diluted with 150 mL distilled water and titrated with 0.005 M iodine solution using starch as an indicator.

The end-point was identified as the first permanent blue-black colouration (Satpathy et al., 2021).

10. Appendix J: Mineral Analysis

The operating conditions were:

- RF power: 1.0 kW
- Viewing geometry: Axial
- Plasma gas flow rate: 15.0 L min⁻¹
- Auxiliary gas flow rate: 1.50 L min⁻¹
- Nebulizer gas flow rate: 0.75 L min⁻¹
- Replicate reading time: 9.0 s