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Research Article
Effect of Citric Acid Extracted from June Plum on the Antioxidant Properties of Watermelon Juice (*Citrullus* spp.)

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Abstract

Objective: This study was conducted to evaluate the antioxidant properties of watermelon juice preserved with citric acid extracted from June plum. **Materials and Methods:** The Box-Behnken experimental design of response surface methodology was employed in the experimental design. The independent variables for watermelon juice preserved with citric acid were citric acid concentration (0.5-10 g), pasteurization time (10-20 sec), storage temperature (0-30°C) and pasteurization temperature which was kept constant at 75°C. To make watermelon juice, the fruit was washed, diced, juiced and pasteurized (75°C) to ensure safety and extend shelf life. As part of the production process for citric acid crystals from June plum, pH was adjusted, filtration was performed, $CaCl_2$ was added, heating, acidification and evaporative crystallization occurred. **Results:** The dependent variables: phenolic acid, flavonoid, vitamin A, Vitamin C and E and lycopene ranged from 0.54-1.14 mg GAE/100 mL, 3.15-3.84 µg QE mL^{-1}, 1.71-1.87 mg, 8.10-9.66 mg, 3.06-3.37 mg, 3.80-4.56 mg L^{-1}, respectively. **Conclusion:** The research findings revealed that the antioxidant properties of the watermelon juice were strongly affected by citric acid extracted from June plum.

Key words: Antioxidant properties, face centered composite design, June plum, process variables, watermelon juice

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Food and beverages are susceptible to spoilage due to the growth of microorganisms, which not only decreases their quality but also poses a risk to human health[1]. Preservatives, such as citric acid, are used in the food industry to prevent or slow down the growth of microorganisms, preserving their quality and safety[2]. Citric acid is a weak organic acid found in many fruits and vegetables, including the June plum, which is effective against bacteria, yeasts and moulds[3]. It is widely used as a flavoring agent, acidifier and preservative in various food and beverage products[4].

The June plum, also known as ambarella, golden apple, or hog plum, is a fruit tree native to tropical regions and is known for its luscious and sweet flesh with a tart flavour and green to yellow skin[5,6]. The fruit is often eaten raw but can also be used to make jams, jellies and drinks[6]. The June plum has several health benefits, including antioxidant and antimicrobial properties, as well as being a good source of nutrients like vitamin C, vitamin A and potassium[6,7]. Additionally, it has potential therapeutic properties, such as antidiabetic and anti-inflammatory effects.

Watermelon (*Citrullus lanatus*), another popular fruit, has been found to have strong antioxidant activity due to its phenolics, which are mostly derivatives of hydroxycinnamic acid and have a significant quantity of lycopene[8]. Watermelon juice has been found to have sensory, physical and nutritional qualities, making it more popular in recent years. Nonthermal procedures are used to produce more palatable watermelon juice[9]. Citric acid is used as a preservative in grapefruit, orange and apple juices etc. Research by hydroxycinnamic *et al.*[10] has shown that adding citric and malic acids to orange juice extended its shelf life by five weeks, inhibiting the development of bacteria. Another study conducted by Yang *et al.*[11] found that treating peach fruits with 10 g L^{-1} citric acid may successfully preserve their texture, flavour and nutritional value while reducing postharvest deterioration. However, there is limited study on the possible use of citric acid derived from June plum as a preservative in watermelon juice. This study aimed to investigate the preservative potential of citric acid extracted from June plum on watermelon juice and evaluate its impact on the physicochemical and sensory properties of the juice.

MATERIALS AND METHODS

Sources of raw material: The study was conducted at Food Science and Technology Laboratory at Nnamdi Azikwe university Awka, Anambra state on 18th February 2023. The raw materials were sourced from different locations. The June Plum was acquired from the Mile 1 market in Port Harcourt, Rivers State. The watermelon fruit was obtained from Eke Awka Market. Additionally, the extraction of both the watermelon fruit juice and the June Plum juice was conducted in the Food Science and Technology Laboratory at Nnamdi Azikiwe University in Awka. Data were analyzed using analysis of variance (ANOVA) followed by Duncan's multiple range test using the SPSS Software (Version 25) (SPSS, Inc., IBM, Chicago, Illinois, USA). All tests were performed at least in duplicates. Differences were considered significant at $p<0.05$.

Sample preparation

Production of June plum juice (Unripe): June Plum juice was produced according to the method described by Chang *et al.*[12], with slight modi cation. A full bag (25 kg) of unripe June plums was sorted to remove the spoilt ones, washed, peeled, the seed was removed and the flesh diced. The juice was extracted using a Kenwood juicer (model: HHB 100E, Ajanta Limited, Morbi, India) and the juice was strained into a container, corked and stored for further studies. The production of juice from June plum fruit is shown in Fig. 1.

Production of watermelon juice: June Plum Juice was produced according to the method described by Kumar *et al.*[13]. A whole watermelon is used to make watermelon juice, which was first thoroughly washed to remove surface contaminants. After washing, the watermelon was cut open and diced into smaller pieces to facilitate processing. A juicer was used to extract the juice from the diced watermelon pieces while separating the pulp and seeds, 4500 mL of watermelon juice was obtained. After juicing, the fresh watermelon juice was pasteurized at a constant temperature (75°C) for 10-20 sec for the different samples to eliminate harmful bacteria and enzymes, thereby extending the juice's shelf life. After pasteurization, the juice was rapidly cooled to a safe temperature, preserving its flavour and quality while preventing further bacterial growth. The production of juice from watermelon fruit is shown in Fig. 2.

Extraction of citric acid crystals from June plum juice: In the experiments, sodium hydroxide, calcium chloride and sulfuric acid of analytical grade were used without further processing. Citric acid was chemically synthesized in three steps, involving: (I) pH adjustment (10) using a 2.8 M NaOH solution, (ii) addition of $CaCl_2$ solution [40.3-41.1% (w/v)] and (iii) acidification with H_2SO_4 solution (1.5-2.3 M) to produce citric acid. During neutralization, 2.8 M NaOH solution [10% (w/w)] was incrementally added to the June plum juices to achieve a pH of 10 while sodium citrate, being soluble, remained in

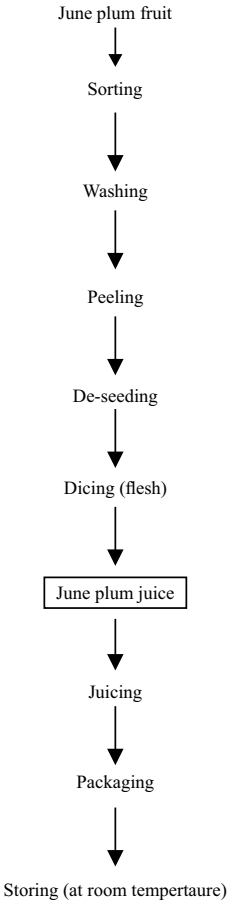

Fig. 1: Production of June plum Juice

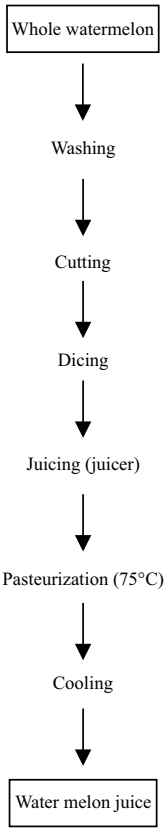

Fig. 2: Production of Watermelon Juice

solution while other products became insoluble. The resultant mixture was filtered to remove the insoluble and the filtrate containing an aqueous solution of sodium citrate was filtered three times before proceeding to the second step. In the second step, 500 mL of 40.7% (w/v) $CaCl_2$ solution was added to the sodium citrate solution, heated in a boiling water bath for 30 min and calcium citrate precipitated at the bottom. The resulting mixture containing calcium citrate was vacuum-filtered and the residue was washed with 100 mL of hot water in four steps to remove impurities and byproducts. A neutral pH of 7 was maintained in the filtrate and the residue was dried to a constant weight in a hot air oven. The dried calcium citrate was then acidified with 250 mL of dilute H_2SO_4 (1.9 M) at 60°C while being stirred with a glass rod. Both calcium citrate and calcium sulfate are insoluble in water and calcium sulfate settles at the bottom while citric acid remains on top. The mixture was vacuum-filtered similarly to the second step. Finally, citric acid was crystallized from its aqueous solution through evaporative crystallization, with the yield estimated gravimetrically and characterized FTIR, 293 g of citric acid crystals was obtained. The percentage yield of citric acid was calculated as shown in equation 1[12]:

$$\text{Yeild of citric acid}(\%) = \frac{\text{Mass of citric acid in product}}{\text{Volume of juice used}} \times 100 \quad (1)$$

Experimental design: The face-centred central composite design (FCCD) was used in this research using Design Expert software version 13. Table 1 shows the process variables and their levels. The experimental matrix, based on a central composite face-centered design, is shown in Table 2. The experimental space had a total of twenty (20) samples. Sample 21(Ctr^-) is the Watermelon juice with no citric acid while sample 22($Ctrl^+$) is the watermelon juice with commercially made citric acid. The data obtained from the study was fitted to the second-order polynomial regression model[14] of the form:

Table 1: Key depicting independent variables and their levels of replication

	Levels of factors		
Parameters	-1	0	+1
Citric acid Conc (g) A	0.5	5.25	10
Pasteurization time (s) B	10	15	20
Storage temp (°C) C	0	15	30

Table 2: Central Composite face-center (CCFC) design matrix and the independent variables and their actual levels and coded values

	Factor 1	Factor 2	Factor 3
Runs	A: Citric acid conc. (g)	B: Pasteurization time (sec)	C: Storage temp (°C)
1	10 (+1)	20 (+1)	0 (-1)
2	10 (+1)	10 (-1)	0 (-1)
3	5.25 (0)	15 (0)	15 (0)
4	5.25 (0)	15 (0)	15 (0)
5	5.25 (0)	15 (0)	15 (0)
6	5.25 (0)	15 (0)	30 (+1)
7	5.25 (0)	15 (0)	15 (0)
8	0.5 (-1)	20 (+1)	30 (+1)
9	5.25 (0)	10 (-1)	15 (0)
10	5.25 (0)	15 (0)	15 (0)
11	0.5 (-1)	20 (+1)	0 (-1)
12	0.5 (-1)	10 (-1)	0 (-1)
13	10 (+1)	20 (+1)	30 (+1)
14	0.5 (-1)	15 (0)	15 (0)
15	5.25 (0)	15 (0)	15 (0)
16	5.25 (0)	20 (+1)	15 (0)
17	5.25 (0)	15 (0)	0 (-1)
18	10 (+1)	15 (0)	15 (0)
19	10 (+1)	10 (-1)	30 (+1)
20	0.5 (-5)	10 (-1)	30 (+1)
$CTRL^+$	2.5	20	0
$CTRL^-$	0	20	0

Values in bracket are the coded values while the ones not in bracket are the actual values

$$Y = b_0+b_1A+b_2B+b_3C+b_{11}A^2+b_{22}B^2+b_{33}C^2+ b_{12}AB+b_{13}AC+ b_{23}BC +e \quad (2)$$

Where:

- Y = Response parameters
- b_0 = Intercept
- b_1-b_{23} = Coefficient estimate of the linear, interaction and square terms
- A = Citric acid concentration (mL)
- B = Pasteurization time (sec)
- C = Storage temperature (°C)
- e = Estimated error

Determination of anti-oxidant properties

Determination of vitamin A: AOAC[15] procedures were used to determine Vitamin A content (model; spectrum lab 23A). A 5 mL sample was initially saponified using an alcoholic solution of potassium hydroxide. The unsaponified matter, which contained vitamin A, was subsequently extracted using a mixture of diethyl ether and petroleum spirit. The resulting extract was evaporated under nitrogen and the residue was dissolved in methanol. This extract was chromatographed using a reverse-phase octadecyl silane (ODS) column, with the mobile phase consisting of 95% acetonitrile and 5% water. The separated retinol was quantified using a UV absorbance detector at 328 nm. The content of vitamin A in International Units per gram was calculated from the provided expression by AOAC[15] as shown in equation 3:

$$\text{Vitamin A}\left(\frac{\text{mg}}{100\text{ g}}\right)=\frac{A\times V\times 1900}{100\times m} \quad (3)$$

Determination of Vitamin C (ascorbic acid): Vitamin C was determined using the procedure described by AOAC[15]. A 10 g of the sample was extracted with 50 mL EDTA/TCA extracting solution for 1 hr and filtered through a Whatman filter paper into a 50 mL volumetric flask and made up to the mark with the extracting solution. After this, 20 mL of the extract was

pipetted into a 250 mL conical flask and 10 mL of 10% KI and 50 mL of water were added. This was titrated against 0.01 N $CuSO_4$ solution to a dark endpoint and Ascorbic acid was calculated using equation 4:

$$\text{Vitamin C}\left(\frac{\text{mg}}{100\text{ g}}\right)=\frac{20\times(V_1-V_2)\times C}{\text{Weight of sample}} \quad (4)$$

Determination of lycopene content: The method of AOAC[15] was used to determine the lycopene content. Then, 1.0 g of each sample was accurately weighed into a 125 mL Erlenmeyer flask and then 100 ml of hexane: ethanol: acetone in ratio 2:1:1 was added. The flask was then sealed with a rubber stopper and after 30 min of extraction, the absorbance of the supernatant containing lycopene was measured at 503 nm using a spectrophotometer (Buck Model 20 A; Buck Scientific, East Norwalk, CT, USA) and calculated as shown in equation 5 (AOAC[15]):

$$\text{Lycopene}\left(\frac{\text{mg}}{\text{kg}}\right)=\frac{A_{503}\times 171.7}{W} \quad (5)$$

Where:

A_{503} = Absorbance at 503 nm
W = Weight of sample

Total phenolic compound analysis: Total polyphenol content was estimated using the Folin-Ciocalteu (FC) assay which is widely used in routine analysis[16]. A known amount of extract (10 mg mL^{-1}) was mixed with 1.0 mL of FC reagent and 0.8 mL of 2% Na_2CO_3 was added and the volume was made up to 10 mL using water-methanol (4:6) as diluting fluid. Absorbance was read at 740 nm after 30 min using a spectrophotometer. Tannic acid (0-800 mg L^{-1}) was used to produce a standard calibration curve. The total phenolic content was expressed in mg of Tannic acid equivalents (TAE)/100 g of sample[17].

Determination of total flavonoids: The total flavonoid content was determined using the Dowd method as adopted by Arvouet-Grand *et al.*[18]. A 5.0 mL of 2% aluminium trichloride ($AlCl_3$) in methanol was mixed with the same volume of the extract solution (10 mg mL^{-1}). Absorption readings at 415 nm using a Perkin Elmer UV-VIS spectrophotometer were taken after 10 min against a blank sample consisting of extract solution with 5.0 mL methanol without $AlCl_3$. The total flavonoid content was determined using a standard curve with quercetin. Total flavonoid content was expressed as g of quercetin equivalents/100 g of sample.

Determination of vitamin E: For the determination of vitamin E, 10 g of the sample was mixed with 10 mL of ethanoic sulfuric acid and boiled gently for 5 min. It was transferred to a separating funnel and treated with 3×30 mL of diethyl ether, with recovery of the ether layer each time. The ether extract was transferred to a desiccator and dried for 30 min, later being evaporated to dryness at room temperature. The dried extract was dissolved in 10 mL of pure ethanol. Then, 1 mL of the dissolved extract and an equal volume of standard vitamin E were transferred to separate tubes. After the continuous addition of 5 mL of absolute alcohol and 1 mL of concentrated nitric acid solution, the mixture was allowed to stand for 5 min and the respective absorbance was measured in a spectrophotometer at 410 nm, with the blank reagent set at zero and the vitamin E was calculated as shown in equation 6[15].

$$\text{Vitamin E}\left(\frac{\text{mg}}{100\text{ g}}\right)=\frac{\text{Absorbance of sample}\times\text{concentration of standard}}{\text{Absorbance of standard}} \quad (6)$$

RESULTS AND DISCUSSION

Based on the data in Table 3, statistically significant variations ($p<0.05$) were observed in the anti-oxidant and microbial properties of the samples. Regression analysis of parameters such as pH, phenolic acids, flavonoids and Vitamins A, C and E confirmed that the data met the criteria for model adequacy. Therefore, these parameters were effectively converted into mathematical models within the scope of this study.

Anti-oxidant properties: Table 4, shows the presence of the Phenolic acid, Flavonoids, vitamin A, Vitamin C, Vitamin E and Lycopene in varying proportions. The Idea regression equation showing the response variables as a function of the independent variables (Process variables) is presented in equation 7.

Phenolic acid: Table 3 shows that the phenolic acid content of the watermelon juice produced with citric acid differs significantly ($p<0.05$) as they ranged from 0.47 mg GAE/100 mL to 1.14 mg GAE/100 mL while the watermelon juice with no citric acid (sample 22) had 0.49 mg GAE/100 mL phenolic acid content and that produced with commercially made citric acid (21) had 0.81 mg GAE/100 mL phenolic acid content. Sample 8 (with citric acid concentration at 0.5 mL, pasteurized

Table 3: Antioxidant properties of watermelon juice produced with citric acid extracted from June plum

Sample	P	V	C	Phenolic acid	Flavonoid	Vitamin A	Vitamin C	Vitamin E	Lycopene
1	10	20	0	1.14±0.05^{ab}	3.56±0.06^{d}	1.71±0.00^{hi}	9.06±0.01^{f}	3.18±0.02^{g}	4.28±0.03^{d}
2	10	10	0	1.04±0.00^{ef}	3.84±0.02^{a}	1.82±0.02^{b}	9.64±0.02^{a}	3.26±0.00^{e}	4.17±0.01^{e}
3	5.25	15	15	1.07±0.02^{cd}	3.24±0.02^{k}	1.74±0.01^{g}	8.94±0.01^{h}	3.13±0.02^{i}	3.94±0.01^{h}
4	5.25	15	15	1.05±0.00^{de}	3.26±0.01^{k}	1.75±0.02^{g}	8.90±0.02^{i}	3.16±0.00^{h}	3.97±0.00^{g}
5	5.25	15	15	1.05±0.00^{de}	3.25±0.01^{k}	1.74±0.00^{g}	8.97±0.00^{g}	3.16±0.01^{h}	3.92±0.00^{ij}
6	5.25	15	30	0.92±0.03^{g}	3.19±0.01^{l}	1.71±0.01^{ij}	8.69±0.04^{l}	3.01±0.01^{l}	3.94±0.01^{h}
7	5.25	15	15	1.05±0.01^{de}	3.15±0.00^{m}	1.78±0.01^{d}	8.81±0.00^{j}	3.07±0.00^{k}	3.90±0.00^{jk}
8	0.5	20	30	0.47±0.02^{m}	3.64±0.02^{c}	1.74±0.00^{g}	8.21±0.00^{o}	3.01±0.00^{l}	3.81±0.00^{m}
9	5.25	10	15	1.02±0.00^{f}	3.57±0.01^{d}	1.78±0.00^{d}	9.22±0.00^{c}	3.15±0.00^{h}	3.97±0.00^{g}
10	5.25	15	15	1.06±0.01^{cde}	3.65±0.02^{c}	1.77±0.01^{d}	8.98±0.00^{g}	3.21±0.02^{f}	3.92±0.02^{ij}
11	0.5	20	0	1.07±0.00^{cd}	3.51±0.01^{e}	1.87±0.00^{a}	9.66±0.00^{a}	3.32±0.00^{d}	4.56±0.01^{a}
12	0.5	10	0	1.12±0.02^{b}	3.75±0.00^{b}	1.80±0.01^{c}	8.36±0.00^{n}	3.37±0.00^{c}	4.49±0.01^{c}
13	10	20	30	0.83±0.01^{h}	3.30±0.00^{j}	1.70±0.00^{ij}	8.10±0.01^{p}	3.06±0.00^{k}	3.80±0.00^{m}
14	0.5	15	15	0.85±0.00^{h}	3.39±0.01^{g}	1.77±0.00^{de}	9.05±0.01^{f}	3.12±0.00^{i}	3.94±0.02^{hi}
15	5.25	15	15	1.08±0.00^{c}	3.30±0.01^{j}	1.78±0.00^{d}	9.14±0.00^{e}	3.16±0.01^{h}	3.90±0.00^{jk}
16	5.25	20	15	1.03±0.02^{f}	3.35±0.00^{h}	1.74±0.01^{g}	8.76±0.01^{k}	3.18±0.00^{g}	3.90±0.00^{jk}
17	5.25	15	0	1.15±0.00^{a}	3.35±0.00^{h}	1.72±0.00^{h}	9.42±0.02^{b}	3.10±0.00^{j}	4.52±0.03^{b}
18	10	15	15	0.67±0.67^{j}	3.34±0.00^{hi}	1.75±0.00^{fg}	9.07±0.00^{f}	3.13±0.01^{i}	3.97±0.02^{g}
19	10	10	30	0.54±0.01^{k}	3.32±0.00^{ij}	1.80±0.00^{c}	9.19±0.01^{dd}	3.15±0.00^{h}	3.90±0.00^{jk}
20	0.5	10	30	0.66±0.01^{j}	3.45±0.01^{f}	1.82±0.00^{b}	8.64±0.02^{m}	3.25±0.00^{e}	3.85±0.01^{l}
21(CTRL^{+})	2.5	20	0	0.81±0.01^{i}	3.53±0.02^{e}	1.76±0.00^{ef}	8.75±0.00^{k}	3.71±0.01^{a}	4.04±0.01^{f}
22(CTRL^{-})	0	20	0	0.49±0.01^{l}	3.18±0.00^{j}	1.69±0.01^{j}	8.37±0.01^{n}	3.68±0.00^{b}	3.89±0.00^{k}

Values are means of duplicate determinations ±Standard Deviation. Values in the same column bearing different superscripts differ significantly ($p<0.05$). Sample 21: With commercial citric acid, 22: Control Sample without any added citric acid and PVC: Process Variable Combination-Citric acid concentration (g), Pasteurization time (sec) and Storage temp (°C)

Table 4: Summary of ANOVA and coefficient Estimate of the antioxidant properties of watermelon juice produced with citric acid extracted from June plum for the terms that showed a significant model

Terms	Coefficient	Phenolic acid	Flavonoid	Vitamin A	Vitamin C	Vitamin E	Lycopene
n intercept	b_0	1.0400	3.39	1.75	8.9400	3.1600	3.9500
(A)	b_1	0.0050	0.0460	-0.0220	0.1140	-0.0290	-0.0530
(B)	b_2	0.0160	-0.0910	-0.0260	-0.1260	-0.0430	-0.0030
(C)	b_3	-0.2100	-0.1290	-0.0150	-0.3310	-0.0750	-0.2720
(AB)	b_{12}	0.0787	-	-	-0.3175	-	-0.0025
(AC)	b_{13}	0.0312	-	-	-0.0300	-	0.0800
(BC)	b_{23}	0.0063	-	-	-0.2800	-	-0.0400
(A^2)	b_{112}	-0.2423	-	-	-	-	-0.0291
(B^2)	b_{222}	0.0227	-	-	-	-	0.0491
(C^2)	b_{332}	0.0327	-	-	-	-	0.2459
R^2 adj		0.8313	0.3760	0.8113	0.8113	0.4244	0.9448
CV (%)		8.9200	4.04	2.01	2.01	2.21	1.3900

for 20 sec and stored at 0°C) has the highest content of phenolic acid of 0.47. In comparison, Sample 1 (with citric acid concentration at 10 mL, pasteurized for 20 sec and stored at 0°C) had the lowest phenolic acid concentration. A similar outcome was observed by Liu *et al.*[19], who determined the total phenolic content of watermelon juice to be 1.62 mg GAE/100 mL. Their findings indicated that the freezing of watermelon juice did not change its total phenolic acid content significantly ($p>0.05$). Phenolic acids are a group of compounds that are widely distributed in fruits and vegetables and are known for their antioxidant properties[20]. Watermelon juice is a good source of phenolic acids and its phenolic content can vary depending on various factors such as the preservation method and storage conditions[21]. Aadil *et al.*[22] also investigated the phenolic content of fresh watermelon juice and found that it contained 25.95 mg GAE/100 mL of total phenolic content. This indicated that watermelon juice is a rich source of phenolic compounds. The preservation of the phenolic components in watermelon juice has also been significantly influenced by storage temperature. Salin *et al.*[21] found that storage temperature affected the physicochemical and antioxidant properties of watermelon juice, indicating that proper storage conditions are necessary to preserve the phenolic content.

$$\text{Phenolic Ac} = 1.04+0.0050A+0.0160B-0.2100C+0.0787AB+0.0312AC+0.0063BC-0.2423A^2+0.0227B^2+0.0327C^2 \quad (7)$$

The mathematical model for the phenolic content of the watermelon juice produced with citric acid extracted from June plum is presented in Equation 8. The equation illustrates the relationship between the concentrations of citric acid, pasteurization time and storage temperature in watermelon juice and the concentration of phenolic acid. It suggested that these variables, both individually and in combination, can influence the concentration of phenolic acid in the juice. The quadratic terms indicated that the relationships may not be linear and it is possible that the concentration of phenolic acid in juice can be maximized by optimizing the concentration of these variables. The coefficient for the concentration of citric acid (A) was 0.0050 and the coefficient for the pasteurization time (B) was 0.0160, A and B indicated that an increase in the concentration of citric acid and pasteurization time led to a slight increase in the concentration of phenolic acid in the juice. The coefficient for the storage temperature (°C) was -0.2100, indicating that an increase in the storage temperature led to a decrease in the concentration of phenolic acid in the juice. There are also interaction terms in the equation which was the coefficient for the interaction between citric acid (A) and pasteurization time (B) (AB) which was 0.0787, suggesting that the combined effect of these two variables led to a larger increase in the concentration of phenolic acid in the juice compared to their individual effects. Similarly, the coefficients for the interactions between citric acid (A) and storage temperature (C), (AC) and between pasteurization time (B) and storage temperature (C), (BC) were 0.0312 and 0.0063, respectively. These coefficients indicated that the combined effects of these variables also contributed to the concentration of phenolic acid in the juice. The equation also included quadratic terms for each variable. The coefficient for the square of citric acid (A^2) was -0.2423, suggesting that the relationship between the concentration of citric acid and phenolic acid was not linear and that there may be an optimal concentration of citric acid for maximizing the concentration of phenolic acid in the juice. Similarly, the coefficients for the squares of pasteurization time (B^2) and storage temperature (C^2) were 0.0227 and 0.0327, respectively. These coefficients indicated that the relationship between these variables and the concentration of phenolic acid may also be nonlinear.

Coefficient of variation (8.92) suggested that there was some moderate variability in the data, which means that the concentration of phenolic acid can vary by approximately 8.92% around the mean value (Table 4). However, the adjusted R^2 value (0.83) indicated that the independent variables in the equation explained a significant portion of the variation in the concentration of phenolic acid. This suggested that the equation was a reasonably good fit for the data and could be used to predict the concentration of phenolic acid in watermelon juice based on the concentrations of citric acid, pasteurization time and storage temperature.

Figures 3 shows the contours of the model, which represent the different levels of phenolic content at different combinations of citric acid concentration, pasteurization time and storage temperature. Figure 3a shows that the phenolic acid content of watermelon juice produced with citric acid extracted from June plum increased with increasing citric acid concentration and pasteurization time. As the pasteurization time increased from 14.44-19.99 sec, the citric acid concentration also increased from 6.66-8.84 g and the phenolic acid concentration increased from 0.8-1 mg GAE/100 mL. Figure 3b shows that the phenolic acid content of watermelon juice produced with citric acid extracted from June plum increased with increasing citric acid concentration and decreased with increasing storage temperature. As the Storage temperature increased from 3-9.99°C, the citric acid concentration increased from 2.27-7.71 g and the phenolic acid content decreased from 1.2-1 mg GAE/100 mL. Figure 3c shows that the phenolic acid content decreased as the storage temperature increased. This was likely because phenolic acids are degraded by enzymes and other compounds at higher temperatures. Therefore, the phenolic acid content of watermelon juice produced with citric acid extracted from June plum decreased from 1.2 mg GAE/100 mL to 0.9 mg GAE/100 mL as the storage temperature increased from 18.12-20.97°C, this represents a decrease of approximately 58%.

Flavonoids: From Table 3, the flavonoid content of the watermelon juice produced with citric acid differs quite significantly ($p<0.05$) as they ranged between 3.15 µg QE mL^{-1} and 3.84 µg QE mL^{-1} while the watermelon juice with no citric acid had 3.18 µg QE mL^{-1} flavonoid content, this indicated that watermelon juice naturally contained flavonoids but the addition of citric acid, whether from June plum or commercial sources, could further enhance the flavonoid content and the one produced with that commercial citric acid (sample 21) had 3.53 µg QE mL^{-1} flavonoid content, which suggested that the use of citric acid may result in slightly higher flavonoid content. This finding contrasted significantly with the research conducted by Altaş *et al.*[23], who reported a notably higher flavonoid content of 9.84 µg QE mL^{-1} in watermelon juice. The addition of citric acid may have affected the flavonoid content, emphasizing the influence of preservation techniques on the final composition of watermelon juice. Salin *et al.*[21] investigated the effect of storage temperatures on the physicochemical properties, phytochemicals and antioxidant properties of watermelon juice. The study found that the

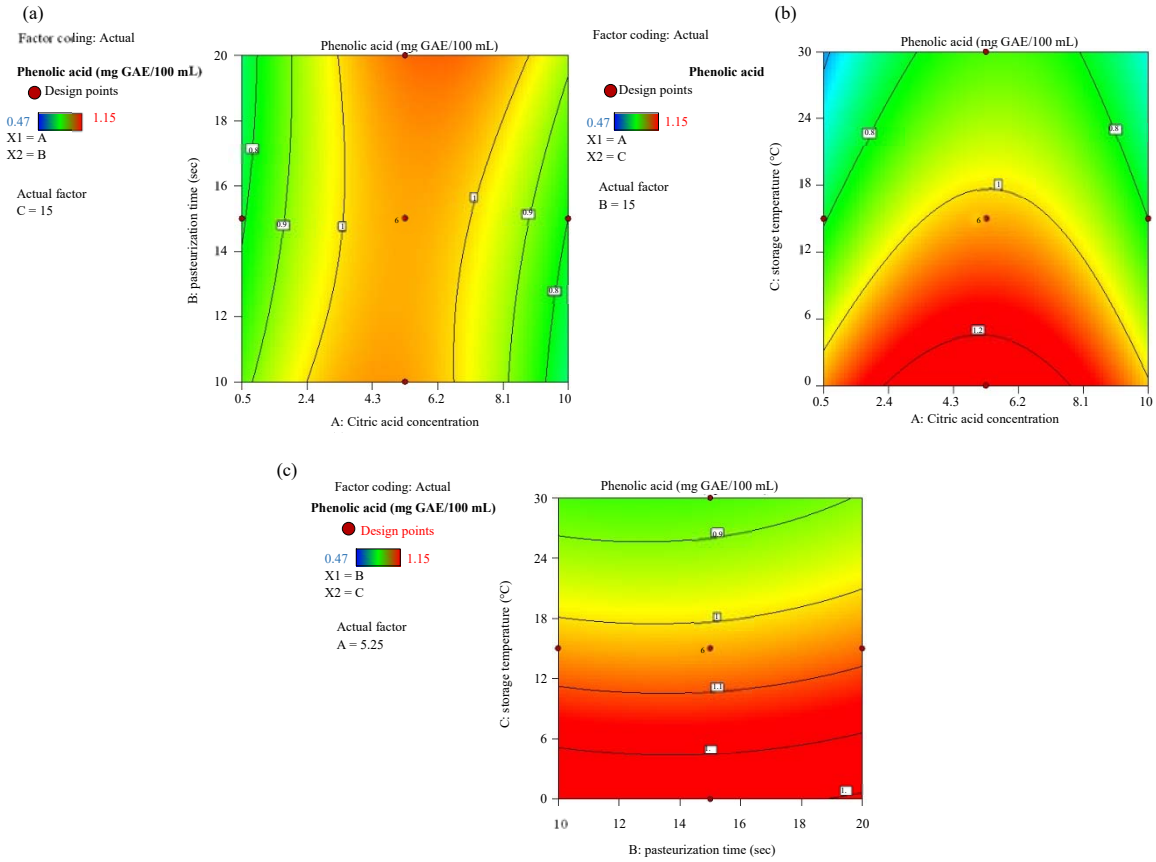

Fig. 3(a-c): Contour of the interaction effect of pasteurization time, citric acid concentration and storage temperature on the phenolic acid concentration of watermelon juice produced with citric acid extracted from June plum

flavonoid content of freeze-dried watermelon juice increased on day 7 and day 9 of storage. However, the phenolic content decreased, possibly due to limitations in the method used to quantify total phenolics. This suggested that the flavonoid content of watermelon juice can be influenced by storage conditions. Also, Sánchez Moreno *et al.*[24] compared the impact of different processing technologies on the bioactive compounds and antioxidant activity of orange juice. This study focused on orange juice but it provided insights into the effects of processing on bioactive compounds in fruit juices. The study found that bioactive compounds, including flavanones, were affected by the processing method. This suggested that the processing method used for watermelon juice produced with citric acid extracted from June plum could potentially influence the flavonoid content.

$$\text{Flavonoids} = 3.39+0.0460A-0.0910B-0.129°C \quad (8)$$

The mathematical model for the flavonoid content of the watermelon juice produced with citric acid from June plum is presented in Equation 9 which shows the relationship between the concentration of citric acid (A), pasteurization time (B) and storage temperature (C) on the concentration of flavonoids in watermelon juice produced with citric acid extracted from June plum. The coefficient for citric acid (A) was 0.0460, indicating that an increase in the concentration of citric acid led to an increase in the concentration of flavonoids in the watermelon juice produced with citric acid extracted from June plum. This suggested that citric acid had a positive effect on the flavonoid content. On the other hand, the coefficients for pasteurization time (B) and storage temperature (°C) were -0.0910 and -0.1290, respectively. These negative coefficients indicated that an increase in either pasteurization time or storage temperature resulted in a decrease in the concentration of flavonoids in the watermelon juice. This suggested that higher time during pasteurization

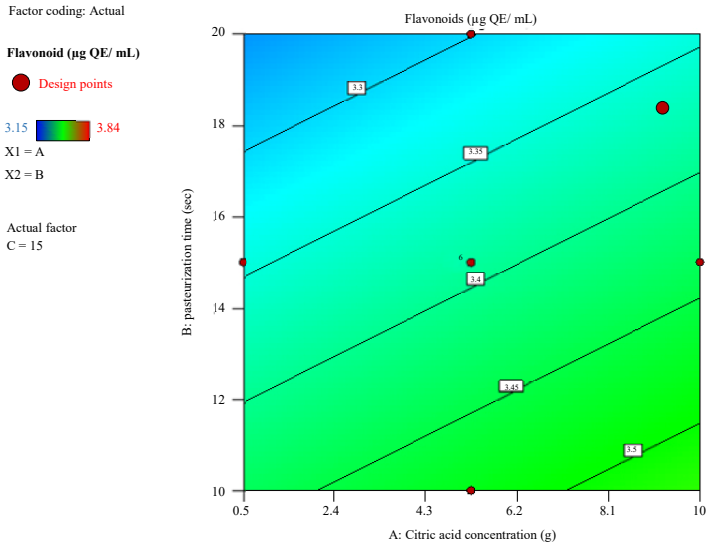

Fig. 4: Contour of the interaction effect of pasteurization time and citric acid concentration on flavonoid content of watermelon juice produced with citric acid extracted from June plum

and higher temperature during storage negatively impacted the flavonoid content. From Table 4 the R^2 adjusted value of 0.3760 suggested that approximately 37.60% of the variation in the flavonoid content could be explained by the independent variables included in the equation. The remaining 62.40% of the variation may be attributed to other factors not considered in the equation. The coefficient of variation was a measure of the relative variability of the data[25]. It was calculated as the ratio of the standard deviation to the mean, expressed as a percentage[25]. In this case, a coefficient of variation of 4.04 suggested that the flavonoid content in the watermelon juice had a relatively low variability compared to the mean value. This indicated that the data points for the flavonoid content were relatively close to the mean, suggesting a more consistent concentration of flavonoids in the juice.

Figure 4 shows the contour of the model, which shows the combinations of citric acid concentration and pasteurization time. Figure 4 shows that as the pasteurization time decreased from 17.45-11.46 sec, the citric acid concentration also increased from 3.3-7.2 g. Additionally, the flavonoid content in the watermelon juice produced with citric acid extracted from June plum increased from 3.3-3.5 µg QE/mL. When there was a decrease in the pasteurization time, we tended to have more citric acid in the juice and this appeared to positively influence the flavonoid content.

Vitamin A: From Table 3, the vitamin A content of the watermelon juice produced with citric acid extracted from June plum differed quite significantly ($p<0.05$) as they had ranged from 1.87-1.71 mg/100 mL, which was slightly lower than the vitamin A content of watermelon juice produced with commercial citric acid (sample 21) (1.76 mg/100 mL) and higher than sample 22 (watermelon juice with no citric acid added) (1.69 mg/100 mL). These values indicated that the addition of citric acid, regardless of the source, had slightly increased the vitamin A content of watermelon compared to when no citric acid was added. Citric acid is a common additive used in the preservation of fruit juices, including watermelon juice. It was known for its antioxidant properties and ability to enhance the flavour and shelf life of juices[26]. The addition of citric acid, regardless of the source, may have contributed to the preservation of the vitamin A content in the watermelon juice, preventing its degradation during storage[27]. Furthermore, the vitamin A content of watermelon juice could have varied depending on various factors such as the ripeness of the fruit, storage conditions and processing methods. A study by Tlili *et al.*[28] investigated the bioactive compounds and antioxidant activities of different watermelon cultivars. The researchers found that the vitamin A content of watermelon varied depending on the fruit sampling area. This suggested that environmental factors and growing conditions could have influenced the vitamin A content of watermelon. Another study by Fredes *et al.*[29] assessed the fruit quality of

watermelons grafted onto citron melon rootstock. The researchers found that the volatile organic compounds, including acids, in watermelon, were influenced by the rootstock used. This suggested that the addition of citric acid may have altered the composition of organic compounds in watermelon, including vitamin A. Vitamin A was essential for maintaining healthy vision, immune function and cell growth[30].

$$\text{Vitamin A} = 1.75 - 0.0220A - 0.0260B - 0.0150C - 0.0250AB + 0.0100AC - 0.0175BC + 0.0245A^2 + 0.0245B^2 - 0.0205C^2 \quad (9)$$

The mathematical model for the Vitamin A content of the watermelon juice produced with citric acid extracted from June plum was presented in Equation 10. The coefficient of A (-0.0220) suggested that an increase in the concentration of citric acid had led to a decrease in the concentration of Vitamin A. Similarly, the coefficient of B (-0.0260) indicated that an increase in pasteurization time had resulted in a decrease in Vitamin A concentration. The coefficient of C (-0.0150) suggested that an increase in storage temperature had also led to a decrease in Vitamin A concentration. The interaction terms in the equation, such as AB (-0.0250), AC (0.0100) and BC (-0.0175), indicated that the combined effect of two variables had an impact on the concentration of Vitamin A. For example, the negative coefficient of AB suggested that the interaction between citric acid concentration and pasteurization time had negatively affected Vitamin A concentration. The squared terms in the equation, such as A^2 (0.0245), B^2 (0.0245) and C^2 (-0.0205), indicated that the relationship between the variables and Vitamin A concentration was not linear. These squared terms suggested that the relationship may have been nonlinear and that the effect of the variables on Vitamin A concentration may have changed as their values had increased or decreased.

Table 4 showed R^2 adjusted value of 0.5885 suggesting that approximately 58.85% of the variance in the vitamin A content could be explained by the independent variables in the equation. This indicated that the equation had moderate predictive power for the vitamin A content of the watermelon juice. CV (Coefficient of Variation) of 1.57 represented the relative variability of the vitamin A content in the watermelon juice. A CV of 1.57 suggested that the vitamin A content had a moderate level of variability relative to its mean value. This indicated that there may be some factors other than the independent variables in the equation that contributed to the variability in vitamin A content.

Figures 5 shows the contours of the model, which represents the different levels of Vitamin A content at different combinations of citric acid concentration, pasteurization time and storage temperature. Figure 5a shows that the vitamin A content of watermelon juice increased from 1.74 mg/100 mL to 1.78 mg/100 mL. This represented an increase of approximately 9%. Similarly increasing the pasteurization (12.76-16.38 sec) time and citric acid concentration (2.74-6.19 g) decreased the vitamin A content of the watermelon juice. Figure 5b shows that the vitamin A content of watermelon juice decreased from 1.87-1.76 mg/100 mL. This represented a decrease of approximately 9%. This also showed that the vitamin A content of watermelon juice continued to decrease as the storage temperature increased from 12.61 to 27.96°C. This is likely because vitamin A is a fat-soluble vitamin, which means that it dissolves in fat. Fat-soluble vitamins are more susceptible to degradation at higher temperatures than water-soluble vitamins[31]. The citric acid concentration also increased from 0.56 to 3.52 g as the vitamin A content increased. Figure 5c shows that the vitamin A content of watermelon juice decreased from 1.74 g/100 mL to 1.72 mg/100 mL. This represented a decrease of approximately 9%. Invariably the vitamin A content of watermelon juice continued to decrease as the storage temperature increased from 18.56-24.51°C and pasteurization time increased from 12.73-14.54 sec.

Vitamin C: From Table 3, the Vitamin C content of the watermelon juice produced with citric acid extracted from June plum differed significantly ($p<0.05$) as they ranged from 9.66 mg/100 mL and 8.10 mg/100mL while the watermelon juice with no citric acid had 8.37 (sample 22) mg/100 mL vitamin C content and that with commercial produced citric acid (sample 21) had 8.75 mg/100 mL vitamin C content. Sample 11 (with citric acid concentration at 0.5 g, pasteurized for 20 sec and stored at 0°C) had the highest content of vitamin C of 9.66 mg/100 mL while Sample 13 (with citric acid concentration at 10 mL, pasteurized for 20 sec and stored at 30°C) had the lowest Vitamin C content. Citric acid is known to have antioxidant properties and can help preserve the vitamin C content in fruits[32]. The addition of citric acid may have contributed to the retention of vitamin C in the produced watermelon. Watermelon juice is also a good source of vitamin C. A cup (237 mL) of watermelon juice contains 20% of the daily value of vitamin C[33]. Rapisarda *et al.*[34] investigated on the effects of storage temperature on blood orange fruit quality and found that ascorbic acid (vitamin C) decayed more rapidly at higher temperatures. This suggested that proper storage conditions are important for maintaining the vitamin C content of fruits.

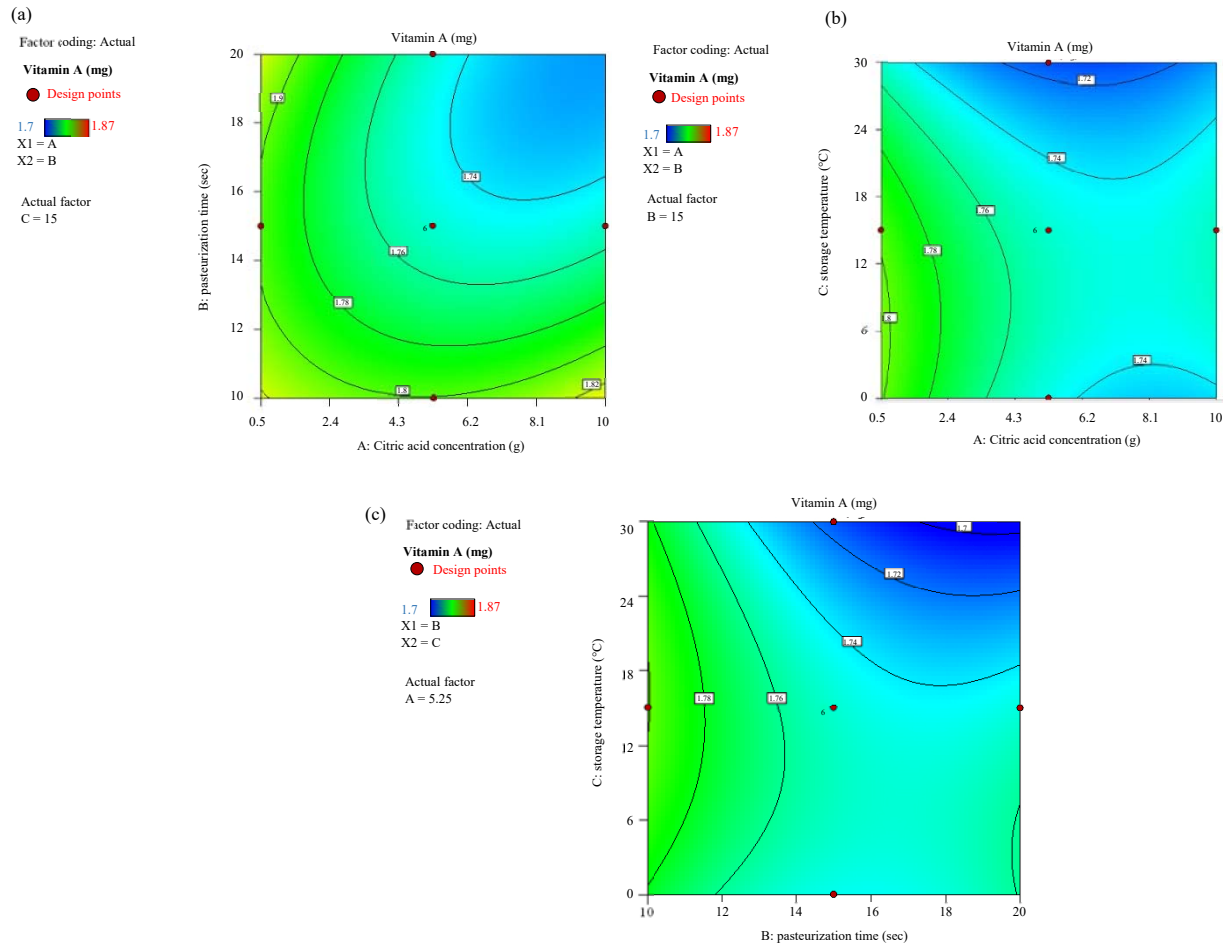

Fig. 5(a-c): Contour of the interaction effect of pasteurization time, citric acid concentration and storage temperature on vitamin A content of watermelon juice produced with citric acid extracted from June plum

$$\text{Vitamin C} = 8.94+0.1140A-0.1260B-0.3310C-0.3175AB -0.0300AC-0.2800BC \quad (10)$$

The mathematical model for the Vitamin C content of the watermelon juice produced with citric acid from extracted June plum was presented in Equation 11. In Equation 11, A represent the concentration of citric acid, B represented pasteurization time and C represented storage temperature. The coefficients in front of each variable indicated the effect of that variable on the concentration of vitamin C in the watermelon juice. The coefficient for A (0.1140) suggested that an increase in the concentration of citric acid had led to an increase in the concentration of vitamin C in the juice. This indicated that citric acid had a positive effect on the preservation of vitamin C. The coefficient for B (-0.1260) suggested that an increase in pasteurization time had led to a decrease in the concentration of vitamin C in the juice. This implied that longer pasteurization times may have resulted in a loss of vitamin C. The coefficient for C (-0.3310) suggested that an increase in storage temperature had led to a decrease in the concentration of vitamin C in the juice. This indicated that higher storage temperatures may have resulted in a degradation of vitamin C. The coefficients for AB (-0.3175), AC (-0.0300) and BC (-0.2800) suggested that there were interactions between the variables. These interactions indicated that the combined effect of two variables may have had a greater impact on the concentration of vitamin C than the individual effects of each variable alone. From Table 4, the R^2 adjusted value of 0.8113 indicated that approximately 81.13% of the variation in the vitamin C content of the watermelon juice had been explained by the variables included in the equation. This suggested that the equation was a reasonably good fit for the data. The CV (coefficient of variation) of 2.01 indicated the relative variability of the

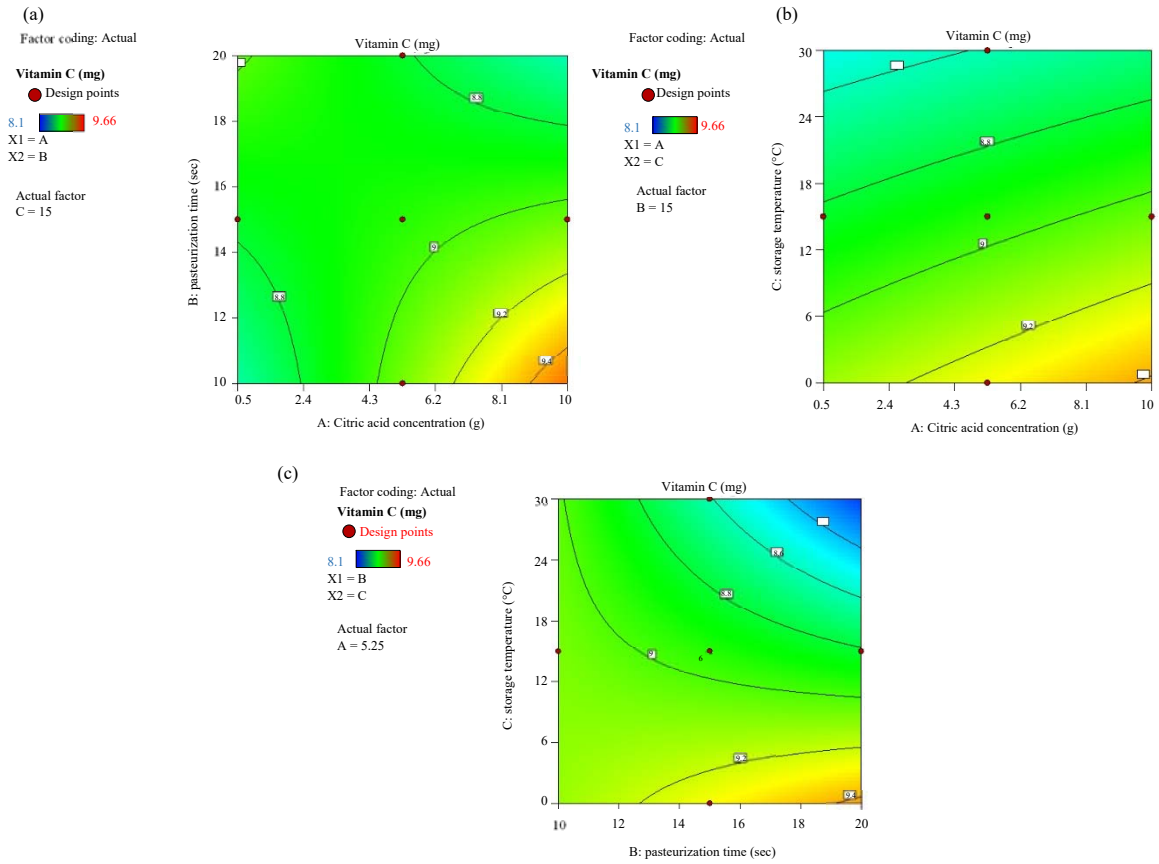

Fig. 6(a-c): Contour of the interaction effect of pasteurization time, citric acid concentration and storage temperature on vitamin C content of watermelon juice produced with citric acid extracted from June plum

vitamin C content in the watermelon juice. A CV of 2.01 suggested that the vitamin C content had a moderate level of variability compared to the mean value.

Figures 6 shows the contours of the model, which represent the different levels of Vitamin C content at different combinations of citric acid concentration, pasteurization time and storage temperature. Figure 6a shows that the vitamin C content of watermelon juice decreased as the pasteurization time and storage temperature increased. This is likely because vitamin C is a water-soluble vitamin, which means that it dissolves in water. Water-soluble vitamins are more susceptible to degradation at higher temperatures than fat-soluble vitamins[31]. As the pasteurization time increased from 11.03 to 17.86 sec and citric acid concentration increased from 8.95 to 10.02 g, the vitamin C content of watermelon juice decreased from 9.4 mg/100 mL to 8.8 mg/100 mL. This represented a decrease of approximately 26%. Figure 6b showed as the storage temperature increased from 8.98 to 26.40°C and citric acid concentration increased from 2.91 to 4.60 g, the vitamin C content of watermelon juice produced with citric acid from June plum decreased from 9.2 mg/100 mL to 8.6 mg/100 mL. Vitamin C is heat-sensitive due to its water-soluble nature, meaning it can dissolve in water[31]. Figure 6c showed that as the storage temperature increased from 5.53 to 25.37°C and pasteurization time increased from 12.71 to 17.65 g, the vitamin C content of watermelon juice produced with citric acid from June plum decreased from 9.2 mg/100 mL to 8.4 mg/100 mL.

Vitamin E: From Table 3, the Vitamin E content of the watermelon juice produced with citric acid extracted from June plum differed significantly ($p<0.05$) as they ranged from 3.37 mg/100 mL and 3.01 mg/100 mL while the sample 22 (watermelon juice with no citric acid) had 3.68 mg/100 mL vitamin E content and that with commercial made citric acid (sample 21) had 3.71 mg/100 mL vitamin E content. Sample 12 with citric acid concentration at 0.5 g, pasteurized for 10 sec and stored at 0°C has the highest content of vitamin E of

3.37 mg/100 mL while Sample with citric acid concentration at 0.5 g, pasteurized for 20 sec and stored at 30°C had the lowest Vitamin E content of 3.01 mg/100 mL. This indicated that the addition of citric acid from June plum to watermelon juice can slightly decrease the vitamin E content compared to the control sample without citric acid, which had a vitamin E value of 3.71 mg/100 g. This suggested that watermelon juice may retain more vitamin E if commercial citric acid is used. It is worth noting that the vitamin E content of watermelon can vary depending on various factors, including preharvest and postharvest conditions. Factors such as bruising, mechanical injuries and excessive trimming can lower the retention of vitamin E[35]. Therefore, it is important to handle watermelon carefully to minimize vitamin E loss. In addition to citric acid, other organic acids such as malic and oxalic acid can also be found in watermelon[36]. These organic acids may influence the overall nutrient composition of watermelon, including the vitamin E content.

$$\text{Vitamin E} = 3.16+0.0290A-0.0430B-0.075\,^{\circ}C \quad (11)$$

The mathematical model for the Vitamin E content of the watermelon juice produced with citric acid extracted from June plum is presented in Equation 4. It suggested that the concentration of Vitamin E in the watermelon juice is influenced by the concentration of citric acid (A), pasteurization time (B) and storage temperature (C). The coefficients associated with each variable indicated the magnitude and direction of their effect on the concentration of Vitamin E. The coefficient for A (0.0290) suggested that when citric acid concentrations were increased, Vitamin E concentrations were also increased. Similarly, the coefficients for B (-0.0430) and for C (-0.0750) indicated that when the pasteurization time and storage temperature were increased the concentration of Vitamin E decreased. From Table 4 the R^2 adjusted value of 0.42, measured the proportion of the variance in the dependent variable (Vitamin C content) that can be explained by the independent variables (concentration of citric acid, pasteurization time and storage temperature). An R^2 adjusted value of 0.42 indicated that approximately 42% of the variation in the Vitamin C content can be accounted for by the variables included in the equation. The CV (Coefficient of Variation) of 2.21 for the Vitamin C content indicated the relative variability of the data. A CV of 2.21 suggested that the standard deviation of the Vitamin C content was approximately 2.21 times the mean. This indicated a moderate level of variability in the Vitamin C content of the watermelon juice produced with citric acid extracted from June plum.

Figure 7 shows the contour of the interaction effect of pasteurization time and citric acid concentration. Figure 7 shows that as the pasteurization time decreased from 13.63-18.52 sec, the citric acid concentration increased from 5.5-7.87 g. Additionally, the vitamin E content in the watermelon juice produced with citric acid extracted from June plum decreased from 3.2-3.1 mg 100/mL. The vitamin E content was negatively affected by higher pasteurization times and citric acid concentrations.

Lycopene: The lycopene content of watermelon juice produced with citric acid extracted from June plum ranged from 4.56-3.81 mg $L^{-}1$, while watermelon made with commercial citric acid (sample 21) had a lycopene content of 4.04 mg/L and watermelon with no citric acid (sample 22) had a lycopene content of 3.89 mg $L^{-}1$. A similar study was conducted by Rawson *et al.*[37], who obtained a lycopene content in watermelon juice to be 4.02 mg $L^{-}1$. Lycopene is reported to be the prevailing carotenoid in red-fleshed watermelons, comprising 70-90% of total carotenoids[38]. The lycopene content can vary among different cultivars of watermelon, as demonstrated in a study that found variability in lycopene content among 11 red-fleshed watermelon cultivars[39]. Lv *et al.*[40] investigated changes in carotenoid profiles during fruit development and ripening in different watermelon cultivars. The researchers found that lycopene content varied widely among cultivars, with red-fleshed cultivars having the highest lycopene content. This suggests that lycopene content in watermelons can be influenced by genetic factors.

$$\text{Lycopene} = 3.95-0.0530A-0.0030B-0.2720C-0.0025AB+ 0.0800AC-0.0400BC-0.029A^2-0.0491B^2+0.2459C^2 \quad (12)$$

The mathematical model for the Lycopene content of the watermelon juice produced with citric acid extracted from June plum is presented in Equation 13. The coefficients in the equation showed the effect of each variable on the concentration of lycopene in the watermelon juice. The positive coefficients indicated a positive relationship, while the negative coefficients indicated a negative relationship. The coefficient for A (-0.0530) suggested that an increase in the concentration of citric acid led to a decrease in the concentration of lycopene in the juice. Similarly, the coefficient for B (-0.0030) indicated that an increase in pasteurization time led to a decrease in lycopene concentration. The coefficient for C (-0.2720) suggested that

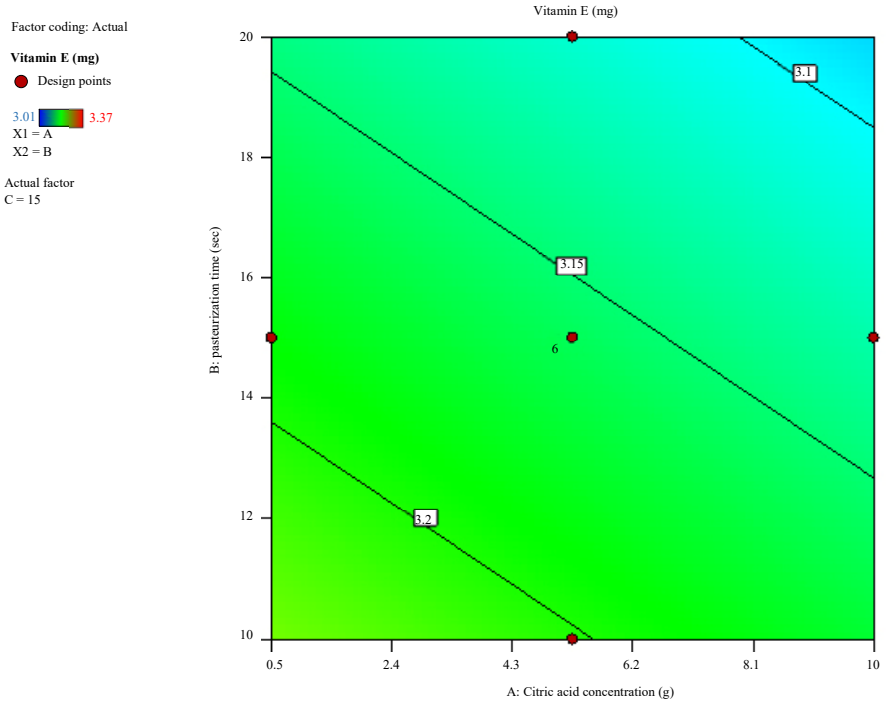

Fig. 7: Contour of the interaction effect of pasteurization time and citric acid concentration on vitamin E content of watermelon juice produced with citric acid extracted from June plum

an increase in storage temperature also led to a decrease in lycopene concentration. The interaction terms in the equation, such as AB (-0.0025), AC (0.0800) and BC (-0.0400), indicated the combined effect of two variables on lycopene concentration. For example, the negative coefficient for AB suggested that the interaction between citric acid concentration and pasteurization time negatively affected lycopene concentration. The squared terms in the equation, such as A^2 (-0.029), B^2 (-0.0491) and C^2 (0.2459), represented the nonlinear relationship between the variables and lycopene concentration. These terms indicate that the relationship between the variables and lycopene concentration was not linear. The R^2 adjusted value of 0.9448, measured the proportion of the variance in the dependent variable (vitamin C content) that can be explained by the independent variables (concentration of citric acid, pasteurization time and storage temperature). An R^2 adjusted value of 0.9448 suggested that approximately 94.48% of the variance in the vitamin C content can be explained by the independent variables in the model. The CV (coefficient of variation) of 1.39 for the vitamin C content indicated the relative variability of the data. A CV of 1.39 suggested that the standard deviation of the vitamin C content was 1.39 times the mean. This indicated a moderate level of variability in the vitamin C content of the watermelon juice produced with citric acid extracted from June plum.

Figure 8 show the contour of the model, which represents the combinations of citric acid concentration (A), pasteurization time (B) and storage temperature (°C). Figure 8a shows that lycopene content decreased with increasing pasteurization time. This is because pasteurization is a heat treatment process that kills harmful bacteria and other microorganisms[41]. The lycopene content of the fruit drink pasteurized for 10 seconds was slightly higher than the lycopene content of the fruit drink pasteurized for 6.2 sec. This suggested that there was a point of diminishing returns for pasteurization time. However, heat can also degrade nutrients, such as lycopene. Invariably the lycopene content decreased with increasing citric acid concentration. Citric acid is a natural preservative that helps to lower the pH of the fruit drink[41]. Figure 8b shows that lycopene content decreased with increasing storage temperature. This is because lycopene is a heat-sensitive compound[42]. The lycopene content of the watermelon juice stored at 3 °C was higher than the lycopene content of watermelon juice stored at 13.90 °C. When the fruit drink was stored at a high temperature, the lycopene degraded and the concentration of lycopene in the drink decreased[42]. The graph also showed that the rate of lycopene degradation increased with increasing storage temperature. This means that the fruit drink lost its lycopene content more quickly when stored at a high temperature. Figure 8c shows

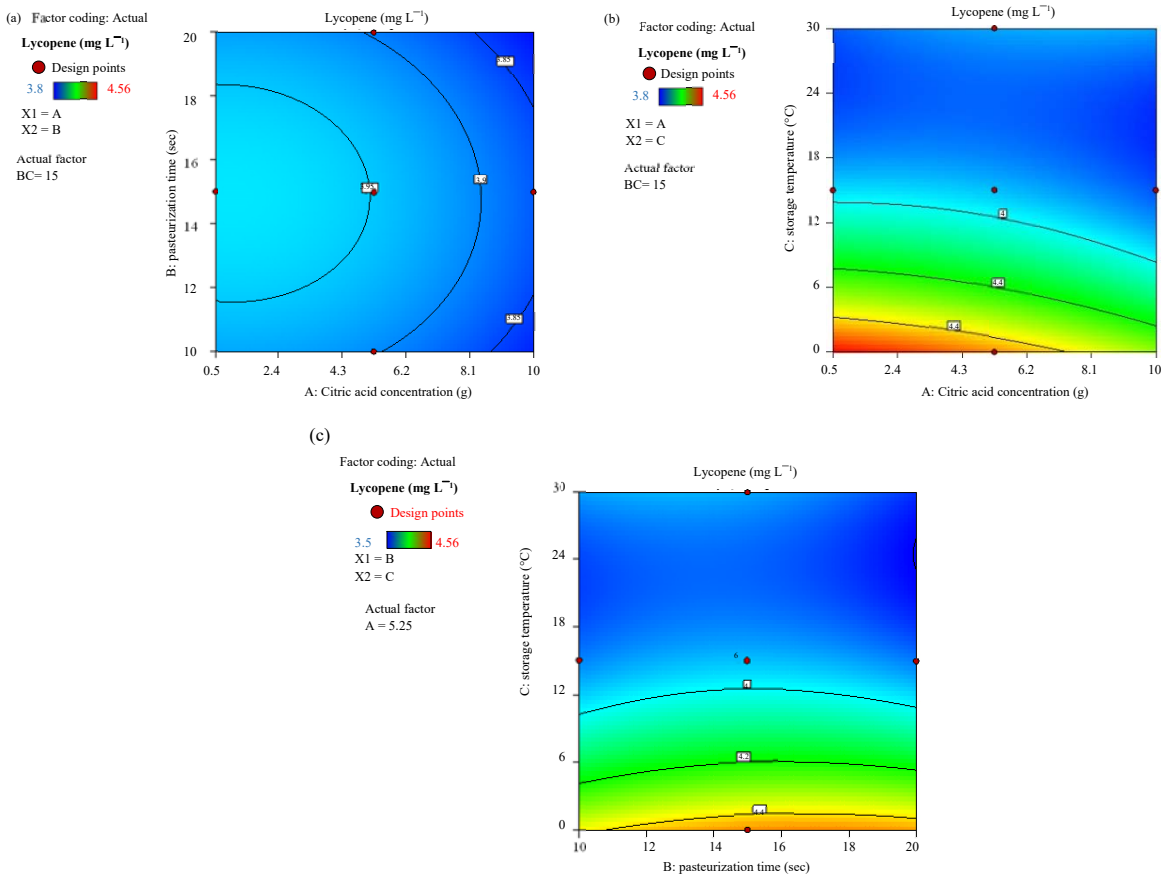

Fig. 8(a-c): Contour of the interactions effect of pasteurization time, citric acid concentration and storage temperature on lycopene content of watermelon juice produced with citric acid extracted from June plum

that lycopene content decreased with increasing storage temperature. This is because lycopene is a heat-sensitive compound. The lycopene content of the watermelon juice stored at 4.2°C was higher than the lycopene content of watermelon juice stored at 10.22°C, invariably the lycopene content decreased from 4.2 to 4.0 mg L^{-1}. When the fruit drink is stored at a high temperature, the lycopene degrades and the concentration of lycopene in the drink decreases.

CONCLUSION

The research findings reveal significant differences ($p<0.05$) in various components of the juice, including phenolic acid, flavonoids, vitamins A, C and E and lycopene. These differences were influenced by factors such as storage temperature (0°C, 15°C and 30°C), pasteurization time (10, 15, 20) and citric acid concentration (0.5, 5.25 and 10). Where the pasteurization temperature was kept constant at 75°C. Citric acid and pasteurization time played a vital role in affecting the phenolic acid content of watermelon juice. Higher levels of citric acid and longer pasteurization times tend to increase it, when stored at higher temperatures, its concentration decreases in a non-linear manner. The addition of citric acid, regardless of its source, enhanced the flavonoid content of the juice. Moreover, vitamins A, C and E are preserved by citric acid, possibly because of its antioxidant properties that safeguard these vitamins during storage. Using citric acid from June plum offers advantages in preserving the vitamin C and E content of the juice, with optimal conditions involving low citric acid concentration, brief pasteurization and low-temperature storage. Additionally, citric acid from June plum aided in protecting lycopene from degradation during storage.

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