Effect of Sugar, Pectin, and Processing Temperature on the Qualities of Pineapple Jam

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ABSTRACT
The present study aimed to investigate the effects of sugar, pectin, and processing temperature on the qualities of jam developed from pineapple (smooth cayenne). The physico-chemical, and proximate composition of pineapple fruit pulp and jam were studied and the results were reported. The jam quality depended highly on the concentration of sugars, pectin, and the processing temperature. Processing of pineapple fruit pulp into jam resulted in a substantial increase in physicochemical properties such as TSS and TA and showed some loss in the nutritional, vitamin C, and mineral composition of the products compared to fresh fruits. The processing methods showed significant effects on the phytochemical contents of the produced jam. Jam formulated with (45%) sugar, and (5%) pectin and processed at (90°C) temperature are proven as best products in terms of their nutritional composition, color, phytochemicals, and vitamin C. In conclusion, these results indicate that converting fresh pineapple into jam has an enormous potential to reduce the post-harvest loss of fresh pineapple fruits, and value-added product jam provides health-promoting compounds to human health.

KEYWORDS
Characterization; pineapple jam; optimization; vitamin C

Introduction
Food preferences and market expectations have changed dramatically over the last decade, with food goods with high nutritive value and bioactive compounds (Dubey et al., 2021). Fruits are essential sources of vital nutrients in the diet, such as carbohydrates, vitamins, bioactive components, and minerals. Pineapple (Smooth cayenne) which is commonly known as the king of fruits has an attractive flavor, and good nutritional value and is used as a source of vitamin C. Pineapple is produced for both fresh consumption and processing. It ranks third in tropical fruit production, following bananas and citrus fruits (Ali et al., 2020). Globally in 2019, around 26 million tons of pineapples were produced (Hadidi et al., 2020). However, more than 30% of these fruits are lost during and after leaving the farm gate, which leads to high annual economic losses. Fruit processing is one of the ways that is being used to reduce postharvest losses and it ensures fair returns to the growers to improve their financial condition (Dereje and Adera, 2020). It also promotes the availability of nutritious products in the market throughout the year to a wide range of consumers. Hence, to avoid postharvest losses and to increase the shelf life, pineapple fruits has to be processed into shelf-stable products such as juice, fruit bar, jelly, and jam. Jam is a good source of numerous nutrients including fibers, proteins, vitamins, and antioxidant compounds (Dubey et al., 2021). Pineapple is one of the fruits rich in sugar, especially sucrose, glucose and fructose, and other components such as minerals and vitamins which makes it an ideal raw material for jam preparation (JohAli et al., 2020; N et al., 2018). Fruit jam

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processing processes include steps such as extracting, clarifying, boiling, and stabilizing (Bhatnagar and Subramanyam, 2000). However, the quality of the jam is highly dependent on the concentration of each ingredient and processing parameters. In Ethiopia, very few studies were reported regarding the optimization of ingredients level and processing parameters for acceptable jam production from the pineapple fruit. As a result, the objective of this study was to assess the effect of sugar, pectin, and processing temperature on the qualities of pineapple jam and to optimize the process parameters.

Materials and Methods

Raw Material Collection

Fresh pineapple fruits having uniform maturity were obtained from Jimma Agricultural Research Center found in the Jimma area which is located 346 km from Addis Ababa, Ethiopia. The selected pineapple (Smooth cayenne) used for this study was due to its availability and nutritional quality. All collected raw materials were transported to Addis Ababa University’s School of Chemical and Bio-Engineering, Food Engineering laboratory. All samples were packed in a plastic bag and stored at 4°C in a refrigerator for further use. The reference or control sample was obtained from a local supermarket and stored at 4°C in a refrigerator. Sugar, pectin, and citric acid were bought from laboratory equipment and chemical suppliers (Merck and SD fine chemical suppliers) found in Addis Ababa, Ethiopia.

Experimental Design

The experimental design was planned with three factors (Temperature (°C), sugar (°Brix) and pectin (%)), with two levels. The two levels of these variables in random and standard orders were obtained using general factorial design (Design Expert 6.0.8) and given in Table 1 (a and b, respectively).

Preparation of Pineapple Jam

Five kilograms of pineapple were sorted and washed. The fruit was coarsely ground with a grinder for approximately 30s. The pineapple pulp (45%, 50%, and 55%), was mixed with sugar (45%, 50%, and 55%), and pectin (3% and 5%) in various combinations. The ground fruit pulp was brought to boil 90°C in a steam kettle to inactivate enzymes. Pectin (Purix powdered pectin) was added under manual agitation and the mixture was boiled at 100°C for 2 min to allow proper pectin hydration. The pH was checked and adjusted to a pH of 3.0 to 3.2 by the addition of a few drops of 50% citric acid solution. Sugar was added and the mixture was boiled to a final concentration of 65 to 68°Brix at different temperatures (90°C and 105°C). The jam was hot-packed at 90°C in glass jars and the jars were then cooled at room temperature (25°C) and stored at 4°C in a refrigerator until further analysis.

Chemical Composition

The chemical composition (moisture, protein, fat, ash, and crude fiber) of the fresh pineapple and the jam were determined as described in AOAC (2004). The total soluble solids were measured by the lab bench digital refractometer (Model RFM960-C, Bellingham Stanley) with samples equilibrated at 20°C before taking a measurement. In brief, 1 mL of each sample was poured on a refractometer prism and readings were taken and the values were expressed as °Brix. The pH measurements were done using edge” Multiparameter pH Meter (HI202001) attached to digital electrodes (Hanna Instruments, Inc). Before taking measurements, a three-point calibration with three different buffers (pH7.0, pH4.0, and pH10.0) was performed. Titratable acidity was determined by titration to a phenolphthalein end-point as described by AOAC (2004). In brief, a 10 mL sample was taken in a conical flask and mixed with
10 mL distilled water, and later titrated against 0.1 NaOH solution until the color of the solution was changed to pink using 3–4 drops of phenolphthalein indicator.

**Mineral Concentration**

The mineral concentration of the pineapple fruits and jam sample was determined by the principles of flame atomic absorption spectrophotometry (FAAS) using the atomic absorption spectrophotometer instrument (Model iCE 2100, v1.2, Australia, 2014) following the method of Issac and Johnson (1975).

**Vitamin C**

The vitamin C content of the pineapple fruit pulp and jam was determined by the titration method. Thirty grams of samples were weight and blended with an equal weight of 6% meta-phosphoric acid for 3–4 minutes. Ten ml of filtered solution was taken into a conical flask and titrated immediately against standard 2, 6-dichlorophenol indophenols dye solution till faint pink color was observed.

The ascorbic acid concentration was determined according to the following.

\[
\text{Ascorbic acid (mg/100 g)} = \frac{v \cdot t}{w} \cdot 100
\]

Where, \(v\) = volume of dye used in titration against an aliquant diluted sample,

\(t\) = value of standardized dye,

\(w\) = weight of the sample

**Phytochemical Analysis**

**Extract Preparation**

A 5-gram sample was extracted with 50 mL of methanol at 25°C at 150 rpm using an incubator shaker for 24 h. Afterward, the solution was filtered and concentrated using a water bath.

**Total Phenol**

The total phenolic content was determined by the spectrophotometric method (Kim et al., 2003) with slight modification. In brief, 1 mL of methanol 80% fruit extract was mixed with 1 mL of Folin-Ciocalteu’s phenol reagent and incubated for 5 min at room temperature (25°C) (State the temp). After 5 min, 10 mL of a 7% Na2CO3 solution was added to the mixture and adjusted to 13 mL with distilled water. The mixture was kept in the dark for 90 min, after which the absorbance was read at 750 nm. The total phenolic content was determined from extrapolation of the calibration curve (the standard curve was prepared by Gallic acid solution, 20–100 μg/mL) and expressed as μg mL/g of dried extract.

**Total Flavonoids**

The total flavonoid content of pineapple fruit pulp and jam was estimated by a method described by Zhishen et al. (1999) with slight modification. A volume of 1 mL of methanol 80% extract was mixed with 4 mL of distilled water and subsequently with 0.30 mL of a NaNO2 solution (10%). After 5 min, 0.30 mL AlCl3 solution (10%) was added followed by 2 mL of NaOH solution (5%) to the mixture. Immediately, the mixture was thoroughly mixed and the absorbance was then determined at 510 nm versus the blank. A standard curve of quercetin was prepared (10–500 μg/mL) and the results were expressed as quercetin equivalents (μg quercetin/g dried extract).

**Total Tannins**

The tannin content was determined by adopting the method of Peng et al. (2019) with slight modification. In brief, 1 gram of sample was mixed with 10 mL 1% HCl in methanol in the tube containing the sample, the mixture was shaken using a mechanical shaker for 24 h at room temperature (25°C) (state the temp) and then centrifuged the tube at 1000 rpm for 5 min. A volume of 1 mL supernatant was mixed with 5 mL of the vanillin-HCL reagent in another test tube. After 20 min the
absorbance of the solution was taken at 500 nm using a spectrophotometer (V-770, Japan). The total tannin content was calculated using the standard curve prepared from tannic acid (20–100 μg/mL) and expressed as μg mL/g dry extract.

**Color Measurement**

The developed pineapple jam samples were monitored for their surface color using a color flex spectrophotometer (Hunter Lab Reston, Model no. 45/0, USA, 2002) after being standardized using a Hunter Lab color stabilizer. The pineapple jam with different formulations covered by a glass plate was placed beneath the optical sensor at the tip of the instrument and allowed for postprocessing. The parameter recorded were, L*, a*, b*, Chroma, and Hue angle of the CIE scale.

**Statistical Analysis**

Data analysis was performed with SAS (SAS Institute Inc., Cary, NC). All results are mean ± standard deviation. Each analysis was made in duplicate. Analysis of variance (ANOVA) by Tukey’s range test at P ≤ .05 was applied for multiple comparisons of the means.

**Results and Discussion**

**Physical and Chemical Parameters of Fresh Pineapple Fruits**

The physical properties and chemical composition of raw pineapple fruit are part of the most important parameters required for the production of a good quality final product. The result of the physical parameters and chemical composition of the selected fresh pineapple fruit (Smooth Cayanne) is presented in Table 2. The results indicated that the measured parameters of the selected variant are within the range of common ripe pineapple cultivars grown in different countries (Ali et al., 2020; Sun et al., 2016).

**Effect of sugar, pectin concentrations, and processing temperature on the chemical composition of pineapple jam**

Table 3 shows the chemical parameters of the developed jam from the pineapple fruit such as pH, moisture content, ash, total acidity, soluble solids protein, fiber, fat, mineral, and vitamin C. The moisture contents ranged from 29.23% to 32.98%. The result was comparable with commercially produced jams with a moisture content of 31.23% to 33.36% on average. The processing parameters showed a significant difference in the moisture content of the developed jam (Table 3). The increase in the concentration of sugar, pectin, and temperature from 45% to 55%, 3% to 5%, and 95°C to 105°C, respectively, was found to lower the moisture content slightly. A similar observation was detected by Nwosu et al. (2014) in which they found that the difference in the moisture content of the end product depends upon the type of pectin used in the formulation. The shelf life of any food commodity is dependent on its moisture content (Fellows, 2004). The moisture content observed in all samples of the present study showed that all the jam samples could have a good shelf life as their moisture contents were found in the range with that of commercially available jam in the market. The ash contents of the pineapple jam were found in the range of 0.166–0.387%, which are comparable to that of grape, apricot, blueberry, and strawberry jams 0.18, 0.25, 0.12, and 0.23 g/100 g, respectively (Mohd Naem et al., 2017). There were significant (p < .05) differences among the jam samples obtained from the different formulations. Regarding the process parameters, as seen in Table 3, the ash contents of pineapple jam progressively increased with an increase in sugar concentration. However, as the temperature increased the amount of ash became slightly reduced. Ash content represents the total minerals such as calcium, potassium, and iron present in the jam samples.
In the present study, the total soluble solids (TSS) of the pineapple jams showed significant (p < .05) differences among each other due to the sugar and pectin concentration. The TSS was in the range of 63.5 to 71.65°Brix. It was observed that as the concentration of sugars increased the TSS of the jam also showed an increment value. The pectin and sugar concentration showed a significant (p < .05) effect on the TSS. However, the temperature did not show any significant (p > .05) effect on the TSS. Sugar is the most significant constituent of fruits which acts as a preservative and has an effect on the TSS value which is important for the quality of the jam during storage (Ayub et al., 2010).

The values of pH observed in different samples are given in Table 3. The data showed that the pH of the different formulations of pineapple jam ranged from 2.92 to 3.32 which are within the prescribed
Table 3. Proximate composition of pineapple jam as influenced by the processing parameters

| RUN  | MC (%)       | Ash (%)     | pH         | TA         | TSS (°Brix) | C. Fat (%) | C. Fiber (%) | C. Protein (%) |
|------|--------------|-------------|------------|------------|-------------|------------|--------------|----------------|
| J1   | 29.83±0.24c  | 0.28±0.00cde| 3.07±0.03cd| 1.08±0.00c | 68.5±0.14bc | 0.52±0.01a | 0.42±0.03d  | 0.05±0.01f    |
| J2   | 29.40±0.14c  | 0.39±0.00a  | 2.92±0.01f | 1.39±0.01a | 71.65±0.35a | 0.53±0.02a | 0.76±0.02d  | 0.38±0.02a    |
| J3   | 32.07±0.02ab | 0.27±0.00f  | 2.97±0.01ef| 0.90±0.00a | 66.35±0.14cd| 0.54±0.01a | 0.45±0.01f  | 0.05±0.01f    |
| J4   | 31.77±0.02ab | 0.30±0.00c  | 3.02±0.03de| 1.27±0.01h | 66.70±0.14bcd| 0.38±0.05ab| 0.53±0.02f  | 0.26±0.03bc   |
| J5   | 30.32±0.28bc | 0.34±0.00b  | 2.98±0.02ef| 1.27±0.01h | 66.40±0.14ab | 0.15±0.02cd| 0.51±0.02d  | 0.37±0.02bc   |
| J6   | 32.50±0.14ab | 0.17±0.00f  | 3.07±0.01cd| 1.08±0.00c | 63.50±0.14cd| 0.39±0.02ab| 0.57±0.02e  | 0.30±0.01b    |
| J7   | 32.38±0.28ab | 0.28±0.01dfe| 3.32±0.01c  | 1.08±0.00c | 66.30±0.35cd| 0.51±0.02d | 0.4±0.020    | 0.10±0.013ef  |
| J8   | 29.26±0.00f  | 0.27±0.00dfe| 3.08±0.01cd| 1.08±0.00c | 71.10±0.14cd| 0.25±0.02cd| 0.57±0.03e  | 0.17±0.02d    |
| J9   | 29.23±0.01c  | 0.29±0.00de | 3.04±0.00de| 1.08±0.00c | 64.00±0.14ab | 0.24±0.02bc| 0.67±0.03d  | 0.15±0.024ab  |
| J10  | 29.37±0.04f  | 0.30±0.00de | 3.07±0.01cd| 1.09±0.01c | 67.25±0.07abcd| 0.06±0.02cd| 0.88±0.02b  | 0.26±0.04b    |
| J11  | 32.98±0.68a  | 0.29±0.00de | 3.315±0.05a | 0.90±0.00| 66.20±0.14cd | 0.38±0.02ab| 1.02±0.02a  | 0.20±0.01cd  |
| J12  | 33.84±0.00a  | 0.29±0.00cd | 3.13±0.01bc | 0.97±0.01d| 63.30±0.21cd | 0.42±0.02a | 0.74±0.02c | 0.25±0.025bc |
| Control | 31.77±0.02abol | 0.30±0.00c  | 3.02±0.03de | 1.27±0.01b| 66.40±0.14ab | 0.15±0.02cd| 0.42±0.025c | 0.30±0.01b    |
| Range | 4.59         | 0.22        | 0.43       | 0.49       | 8.80        | 0.49       | 0.64        | 0.35            |

All values were the means of duplicate determination ± SD (Standard deviation). Values expressed with similar subscripts are not significantly different by Duncan multiple range Test across the columns (p ≤ 0.05).
limits of Abodolereza and Racionzer (1). These variations are due to differences in the ingredient proportions and processing parameters. The temperature showed a significant \( p < .05 \) difference in the pH value of all samples. It was detected that the pH value of the jam sample become slightly increased with rising in temperature from 90°C to 105°C.

Similarly, sugar concentration resulted in significant \( p < .05 \) differences in the pH values. As the sugar concentration increased from 45% to 55% the pH value of the samples slightly increased, which indicates decreasing acidity of the sample. Pectin also had a significant \( p < .05 \) difference in the pH value. An inverse result was reported by Afokwa et al. (2006) who did not observe any significant effect of pectin on the pH of jam. The pH value of jam is an important factor to obtain optimum gel condition. Hence, it is important to control the pH values during jam processing to obtain a good quality product. The pH value of a food is directly related to the free hydrogen ions in that food and the recommended level of pH is in the range of 3.0 to 3.5 for jam (Abodolereza and Racionzer). Acids present in foods not only improve the palatability of many fruit products but also influence their nutritive value by playing a significant role in the maintenance of acid-base balance in the body. The value of titratable acidity ranged from 0.90 to 1.39 mg/100 g which is in line with the standard value of good quality jam (Garg et al., 2019). The J2 formulation containing 45% sugar had 1.39% acidity which was the highest acidity value. J3 sample having 55% sugar exhibited 0.90%. These variations were due to differences in the ingredient proportions and processing temperature. Sugar concentration and temperature had a significant \( p < .05 \) influence on the titratable acidity. The total acidity values in the present study showed that an increase in sugar concentration decreased the total acidity. Similarly, when the temperature was raised from 90°C to 105°C, the total acidity of the jam slightly decreased. This might be due to the increment of the pH value of jam as the processing temperature increased.

Pectin made no significant \( p > .05 \) difference in total acidity. It was found that the lowest percentage of acidity (0.90%) was exhibited by J3 (sugar 50%, 5% pectin boiled at 90°C). Titratable acidity is one of the most important quality parameters in jam processing. The acidity of a food product influences the stability and shelf life of that product. The protein content of the developed jam samples ranged from 0.05% to 0.373%; with J3 (sugar 50%, 5% pectin boiled at 90°C) having the lowest value whereas the J5 (sugar 50%, 3% pectin, boiled at 105°C) sample had the highest protein content (Table 3). This finding is comparable with the protein content of jackfruit (0.19 g/100 g) and pineapple jam (0.46 g/100 g) reported by Eke-Ejiofor and Owuno (2013). The processing temperature, sugar, and pectin concentration had a significant influence \( p < .05 \) on the protein content of jam samples. When comparing fresh fruit with the jam, the protein content declined in the jam. It decreased with an increase in temperature. The decrease could either be due to protein denaturation or degradation. Similarly, when the concentration of sugar and pectin increased the protein content of the jam samples showed a slight decrease. The present result indicated that the samples had high protein content as compared to the control sample (0.2%) that was obtained from the market and used as a reference. The fat content of the jam samples ranged from 0.15% to 0.535%. The fat content of the control sample was low (0.15%). The result obtained from the study showed that the fat content was significant \( p < .05 \) differently from each other. When comparing fresh fruit pulp with the corresponding developed fruit jam, it is observed that the operation condition led to a decrease in fat content. The fat content of pineapple jam slightly reduced as the concentration of sugar increased. This might be attributed to the ratio of composition of the fruit pulps to sugar. Higher temperatures contribute to a higher percentage reduction in fat content in a jam (Fennema, 1997).

There was a significant \( p < .05 \) difference in the fiber contents among all the samples. Sample J11 (sugar 55%, 5% pectin, boiled at 105°C) had the highest fiber value (1.02%), while the J7 (sugar 50%, 3% pectin, boiled at 90°C) sample had the lowest value (0.4%). This result is consistent with the reports of Ramulu and Rao (2003) on fruit jams such as orange, plum, and guava (0.3 to 5.2 g/100 g). As shown in Table 3 the fiber content of pineapple jam samples indicated a slight decrease as the concentration of sugar and the processing temperature increased. Besides, when compared with fresh pineapple fruit pulp, the crude fiber was low in the developed pineapple jam. This decrease can be attributed to the addition of sugar in the preparation of jam. Similarly, the loss of fiber was likely due to thermal degradation resulting
| sample code | K (mg/100 g) | Mg (mg/100 g) | Ca (mg/100 g) | Fe (mg/100 g) | vitamin C (mg/100 g) |
|-------------|--------------|---------------|---------------|---------------|-------------------|
| J1          | 0.30 ± 0.01<sup>a</sup> | 3.12 ± 0.02<sup>b,c</sup> | 2.18 ± 0.04<sup>b</sup> | 0.58 ± 0.02<sup>def</sup> | 8.20 ± 0.07<sup>def</sup> |
| J2          | 0.26 ± 0.00<sup>a</sup> | 2.6 ± 0.08<sup>d</sup> | 2.28 ± 0.06<sup>ab</sup> | 0.52 ± 0.05<sup>f</sup> | 7.79 ± 0.20<sup>f</sup> |
| J3          | 0.16 ± 0.00<sup>bc</sup> | 3.36 ± 0.01<sup>a</sup> | 2.39 ± 0.02<sup>ab</sup> | 0.88 ± 0.02<sup>bc</sup> | 8.02 ± 0.10<sup>def</sup> |
| J4          | 0.06 ± 0.00<sup>d</sup> | 3.08 ± 0.01<sup>c</sup> | 2.28 ± 0.00<sup>ab</sup> | 0.64 ± 0.02<sup>cd</sup> | 8.82 ± 0.10<sup>d</sup> |
| J5          | 0.06 ± 0.00<sup>c</sup> | 3.08 ± 0.14<sup>c</sup> | 2.26 ± 0.03<sup>ab</sup> | 0.67 ± 0.01<sup>bc</sup> | 8.86 ± 0.07<sup>bc</sup> |
| J6          | 0.23 ± 0.01<sup>a</sup> | 2.83 ± 0.07<sup>d</sup> | 2.19 ± 0.02<sup>b</sup> | 0.60 ± 0.01<sup>d</sup> | 9.78 ± 0.021<sup>bc</sup> |
| J7          | 0.16 ± 0.00<sup>a</sup> | 3.33 ± 0.02<sup>ab</sup> | 2.39 ± 0.01<sup>ab</sup> | 0.88 ± 0.003<sup>a</sup> | 9.90 ± 0.12<sup>bc</sup> |
| J8          | 0.23 ± 0.01<sup>a</sup> | 3.22 ± 0.02<sup>ab</sup> | 2.41 ± 0.02<sup>a</sup> | 0.59 ± 0.08<sup>de</sup> | 7.74 ± 0.09<sup>f</sup> |
| J9          | 0.26 ± 0.05<sup>a</sup> | 3.20 ± 0.01<sup>ab</sup> | 2.401 ± 0.00<sup>d</sup> | 0.67 ± 0.02<sup>bc</sup> | 8.39 ± 0.07<sup>c</sup> |
| J10         | 0.30 ± 0.00<sup>a</sup> | 3.008 ± 0.01<sup>bc</sup> | 2.20 ± 0.00<sup>ab</sup> | 0.56 ± 0.03<sup>de</sup> | 7.92 ± 0.09<sup>ef</sup> |
| J11         | 0.30 ± 0.01<sup>a</sup> | 2.63 ± 0.05<sup>d</sup> | 2.36 ± 0.01<sup>ab</sup> | 0.53 ± 0.01<sup>ef</sup> | 8.33 ± 0.10<sup>cd</sup> |
| J12 Control | 0.07 ± 0.00<sup>c</sup> | 3.10 ± 0.00<sup>c</sup> | 2.321 ± 0.04<sup>ab</sup> | 0.74 ± 0.02<sup>b</sup> | 9.72 ± 0.05<sup>a</sup> |
| Range       | 0.25          | 0.81          | 0.27          | 0.39          | 8.82 ± 0.10<sup>bc</sup> |

All values were the means of duplicate determination ± SD (Standard deviation). Values expressed with similar subscripts are not significantly different by Duncan multiple range Test across the columns (p ≤ .05).
in disruption of the polysaccharide network of the cell wall (Di Scala et al., 2011; Miranda et al., 2010) degradation because of the thermal treatment.

The vitamin C content recorded was in the range of 7.74 to 9.9 mg/100 g on average (Table 4). The present result is in line with the reported values of Siddiqui et al. (2015) on jams. An increase in temperature increased the loss of vitamin C. Similar results were reported by Jawaheer et al. (2003) who observed 62.5% loss of ascorbic acid in guava jam after processing. Ascorbic acid is sensitive to heat, light and high temperature during processing. Long-term heating in the presence of oxygen during processing can reduce the vitamin C content (Dereje and Abera, 2020).

**Effect of Sugar, Pectin Concentrations, and Processing Temperature on the Mineral Composition**

The mineral contents of the jam samples are presented in Table 4. The mineral profile indicated the presence of beneficial mineral elements such as iron (0.884 mg/100 g), potassium (0.303 mg/100 g), calcium (2.405 mg/100 g), and magnesium (0.884 mg/100 g) in the jam formulation. Macro-minerals and micro-minerals are required in amounts greater than 100 mg and less than 100 mg respectively. It is expected that the range of the results should be stated and not absolute values.

Calcium content was found to decrease slightly in pineapple jam as compared to pineapple fruit pulp. Heat-induced firming results in damage to cell membranes that causes an increase in permeability. This leads to the liberation of Ca$^{2+}$ (Tanwar and Modgil, 2014).

As shown in Table 4 there was a significant ($p < .05$) difference in the iron contents of all the samples. Iron improves the component of cytochromes, and electron transport, activates some enzymes, and plays a role in chlorophyll synthesis. The iron content of pineapple jam decreased significantly when compared with the pineapple pulp which can be due to high-temperature processing, but the addition of sugar to the fruit pulp in the processing of pineapple jam showed increasing values in the iron content of each sample.

*Figure 1.* Optimization plot (a-c) showed the effect of process conditions (factors) on the response of composite desirability. Note Vertical Red Line: Current Factor Setting; Number at the top of the column: current factor level setting (in Red); Horizontal Blue lines and numbers (y): Response for current factor level; D: Composite desirability; d: Individual response desirability.
Potassium is a cofactor that functions in protein synthesis, activation of enzymes, major solute functioning in water balance and thus affecting osmosis, operation of stomata. The result showed that potassium contents were slightly increased when the concentration of sugar increased. However, as reflected in Table 4 the concentration of potassium slightly decreased as compared with the fresh pineapple fruit pulp. As indicated in Table 4 the processing condition had a significant ($p < .05$) effect on the magnesium contents of jam samples. The processing temperature has a lowering effect on the magnesium content of pineapple jam samples. Magnesium improves the component of chlorophylls, and activates many enzymes.

**Effect of Sugar, Pectin Concentrations, and Processing Temperature on the Color**

It was observed that the jam lost its particular color due to the reduction of its lightness (lowest L). The Maillard reaction occurred during high processing temperature which contributed to the formation of brown pigment which resulted in a dark color (Touati et al., 2014). One of the most important parameters that determine consumers’ choice of foods is color. The external appearance of the product particularly arising from color is of prime importance (Perez-Lopez, 2010). It was noticed that in this research, color parameters underwent a significant reduction in values. Jam showed significantly lower $L^*$, $a^*$ and $b^*$ values than fresh fruit. The changes in color values were assumed as a result of thermal degradation during heat treatment, illumination, oxygen content and storage conditions (Ma et al., 2008; Perez-Lopez, 2010). A decrease for $L^*$ value in a jam sample was reported by Igual et al. (2010).

**Effect of Treatments on Phytochemical Properties of Pineapple Jam**

The effect of treatments on phenolic contents of all treatments of pineapple jam is presented in Table 6. Processing parameters resulted in a significant ($p < .05$) influence on the total phenolic contents of the pineapple jams It is obvious from the data that maximum total phenolics content was observed in jam samples that were processed at a lower temperature (90°C) and minimum values were observed at the highest processing temperature (105°C). This may be due to the reason that direct and long-term heating of pulp during the processing of jam results in more loss of bioactive compounds. Rababah et al. (2011) observed similar findings on phenolic contents and antioxidant capacity in different jams developed from different fruits.

There was further flavonoid loss during processing. After processing, flavonoid levels decreased further, during high-temperature treatment. The treatment conditions have a significant influence ($p < .05$) on all samples. The addition of sugar had a significant effect on the flavonoid content of the

**Table 5.** Color of pineapple jam as affected by the processing condition.

| Sample code | L*   | a*     | b*     | c     | h     | W     |
|-------------|------|--------|--------|-------|-------|-------|
| J1          | 28.08 | −0.19c | 6.24j  | 6.24j | 91.70b| 27.81f|
| J2          | 30.56 | −0.56e | 7.80b  | 7.82b | 94.11j| 30.12j|
| J3          | 26.34 | −0.98j | 6.78d  | 6.85s | 98.18g | 26.02f|
| J4          | 28.13 | 0.84d | 6.63h | 6.68h | 82.77j | 27.82h |
| J5          | 29.63 | −0.57f | 7.80h  | 7.82s | 94.15j | 29.19j |
| J6          | 29.87d| −0.98k | 6.87n | 6.94d | 98.12d | 29.53d|
| J7          | 29.19 | 0.96i  | 6.33l  | 6.40l | 98.58b | 28.90g |
| J8          | 30.07 | −0.74h | 6.71g  | 6.75g | 96.29g | 27.95c |
| J9          | 25.19 | −0.09b | 6.80p  | 6.80f | 90.72j | 24.88j |
| J10         | 30.53 | 1.26f  | 6.09k  | 6.21k | 101.70a | 30.25a |
| J11         | 26.57 | −0.48d | 5.23l  | 5.25m | 95.20d | 26.38j |
| J12 Control | 29.36 | 26.72j | −0.78  | 5.52b  | 7.72l | 95.89  | 94.21h | 28.95j  | 27.65m |

$L^*$ = Lightness. $a^*$ = Red/ Green coordinate. $b^*$ = Yellow/ Blue coordinate. $C$ = Chroma. $h$ = Hue angle. $W$ = Range of the highest score minus the lowest score. $a$, $b$, $c$ Mean ±SD within the same column followed by different letters are significantly different ($p < 0.05$). SD = Standard deviation of a duplicate sample.
Table 6. Effects of processing parameters on phytochemicals of pineapple jam.

| Sample code | Flavonoid (μg quercetin/g) | Phenol (μg GA/ g) | Tannin (μg GA/ g) |
|--------------|-----------------------------|-------------------|-------------------|
| J1           | 0.28 ± 0.02<sup>a</sup>    | 0.30 ± 0.00<sup>a</sup> | 0.27 ± 0.01<sup>a</sup> |
| J2           | 0.24 ± 0.01<sup>b</sup>    | 0.26 ± 0.01<sup>e</sup> | 0.25 ± 0.02<sup>b</sup> |
| J3           | 0.543 ± 0.03<sup>b<sub>bc</sub></sup> | 0.48 ± 0.03<sup>b</sup> | 0.40 ± 0.00<sup>b</sup> |
| J4           | 0.49 ± 0.03<sup>a</sup>    | 0.42 ± 0.00<sup>c</sup> | 0.35 ± 0.01<sup>c</sup> |
| J5           | 0.57 ± 0.01<sup>a</sup>    | 0.41 ± 0.01<sup>c</sup> | 0.49 ± 0.00<sup>b</sup> |
| J6           | 0.58 ± 0.02<sup>a</sup>    | 0.27 ± 0.01<sup>e</sup> | 0.50 ± 0.01<sup>a</sup> |
| J7           | 0.47 ± 0.02<sup>d</sup>    | 0.36 ± 0.02<sup>d</sup> | 0.42 ± 0.01<sup>d</sup> |
| J8           | 0.23 ± 0.01<sup>n</sup>    | 0.25 ± 0.01<sup>e</sup> | 0.23 ± 0.01<sup>n</sup> |
| J9           | 0.50 ± 0.04<sup>b<sub>cd</sub></sup> | 0.45 ± 0.01<sup>bc</sup> | 0.46 ± 0.01<sup>bc</sup> |
| J10          | 0.25 ± 0.02<sup>e</sup>    | 0.54 ± 0.03<sup>a</sup> | 0.26 ± 0.01<sup>e</sup> |
| J11          | 0.49 ± 0.01<sup>c</sup>    | 0.44 ± 0.01<sup>bc</sup> | 0.48 ± 0.02<sup>c</sup> |
| J12 Control  | 0.56 ± 0.01<sup>b<sub>bc</sub></sup> | 0.43 ± 0.024<sup>d</sup> | 0.54 ± 0.03<sup>a</sup> |
| Range        | 0.36 ± 0.03<sup>c</sup> | 0.41 ± 0.00<sup>c</sup> | 0.52 ± 0.01<sup>a</sup> |
|              | 0.31 ± 0.00<sup>c</sup> | 0.35 ± 0.00<sup>c</sup> | 0.30 ± 0.00<sup>c</sup> |

- All values were means of duplicate determination ± SD (Standard deviation).
- Values expressed with similar subscripts are not significantly different by Duncan multiple range Test across the columns (p ≤ 0.05).

Table 7. Response optimization (parameters).

| Response | Goal  | lower | target | weight | importance |
|----------|-------|-------|--------|--------|------------|
| b*       | maximum | 5.23 | 7.80 | 1 | 1 |
| vitamin C | maximum | 7.67 | 9.96 | 1 | 1 |
| TSS      | maximum | 63  | 71.8  | 1 | 1 |

Table 8. Response optimization (solutions).

| Solution | Temperature (°C) | sugar % | pectin % | b* | vitamin C | TSS | Composite |
|----------|------------------|--------|----------|----|-----------|-----|-----------|
|          |                  |        |          | Fit|           | Fit | Desirability |
| 1        | 90               | 45     | 3        | 7.52 | 9.72 | 71.65 | 0.92 |
| 2        | 90               | 45     | 5        | 6.87 | 9.78 | 66.7 | 0.63 |
| 3        | 105              | 50     | 3        | 7.80 | 8.86 | 67   | 0.62 |

jam samples. A decrease in flavonoids during cooking in an open pan of strawberry jams was also observed by Hakkinen et al. (2000). The cell structure of fruit is damaged during processing, making fruit more susceptible to non-enzymic oxidation, which in turn may be one of the main reasons for the loss of phenolic substances (Patras et al. 2011). The significant (p < .05) decrease in the flavonoid content of pineapple jam when compared with pulp could be due to the addition of sugar in the processing which did not contribute to the flavonoid content of the products. As reported by Crosier et al. (1997), and Price and Rhodes (1997) this decrease could probably be due to chemical or thermal degradation of the flavonoids during processing.

Significant loss (p < .05) of tannins in the pineapple jam than pineapple pulp was observed due to thermal degradation of tannins. The considerable decrease of tannins in the products could be due to the extraction and release of tannins from the cell matrix, due to the breakage of bonds with proteins (Shah, 2001). Pineapple jam which was processed under a lower processing temperature (90°C) had the highest value of total tannins compared with the jam sample which was processed under a high processing temperature (105°C).

Response Optimization

Different process conditions affect the predicted responses (Table 7). Changing variables on the optimization plot was aimed at searching input variable settings with higher composite desirability. Pineapple jam response optimized based on maximum vitamin C, yellowness (for color) and TSS mean value of prepared Pineapple jam (Table 8).
The optimization plot (Figure 1a-c) showed the effect of process conditions (factors) on the response of composite desirability. Individual response and composite desirability for selected experimental runs were displayed on an optimization plot. Table 5b showed pineapple jam preparations from the following combination of process conditions that were selected as optimal process variables with higher TSS, vitamin C and yellowness (for color) with varying composite desirability values (1/ T:90°C: S:45%; P:3%, 2/ T:90°C: S:45%; P:5%, 3/T:105°C: S:50%; P:3%).

**Conclusion**

Fruit jam was successfully developed from pineapple (Smooth Cayenne) fruits, pectin and sugar ingredients. The study concluded that it was necessary to choose adequate ingredients and process conditions so that the high quality and appropriate quality product of pineapple jam was obtained. The pineapple fruit pulp was processed into jam and resulted in a substantial increase in physical-chemical propensities, such as gross soluble solids and titratable acid. Although there was a decrease in the nutritional composition of pineapple products than pulp; it can be said that processing pineapple fruits into jam ensure the safety and quality of the products without much loss of nutrition and vitamin C, which is not feasible with the pineapple fruit as such owing to its perishable nature. Pineapple (Smooth Cayanne) fruits, like most fresh fruits, have a short harvest season and are sensitive to deterioration and even when stored under refrigerated conditions due to biochemical changes and chilling injury. For this purpose, making fruit jams from fresh fruits in the regions of Ethiopia is an effective way to preserve pineapple (Smooth Cayanne) fruits during their peak harvesting season. The study is convenient for different food sectors and customers who are health-conscious. Fruit jam production from local and existing resources can thus be used as a way of substituting imports and contributing to the protection of food and nutrition. The practical application, through the processing and promotion of fruit jam products, contributes to generating work opportunities for the community. Furthermore, the process improvement and shelf life needed to be determined for practical applications.

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