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Research article

Production and Processing Effects on Antioxidant Properties of Jam Produced from Apple (*Malus Domestica*) and Orange (*Citrus Sinensis*) Fruits

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ABSTRACT

Phytochemical content of fruits and their processed products have been linked to their protection against chronic and degenerative diseases as reported in a quite number of studies. Food loss can be attributed to affluent people's willful food waste, avoidable handling/processing operation losses, or losses suffered as a result of the perishability of many agricultural products. The goal of this study was to make jam from apple and orange fruits, evaluates the processing effect on antioxidant properties, assess the organoleptic quality and acceptability of jam produced. Samples of *Malus Domestica* and *Citrus Sinensis*, were purchased from open markets in Ibadan. Jam from samples was and were brought to laboratory in a sterilized jar. Laboratory analysis was used to determine flavonoid, vitamin C, total phenol, total antioxidant activity, pH, titratable acidity, total soluble solid (oBrix). The total soluble solids increased significantly ($p < 0.05$) ranging from (54.00 to 61.00°Brix), total phenolic content ranging from (2.21 to 2.24), total antioxidant capacity ranging from (56.56 to 58.36) and there was decrease in pH, titratable acidity and vitamin C of both samples. The sensory evaluation shows that orange jam was more accepted in terms of flavor and colour, apple jam was accepted in terms of taste, and acceptability in, texture was high for both, the overall acceptability was higher in apple jam. It was therefore concluded that thermal processing does not significantly deteriorate health-promoting antioxidant properties in these fruits.

Keywords: *Food security, Fruits, Jam, phenols and thermal effects*

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INTRODUCTION

Fruits are the fleshy seed associated composition of a plant which has either sweet or sour taste and are edible in the raw state. Fruits are rich in fiber, vitamins (in particular vitamin C), and antioxidants. However fresh fruits might rot, their shelf life can be extended by refrigerating them or removing oxygen from their storage or packaging vessels. Dehydration, canning, fermentation, and pickling are all methods for preserving fruits as juices, jams, and jellies.etc. the most cultivated fruit includes, pineapple, pawpaw, apple, cashew, orange, grape, strawberry, banana, mango and lemon. vitamins, minerals and fiber are common beneficial uses when fruits are consumed (Editors of encyclopedia, 2021).

Fruits have a high content of phenolic compounds, which contribute to their antioxidant activity, these phytochemical content and antioxidant activity of fruits and their processed products have been linked to their protection against chronic and degenerative diseases as reported in number of studies. Because the evaluation of the antioxidant capacity of foods commonly consumed in the diet is of great importance (Ouarda *et al*., 2016). Jam is a shelf-stable food product from fruit pulp, pectin and sugar cooked to form a gel. Fleshy or pulpy fruits such as pineapple, pawpaw, apple, banana and mango or combination of these fruits are usually employed (Ullah *et al*., 2018). Jam has a long shelf life and may therefore be made available all year. To get the intended result, the proper proportions of the right ingredients, which include fruits, acid, pectin, and sugar, must be used in the right proportions. (Olugbenga *et al*., 2018)

Food insecurity is a worldwide problem that has persisted to this day. Appropriate agricultural food production and use to maintain the world's estimated 7.6 billion inhabitants has sparked widespread outrage. Furthermore, research has revealed that food loss occurs as a result of affluent people's willful food waste, avoidable handling/processing operation losses, or losses suffered as a result of the perishability of many agricultural products. (Gayatri Nahak et.,al 2014)

Fruit jam serve as preserve and source of micronutrient and phytonutrients during off season, thereby promoting food security and subduing food insecurity. Jam production help reduce moisture content in the fruit thereby increasing the product (jam) shelf-life. Jam serves as preserve and makes the fruit to be readily available all year round, though with decrease in phytonutrient quality of the food, but still contains substantial nutrient in the products. Also, natural antioxidants, particularly those seen in fruits and vegetables, are obtaining popularity among consumers and scientists because epidemiological studies show that regular consumption of natural antioxidants is linked to a reduced risk of cardiovascular disease and cancer. (Gayati *et al*., 2014). Therefore The goal of this research was to make jam from apples (*Malus Domestica*) and oranges (*Citrus Sinensis*) , determine flavonoid, vitamin C, total phenol, total antioxidant activity and evaluate the processing effect on antioxidant properties of jam.

MATERIALS AND METHODS

Sample Collection: Samples of granny smith apple (*Malus Domestica*), and orange (*Citrus Sinensis*), used for this study were obtained from a Oje market in Ibadan. Sugar, citric acid and pectin were obtained from the open market in Ibadan, Oyo state, Nigeria.150ml transparent jar was also obtained from the local supermarket To ensure that the jars were free of germs, they were thoroughly washed and sterilized. Samples were put in sterile nylon bags and brought to the dietetics kitchen, department of Human Nutrition and Dietetics for preparation before being taken to the laboratory for further processing and analysis.

Preparation of Orange and Apple Fruit into Jam: Fresh good quality of orange and apple were picked for production. The orange fruits were washed thoroughly under running tap water followed by sterilized water that contains vinegar to ensure the fruit is free from dirt and germs. The fruits were then peeled, cut into two halves using a well cleaned sharp knife, and the juice was squeezed with the use of juice extractor, clear fruit pulp was obtained by squeezing the fruit pulp through muslin cloth, the pulp was weighed and mixed with sugar, pectin and citric acid.

The apple fruits were also washed thoroughly under running tap water followed by sterilized water that contains vinegar to ensure the fruit is free from dirt and germs. The center fibrous component of the apple was removed before it was diced into little cubes.. It was then mixed with other ingredients (sugar, pectin and citric acid).

Production of Jam: The following processing method was used in the production of both jams: the extracted pulp was used to prepare the jam which was cooked over direct heat in an uncovered aluminum pan until it reached the necessaery brix as described by Taha *et al*., 2011.

Five hundred grams of orange pulp was mixed with 450g sugar, 2.5g pectin and 2.5g citric acid at room temperature (22 °C), stirred until homogenized. The temperature was checked from time to time using a food thermometer to make sure the jam is prepared to a safe temperature, to prevent overcooking and to get the best flavor. The mixture was cooked until it reached a temperature of 103°C. Hot jams were poured in a 150 ml glass jar at 79–85 °C. The jams were pasteurized for 30 minutes at 65°C; the apple and orange jam was placed in pre-sterilized glass jars while still hot and allowed to cool itself at room temperature (22 °C). The products was further taken to the laboratory for analysis for determination of antioxidant properties such as flavonoid, vitamin c, total phenol, DPPH for the determination of the total antioxidant, pH, Brix and titratable acidity. The flow diagram is described in figure 1.

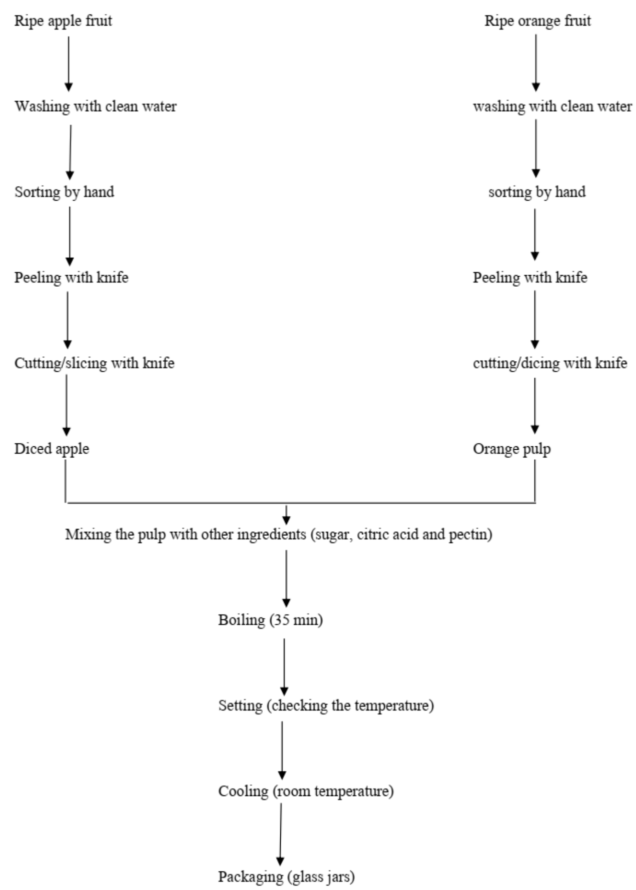

Figure 1:
Production of jam from Orange and Apple

Sensory Evaluation of Jam: Ten untrained panelists scored the orange and apple jams on a five-point hedonic scale ranging from "dislike highly" (score 1) to "like exceedingly" (scoring 5) during sensory evaluation. (Meilgaard 2007). Panelist was given a financial assistance for transportation to the venue as a form of incentive.

Chemical Analysis: Total soluble solids, titratable acidity, vitamin C, total phenolic content, and antioxidant activity were all determined in the preliminary analysis of apple and orange fruit.

Analysis on Jam: Total soluble solids (TSS), titratable acidity, pH, vitamin C, total phenolic content, antioxidant activity (DPPH), and flavonoid concentration were determined by analytical assays and methods.

Determination of Total Soluble Solid: TSS or °Brix of fruits and jams were determined with a Digital Refractometer (HI 96801, 0-90°Brix). First, calibrate the refractometer with distilled water to 0°Brix. Then place the sample on the equipment and record the reading. The readings were taken at 20°C

Determination of Titratable Acidity: Nielsen's approach was used to make this judgment (2003). One gram of the crushed product was dissolved in 50 ml distilled water in a conical flask after thorough shaking, and 5 ml of the sample was added to a 100 ml conical flask containing 2 drops of phenolphthalein indicator. A 0.IN solution of sodium hydroxide was used to titrate the mixture. After a drop of sodium hydroxide, the end-point was reached when a change in color was detected.

Titratable Acidity %

$$= \frac{\text{Volume of titration} * 0.1\text{N NaOH} * 0.067}{\text{Size of the sample}} \times 100\%$$

Determination of pH: As described by Nielsen, the pH was measured directly using a pH meter (Jenway Model) (2003). In a 50 mL glass beaker, 20 mL of the sample was placed. When the pointer on the pH meter became steady, the electrode was placed inside the sample solution and the reading was read directly from the meter's screen.

Determination of Ascorbic Acid Using Spectrophotometer: Klein and Percy's method was used to determine ascorbic acid (1982), for each method 20mg of extract was obtained for 45 minutes at room temperature with 10ml of 1% metaphosphoric acid (union) and filtered through Whatman no 4 filter paper. 1 mL of the filterate was combined with 9 mL 2,6 dichloroindophenol (Sigma), and the absorbance was measured at 515nm in 15 seconds against a blank concentration of ascorbic acid was determined from the calibration curve.

Calculation

$$\text{Vitamin C (ascorbic acid) mg/100g} = \frac{0.5 \times V2 \times 100 \times 100}{V1 \times 5 \times W}$$

Where, V1 = Titre value of standard ascorbic acid solution
V2 = Titre value of sample, W = Weight of sample

Determination of Total Antioxidants: The production of phosphomolybdenum complex was used to assess total antioxidant activity of the extract (Prieto *et al* 1999). To 1.9ml of reagent solution which contains (0.6M H2S04, 28Mm sodium phosphate and 4Mm ammonium molybdate), 0.1ml ethanol extract solution (100ug/ml) was added. The reagent solution in the blank solution was only 2mL and after 90 minutes, the absorbance at 695 nm was measured.

Reducing Power: The ability of the sample to reduce Fecl solution, as stated by Pulido, Bravo, and Saura Calixto, was used to determine its reducing property (2000). 1ml of the sample aliquot (0.5g of the sample homogenized in 20ml ethanol) was mixed with 2.5ml of 200Mm sodium phosphate buffer (PH6.6) and 2.5ml of 1g/100ml potassium ferrocyanide, the mixture was incubated at 50°C for 20 minutes, and then 2.5ml of 10ml/100ml Trichloroacetic acid was added and centrifuged at 650rpm for 10 minutes., The absorbance was measured at 700nm after 2.5ml of supernatants were combined with an equal volume of water and 0.5ml of ferric chloride. A greater absorbance indicates a stronger reducing power.

Scavenging Ability for Free Radicals: The sample's ability to scavenge free radicals against DPPH (1,1-diphenyl-2 picrylhydrazyl) was also tested (Ursini, Maiorino, Morazzoni,Roveri& Pifferi,1994). 0.2ml of the sample aliquot (0.5g malted and unmalted Treculia Africana sample homogenized in 20ml methanol) was combined with 7.6ml,0.4Mm methanolic solution containing 1,1DPPH radical, and the mixture was left in the dark for 30 minutes before the absorbance at 516nm was measured.

Content of Total Phenolics: Using a spectrophotometric method, the concentration of phenolic in the powdered sample was determined. (Singleton *et al*., 1999) In the experiment, a 1mg/ml ethanol solution of the extract was utilized. A blank was made by mixing 1 mL of ethanolic extract solution, 2.5 mL of 10% folinciocalteu's reagent diluted in water, and 2 mL of 7.5 percent NaHCo3. After that, the sample was left for 30 minutes. The sample was generated in triplicate for each assay and the absorbance was evaluated using a spectrophotometer set to 610nm. The calibration line was formed based on the measured absorbance, and the concentration of phenolic was read (mg/g) from the calibration line; the amount of phenolic in extract was then stated in terms of gallic acid equivalent (mg of GA/g of extract).

Flavonoid Content: A colorimetric test was used to determine total flavonoid content (Zhishen *et al* 1999). In a 10ml volumetric flask containing 4ml double distilled water, a 1-ml aliquot of standard solutions of catechin at various concentrations, adequately diluted samples, was added. At the start of the experiment, 0.3ml of 10% ALCl3 was introduced. After 6 minutes, 2 ml of 1M NaOH was added to the mixture, which was then diluted to volume (10 ml) with the double-distilled water and thoroughly mixed. A spectrophotometer was used to measure absorbance at 510nm

RESULTS

Antioxidant Properties of Raw Apple and Orange Fruits: Table 1 presents the antioxidant properties of raw apple (Sample A) and orange (Sample B) fruits. Vitamin C content was substantially higher in orange (42.17 ± 1.272 mg/100g) compared to apple (7.50 ± 0.010 mg/100g), with $p \leq 0.05$. Total phenol levels were comparable between apple (1.94 ± 0.040 mM GAE·100-1 g ds) and orange (1.90 ± 0.015 mM GAE·100-1 g ds). However, flavonoid content was significantly greater in apple (0.29 ± 0.006 mg GAE/g DW) than in orange (0.08 ± 0.010 mg GAE/g DW).

Antioxidant activity was slightly higher in orange (36.79 ± 2.705 mM Fe2+·100-1 g ds) than in apple (32.39 ± 0.00 mM Fe2+ ·100-1 g ds). pH values were slightly higher for orange (3.62 ± 0.010) than for apple (3.55 ± 0.010), while titratable acidity was significantly greater in orange (0.098 ± 0.014) compared to apple (0.047 ± 0.008). Total soluble solid content was higher in orange (10.00 ± 0.010) than in apple (9.50 ± 0.010).

Antioxidant Properties of Jam: Table 2 summarizes the antioxidant properties of apple (Sample A) and orange (Sample B) jams. Vitamin C content was markedly higher in orange jam (39.17 ± 1.422 mg/100g) compared to apple jam (3.50 ± 0.015 mg/100g). Similarly, total phenol content was significantly greater in orange jam (2.43 ± 0.098 mM GAE·100-1 g ds) than in apple jam (2.21 ± 0.091 mM GAE·100-1 g ds). Conversely, flavonoid content was significantly higher in apple jam (0.32 ± 0.040 mg GAE/g DW) than in orange jam (0.06 ± 0.010 mg GAE/g DW).

Antioxidant activity was slightly greater in apple jam (58.36 ± 1.711 mM Fe2+·100-1 g ds) compared to orange jam (56.56 ± 1.877 mM Fe2+·100-1 g ds). Orange jam exhibited higher titratable acidity (0.21 ± 0.008) and total soluble solids (61.00 ± 0.00) compared to apple jam (0.065 ± 0.008 and 54.00 ± 0.00, respectively). pH values differed significantly, with apple jam at 3.91 ± 0.00 and orange jam at 3.15 ± 0.00.

Organoleptic Properties and Acceptability of the Jam

Table 3 outlines the sensory evaluation results for apple (Sample A) and orange (Sample B) jams. The texture scores for both samples were identical (4.80 ± 0.422). Apple jam scored higher for taste (4.90 ± 0.483) compared to orange jam (4.10 ± 0.876). In terms of color, orange jam (4.80 ± 0.422) was rated significantly higher than apple jam (4.70 ± 0.483). For flavor, orange jam (4.90 ± 0.316) also outperformed apple jam (4.40 ± 0.699). Overall acceptability was higher for apple jam (4.70 ± 0.675) compared to orange jam (4.20 ± 0.422).

Table 1:
Antioxidant Properties of Raw Apple and Orange Fruit

VARIABLE	ANTIOXIDANT PROPERTIES		X^2	P value
	Sample A	Sample B		
Vitamin C (mg/100g)	**7.50±0.010**	**42.17±1.272**	**0.599**	**0.05**
Total phenol (mM GAE·100-1 g ds)	1.94±0.040	1.90±0.015	0.024	0.05
Flavonoid (mg GAE/g DW)	0.29±0.006	0.08±0.010	0.047	0.05
Antioxidant activity (mM Fe2+·100-1 g ds)	32.39±0.00	36.79±2.705	0.209	0.05
pH	3.55±0.010	3.62±0.010	0.035	0.05
Titratable acidity	0.047±0.008	0.098±0.014	0.004	0.05
Total soluble solid	9.50±0.010	10.00±0.010	0.018	0.05

Values expressed as mean ± standard deviation. Values in the same column with different superscripts are significantly different at p ≤0.05

Table 2:
Antioxidant Properties of Jam

VARIABLE	ANTIOXIDANT PROPERTIES		X^2	P value
	Sample A	Sample B		
Vitamin C (mg/100g)	**3.50±0.015^b**	**39.17±1.422^a**	**0.352**	**0.05**
Total phenol (mM GAE·100-1 g ds)	2.21±0.091^b	2.43±0.098^a	0.016	0.05
Flavonoid (mg GAE/g DW)	0.32±0.040^a	0.06±0.010^b	0.004	0.05
Antioxidant activity (mM Fe2+·100-1 g ds)	58.36±1.711^a	56.56±1.877^b	0.211	0.05
pH	3.91±0.00^a	3.15±0.00^a	0.000	0.05
Titratable acidity	0.065±0.008^b	0.21±0.008^a	0.004	0.05
Total soluble solid	54.00±0.00^b	61.00±0.00^a	0.020	0.05

Data expressed as mean ± standard deviation. Values in the same column with different superscripts are significantly different (p ≤0.05).

Table 3:
Organoleptic Properties and Acceptability of the Jam

Sample	Texture	Taste	Colour	Flavor	Overall acceptability
A (Apple jam)	4.80±0.422^{a}	4.90±0.483^{a}	4.70±0.483^{b}	4.40±0.699^{b}	4.70±0.675^{a}
B (Orange jam)	4.80±0.422^{a}	4.10±0.876^{b}	4.80±0.422^{a}	4.90±0.316^{a}	4.20±0.422^{b}

DISCUSSION

The aim of the experiment was to make apple and orange jam and see how processing affected the antioxidant capabilities and sensory attributes of the fruit. Vitamin C content in both fruits was found to be higher, however, while orange fruit had a higher value of vitamin C, it decreases in jam which may be as a result of processing of the fruit, similarly, vitamin C in apple jam decreases, this corresponds with (Amir et.al 2018)report that vitamin C content of apple decreased from 7.51 to 5.52 due to processing of the fruit. Research shows, vitamin C is easily loss when subjected to heat since it is a water-soluble vitamin and is subject to leaching during processing.

In comparison to fresh apple and orange fruit, the processes of making apple jam and orange jam have a positive influence on the total phenolics value ($P \leq 0.05$), this is similar to the findings of (Deng *et al*., 2013), who found that the break free of phenolics increased after heat treatment. Due to food dryness and phenol removal in products, heating has been demonstrated to improve the antioxidant potential of fruits (Schweiggert *et al*.2006). In this study, apple jam had the highest total flavonoid content, with an increase in total flavonoid content when compared to raw fruit however, the total flavonoid content of the studied jams decreased significantly in orange jam.

It was observed in this study that apple and orange jam have the highest Total Antioxidant Capacity (TAC) while the TAC values were reduced in the raw fruit that was recorded; similar study showed that the antioxidant in apricots increased after processing, from 80.32±0.44 in raw fruit to 83.09±0.64 in jam. Fruit samples may have lower antioxidant activity due to lower total phenolic content when compared to other processed fruit samples. (Barba,F.J etal., 2013). Further results shows the physicochemical properties of the jams produced, pH and titratable acidity are inversely proportional to each other. Orange jam has the highest titratable acidity of 0.21% and raw fruit of 0.098% citric acid with a pH value of 3.91, with pH of 3.62 in fruit while apple jam had titratable acidity of 0.065 and 0.047 in fruit with pH of 3.15 in jam and 3.55 in fruit. The two samples had same titratable acidity with slight variation in pH values ranging from 4.52 to 4.77. Titratable acidity reflects organic acid content of fruits. According to the Codex Alimentarius Commission's standard pH for quality jam, must have a desired pH of 2.5-3.2.

Also, total soluble solid content of orange jam was found to be higher than that of apple jam. According to studies, TSS concentration levels less than 60°Brix render the gel weak, whereas TSS content values greater than 70°Brix may produce sugar crystallization, resulting in an undesired change in jam texture. (Fasogbon *et al*., 2013). In addition, various writers had reported that jams with a TSS concentration of 65 to 70°Brix showed good sensory acceptability.

The outcome of sensory evaluation of both samples revealed the flavor acceptability of the sample was high in orange jam and low in apple jam due to the strong pleasant flavor of orange fruit. Taste acceptability was high for apple jam but low in orange jam. Color acceptability of jam was found to be higher in orange jam due to maximum concentration of orange pulp that have golden yellowish color and low in apple jam. One of the most basic factors that determine acceptability at first glance is color. The texture acceptability of prepared jam was found to be high in both jams. Apple jam had a higher overall acceptability rating due to the combination of all other sensory parameters such as color, flavor, taste, sweetness etc.

The results obtained from the ‘production and processing effect on the antioxidant properties of jam produced from orange and apple fruit’ showed that the thermal processing does not significantly deteriorate important health-promoting antioxidant properties in the jam, it helps improve the availability of total phenolic, total antioxidant activity, total soluble solids. Processing ripe fruits of apple and orange can be effectively used for the preparation of value-added products like jam that can minimize post-harvest losses of these fruits. It also encourages the preservation of these fruits due to the seasonality which makes them readily available both during and after of the planting season.

REFERENCES

Amir, Imrana, Amina Zuberi, Muhammad Imran, and Sana Ullah. "Evaluation of yeast and bacterial based probiotics for early rearing of Labeo rohita (Hamilton, 1822)." *Aquaculture Research* 49, no. 12 (2018): 3856-3863.

Atanassova M, Georgieva S, Ivancheva K (2011) Total phenolic and total flavonoid contents, antioxidant capacity and biological contaminants in medicinal herbs. *Journal of the University of Chemical Technology and Metallurgy* 46(1): 81-88.

Barba, F. J., M. J. Esteve, P. Tedeschi, V. Brandolini and A. Frigola. 2013. A comparative study of the analysis of antioxidant activities of liquid foods employing spectrophotometric, fluorometric, and chemiluminescent methods. *Food Analytical Methods*. 6: 317–327.

Beatrice Mofoluwaso Fasogbon., Saka O. Gbadamosi and Kehinde A. Taiwo.,. Studies on the chemical and sensory properties of jam from osmotically dehydrated pineapple slices. *British Journal of Applied Science & Technology*, (2013), 3(4), 1327-1335.

Deng, Gui-Fang, Xi Lin, Xiang-Rong Xu, Li-Li Gao, Jie-Feng Xie, and Hua-Bin Li. "Antioxidant capacities and total phenolic contents of 56 vegetables." *Journal of functional foods* 5, no. 1 (2013): 260-266.

Editors of Encyclopedia Britannica “fruits; plant reproductive body” www.britannica.com/science/fruit-plant-reproductive-body updated March 2, 2021.

Gayatri Nahak, Mruntyanjay Suar and Rajani Kanta Sahu., Antioxidant potential and nutritional values of vegetables: A review. *Res. J. Med*. Plant 2014, 8, 50–81

Klein, B.P. and Perry, A.K. (1982) Ascorbic Acid and Vitamin A Activity in Selected Vegetables from Different Geographical Areas of the United Sates. *Journal of FoodScience*,47,941-945.https://doi.org/10.1111/j.1365-2621.1982.tb12750.x

Meilgaard, M. C., Civille, G. V. and Carr, B. T. 2007. Sensory evaluation techniques. 4th ed. New York: C.R.C. Press.

Olugbenga Olufemi Awolu, Grace Oluwaseun Okedele, Modupe Elizabeth Ojewumi and Funmilayo Grace Oseyemi. Functional jam production from blends of banana, pineapple and watermelon pulp. Published January 19, 2018. Vol. 3, No. 1, (2018), pp. x-x, doi: 10. 11648/j.ijfsb.20180301. 12.

Ouarda Djaoudene, Hayette Louaileche., Impact of Storage Conditions on the Bioactive Compounds and Antioxidant Capacity of Commercial Orange Jam, *Journal of Analytical, Bioanalytical and Separation Techniques*, published sept. 9, 2016. 1(1): 8- 11.

Schweiggert, Ute, Andreas Schieber, and Reinhold Carle. "Effects of blanching and storage on capsaicinoid stability and peroxidase activity of hot chili peppers (Capsicum frutescens L.)." *Innovative food science & emerging technologies* 7, no. 3 (2006): 217-224.

Singleton V.L., Orthofer R., Lamuela-Raventos R.M. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods *Enzymol*. 1999; 299: 152-179.

Taha M Rababah, Majdi A Al-Mahasneh, Isra Kilani, Wade Yang, Mohammad N Alhamad, Khalil Ereifej, Muhammad Al-U'datt. Effect of Jam Processing and Storage on Total Phenolics, Antioxidant Activity, and Anthocyanins of Different Fruits. *J. Sci. Food Agric*. 2011, 91, 1096–1102. doi: 10.1002/jsfa.4289. Epub 2011 Jan 19. PMID: 21254073.

Ullah N, Ullah S, Khan A, Ullah I and Badshah S J.1. Editors of Encyclopedia Britannica “fruits; plant reproductive body” www.britannica.com/science/fruit-plant-reproductive-body updated March 2, 2021.

Van Acker,S.A., D.J. Van Den, M.N Tromp and A.Bast, 2011. Structural aspects of antioxidant activity of flavonoids.*free radic.Biol.Med*.,35;331-342.

Waterhouse, Andrew L. "Determination of total phenolics." Current protocols in food analytical chemistry 6, no. 1 2002: I1-1.

Zhishen J., Mengcheng T., Jianming W. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem*, 1999; 64: 555-559.