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Effects of Different Processing Temperatures-Time Frame on the Total Soluble Solids and Titratable Acidity of Three Plant-based Liquid Food Products: A Comparative Analysis

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ABSTRACT

The effects of different thermal processing techniques (temperature-time frames) on total soluble solids (TSS) and titratable acidity (TA) of three plant-based liquid food samples (pawpaw juice, tomato juice, soya milk) were compared in this study. The juice samples were extracted with motorized juice extractor and the soya milk was prepared by cold maceration. The samples were divided into two groups: (1) low temperature–long time (LTLT), (2) High temperature-short time (HTST). The LTLT group was further divided into lots (L_1, L_2, and L_3) and was pasteurized at 65 ℃, for 10 minutes (L1), 20 minutes (L2) and 30 minutes (L3). HTST group was divided into two lots (L_4 and L_5). L_4 was pasteurized at 90 ℃ for 6 seconds and L_5 was pasteurized at ultra-high temperature (UHT), 140 ℃ for 2 seconds. Each lot was cooled down to 4 ℃ in a refrigerator. Biochemical analyses of the samples followed standard methods. Results showed that at LTLT, TSS decreased as the processing time increased for all the foods. At HTST, the highest loss in TSS from 5.43 ^{O}BRIX to 5.18 ^{O}BRIX (4.60 %) was recorded in tomato juice at 90 ^{o}C, 6 seconds. Soy milk increased in TSS from 2.15 ^{O}BRIX to 2.27 ^{O}BRIX (5.58 %). TA decreased as the processing time increased in tomato juice. TA in pawpaw increased from 0.63 to 0.66 (4.76 %) at 60 ^{0}C, 10 minutes, stable at 65 ^{o}C, 20 minutes and decreased thereafter. Soy milk recorded increasing TA across the temperature-time frames.

1. INTRODUCTION

Processing of fruits for production of beverages and drugs has reportedly been in practice in prehistoric Eurosia (Elisa, 2022). Recently, more emphasis is being placed on plant-based liquid food materials as emerging point to the therapeutic effects of plant-based foods on preventive and corrective medicine evidences (Melina *et al.*, 2016; Julieanna and Raymond, 2017; Nora *et al.*, 2021).

The juices from pawpaw (*Carica papaya*), tomato (*Solanum lycopersicum*) and the milk from soya bean (*Glycine max*) are increasingly been recognized in Nigeria as important food materials. They are commonly seen among the commercial fruit blends because of their health benefits. For an example, with Nigeria ranking third among Sub-Saharan African countries cultivating soyabeans, soya milk is fast becoming dairy substitute in many Nigerian homes, especially now information on the nutritional values and low glycemic index is growing (Robert *et al*., 2006).

However, these liquid food products have the shortcoming of high perishability due to a lot of factors, including susceptibility to microbial contamination (Kamal *et al.*, 2014). Consequently, some researchers have reported different processing technologies that will ensure the safety and retention of the nutritive values of juice and milk products (Maria *et al*., 2014; Chandran *et al*., 2018; Christopher *et al.,* 2020). Though pasteurization is an age-long process technology that ensures both food safety and retention of nutritive values. The choice of appropriate temperature-time frame of pasteurization remains one of the problems confronting food engineers (Kamal *et al*., 2014; Adebayo-Oyetoro *et al.,* 2016; Nyam, *et al.,* 2018). Some studies that reported application of different temperature-time frames in liquid foods pasteurization also pointed out its negative effects on nutritive and organoleptic properties (Jayant *et al*., 2018; Patricia and Gerald, 2020).

Total soluble solids (TSS) in fruit juice, expressed as the ^{O}BRIX, is a measure of the amount of sugar in the juice (Mandelova *et al.,* 2011). It is among important attributes because of its role in the organoleptic property of taste and in the mouth feel of liquid food products (Legua *et al*., 2022). Retention of natural sugar in the liquid food products is the desire of any food formulation technologist. Titratable acidity (TA) relates to the total acidity of the food product and affects both its taste and bench life. The ratio of the TSS to the TA is a useful quality control parameter (Jayasena and Cameron, 2008). According to Pareek and Mukherjee (2011) TSS, TA and TSS/TA are affected by heat processing technology, depending on the heat intensity and duration of heat application. Therefore, the aim of the study was to determine the ideal temperature-time frame that would minimally affect the TSS, TA during thermal treatment (pasteurization) of the three plant-based liquid food products.

2. MATERIALS AND METHODS

2.1. Material Collection and Preparation of Samples

The three plant materials (*C. Papaya* and *S. lycopersicum* fruits and *G. max* seed) were purchased from local market women at Ogboete main market, Enugu North Local Government Area, Enugu State, Nigeria. The fruits were washed with tap water and peeled while the seeds were boiled and cracked.

2.2. Extraction of Fruit Juice/Milk Samples and Experimental Design

The juice samples were extracted mechanically using a motorized juice extractor and the soya milk was prepared by cold maceration after boiling and cracking of soya beans seeds according to the method reported in Jayant *et al.* (2018). Briefly, the peeled fruits were sliced in pieces and fed into the juice extractor. The extracted juice was collected in a stainless-steel bowel after straining through a sterile muslin cloth. The soya been seeds were soaked in water overnight and the water discarded. The seeds were dehulled, boiled for 10 minutes, cooled and blended with clean water. The blended soya was strained through a muslin cloth and the milk sample collected in a stainless-steel bowel. The samples were divided into two groups: (1) Low Temperature–Long Time (LTLT), (2) High Temperature-Short Time (HTST). Group 1 was further divided into lots (L_1, L_2, and L_3) and was heat-treated (pasteurized) at 65 ℃, for 10 minutes (L1), 20 minutes (L2) and 30 minutes (L3). Group 2 was divided into two lots (L_3 and L_4) and was heat-treated (pasteurized) at 90 ℃ for 6 seconds (L_3), 140 ℃ for 2 seconds (L_4). Each lot was cooled down to 4 ℃ in a refrigerator. The raw and processed samples of the soya milk and fruit juices were taken to the laboratory under ice for biochemical analyses

2.3. Analyses

2.3.1. Determination of total soluble solids

This was determined as ^{O}BRIX according to the method reported in AOAC (2005) using Abbey refractometer (Model 2WA, PCE Instruments, UK, Southampton Hampshire). The analysis was preceded by cleaning the prism with ethanol, followed by calibration with a drop of pure ethanol. The visual field of the equipment was adjusted to illuminate half of the field while the other half remained dark. The functionality of the equipment was confirmed when a measurement of 1.36 was obtained. Thereafter, a drop of sample was put on the sample holder in order to obtain its refractive index. All measurements were performed in triplicate at 25 °C.

2.3.2. Determination of titratable acidity

This was determined by the titrimetric method using pH meter to monitor the end point. Into a 50 ml beaker containing 10 ml of the sample was dipped the probe of pH meter, previously calibrated with buffer solution (pH 4 and 7). The pH was noted, and 0.1 N of sodium hydroxide was used as the titrant to the end point of pH 8.2. The titratable acidity was calculated from Equation 1.

$$TA\ (g/1000\ ml) = Vt/Vs \times 0.75 \quad (1)$$

Where Vt = volume of the titrant, Vs = volume (10 ml) of the sample.

3. RESULTS AND DISCUSSION

The effects of different processing temperatures-time frame on the total soluble solids and titratable acidity of three plant-based liquid food products are represented in Figures 1 and 2. Figure 1 represents the effect of low temperature-long time (LTLT) on total soluble sugar (^{O}BRIX) content of the three liquid foods. TSS decreased as the processing temperature-time increased for all the foods. However, the effect of temperature-time frame on the ^{0}BRIX value was least at 65 ^{o}C, 10 minutes with pawpaw recording minimal decrease, 0.05 ^{O}BRIX (1.81 %), followed by tomato juice, 1.8 ^{O}BRIX (3.33 %). This is in agreement with Senanayake *et al.* (2013) who reported that depending on the processing temperature there could be slight changes in the soluble sugars. This could be attributed to a breakdown of insoluble polysaccharides into their corresponding soluble monomers. The pawpaw juice with insignificant change in TSS would retain most of its physical and organoleptic properties than the other two liquid food products since soluble solids content of liquid foods at different temperatures affects the rheological and other physical properties responsible for mouth feel and general consumers' acceptability (Anuradha *et al.*, 2011).

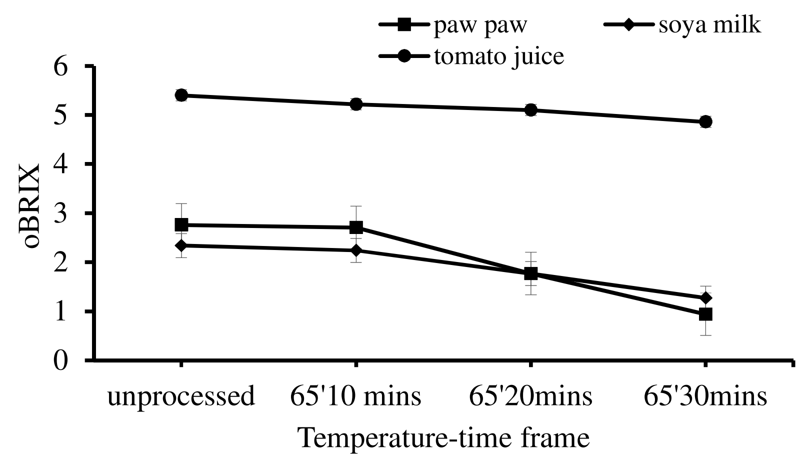

Figure 1: Effect of low temperature-long time frame on total soluble sugar (^{O}BRIX) of three liquid foods

C.G Okeke / Nigerian Research Journal of Engineering and Environmental Sciences
7(2) 2022 pp. 529-536

At high temperature-short time frame, the highest loss in total soluble solids from 5.43 ^{O}BRIX to 5.18 ^{O}BRIX (4.60 %) was recorded in tomato juice at 90 ºC, 6 seconds, followed by pawpaw, from 2.77 to 2.75 ^{O}BRIX (0.72 %). There was an increase in total soluble solids in soy milk from 2.15 ^{O}BRIX to 2.27 ^{O}BRIX (5.58 %). At an ultra-high temperature- short time frame (140 ºC, 2 seconds) the highest loss from 2.77 ^{O}BRIX to 1.69 ^{O}BRIX (38.99 %) content was recorded in pawpaw juice, followed by soya milk, from 2.15 ^{O}BRIX to 1.72 ^{O}BRIX (20 %) and the least, from 5.43 ^{O}BRIX to 5.07 ^{O}BRIX (6.63 %) was recorded in tomato. That there was an increase in total soluble solids in soy milk from 2.15 ^{O}BRIX to 2.27 ^{O}BRIX (5.58 %) probably happened because of a breakdown of insoluble polysaccharides into their corresponding soluble monomers. Soybean contains a high concentration of carbohydrates that consist mainly of non-starch polysaccharides (NSP) and oligosaccharides. The NSP can be divided into insoluble NSP (mainly cellulose) and soluble NSP (mainly pectic polymers, which are partially soluble in water) (Choct *et al.*, 2010). The high temperature could possibly have introduced thermal shock that broke down the pectic polymers bond and released the water-soluble monomers, resulting in the increase of total soluble sugar. Brix value is used to measure the soluble solids in liquid food products. As a general trend, osmotic pressure increases when a solution's level of soluble solids (Brix) increases. Osmotic pressure may kill cells as a consequence of the concentration of solute (preservatives). Water in the system would move across the permeable cell membrane to restore equilibrium and lyses the microbial cell (plasmolysis). So, the increased TSS in soy milk at high temperature-short time pasteurization will enhance the bench life of the soy milk. At an ultra-high temperature short time frame (140 ºC, 2 seconds) the highest loss from 2.27 ^{O}BRIX to 1.69 ^{O}BRIX (38.99 %) content was recorded in pawpaw juice, followed by soya milk, from 2.15 ^{O}BRIX - 1.72 ^{O}BRIX (20 %) and the least, from 5.43 ^{O}BRIX to 5.07 ^{O}BRIX (6.63 %) was recorded in tomato. So, an ultra-high temperature-short time was not BRIX friendly to pawpaw.

Figure 2 represents the effect of low temperature-long time (LTLT) and high temperature-long time (HTST) on titratable acidity (TA) content of the three liquid foods. TA decreased as the processing temperature-time frame increased in tomato juice with maximal decrease, 0.1(10.99 %) at 65 ºC 20 minutes. TA in pawpaw increased from 0.63 to 0.66 (4.76 %) at 60 ºC, 10 minutes, stable at 65 ºC, 20 minutes and decreased thereafter. Soy milk recorded increasing TA across the temperature-time frame with the maximal increase at 65 °C, 10 minutes (Figure 2). The decrease of TA as the processing temperature and time increased in tomato juice with maximal decrease, 0.01 (10.99 %) at 65 ºC, 20 minutes is in tandem with the study of Pareek and Mukherjee (2011) who reported that processing temperature and time decreased the TA of mandarin fruit juice. This decrease could be as a result of volatilization of volatile acidic organic compounds. Tomato is rich in polyphenolic compounds in solution with 95% water content of tomato. So, heating would decrease the water-phenol bond and increased the escaping tendency of some of these organic compounds, increase denaturation of ascorbic acid and thereby decreasing the TA (Mendelova *et al.,* 2011).

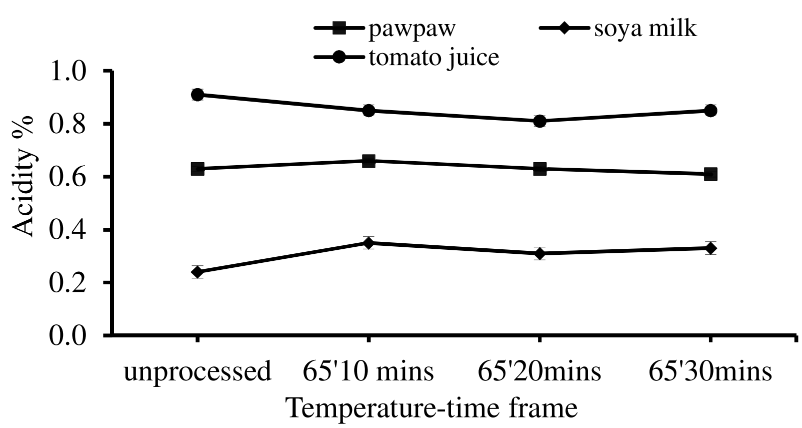

Figure 2: Effect of low temperature-long time frame on titratable acidity of three liquid foods

C.G Okeke / Nigerian Research Journal of Engineering and Environmental Sciences
7(2) 2022 pp. 529-536

Contrarily, TA in pawpaw increased from 0.63 to 0.66 (4.76 %) at 65 ^{0}C, 10 minutes, stable at 65 ^{0}C, 20 minutes and decreased thereafter, and soy milk recorded increasing TA across the temperature-time frame with the maximal increase at 65 ^{0}C, 10 minutes. This observation could be explained by the fact that the acidity of fruit juice is a function of its constituents and the nature of physicochemical interaction between the water and the constituents. Pawpaw juice and soy milk probably contain more non-volatile organic compounds than tomato juice. At high temperature-short time frame, pawpaw juice and soy milk recorded increased TA (3.18 % and 29.17 %, respectively) and tomato juice decreased in TA from 0.91 to 0.79 (13.19 %) at 90 ºC, 6 seconds. At an ultra-high temperature- short time frame (140 ºC, 2 seconds) pawpaw juice and soy milk recorded increased TA (53.97 % and 45.33 %, respectively) while tomato juice decreased in TA from 0.91 to 0.87(4.40 %).

TSS/TA ratio plays significant role in the taste of fruit juice products (Jayasena and Cameron, 2008). The decreased value of TA in tomato juice at 65 ºC, 30 minutes would confer more organoleptic property of good taste than the other two products. On the other hand, the increased TA recorded in pawpaw juice and soy milk at 90 ºC, 6 seconds and ultra-high temperature-short time frame (140 ºC, 2 seconds) would impact negatively on their tastes while favouring tomato juice.

Comparisons of the effects of various processing temperature-time frames on the total soluble solids (TSS) and titratable acidity (TA) contents of the three liquid foods at low temperature-long time are represented in Tables 1 (A-C) and 2.

Table 1 (A): Effect of processing temperature-time frames on the TSS and TA of pawpaw juice

Dependent variable	Temperature-time	Temperature-time	Significance
BRIX	Unprocessed vs	65^0 10 mins	<0.01
		65^0 20 mins	>0.05
		65^0 30 mins	<0.05
	65^0 10 mins vs	65^0 20 mins	<0.05
	65^0 30 mins vs	65^0 10 mins	>0.05
		65^0 20 mins	>0.05
Acidity	Unprocessed vs	65^0 10 mins	>0.05
		65^0 20 mins	<0.05
		65^0 30 mins	>0.05
	65^0 10 mins vs	65^0 20 mins	>0.05
		65^0 30 mins	>0.05
	65^0 30 mins vs	65^0 10 mins	>0.05
		65^0 20 mins	>0.05

Table 1 (B): Effects of various processing temperature-time frames on the TSS and TA of soya milk

Dependent variable	Temperature-time	Temperature-time	Significance
BRIX	Unprocessed vs	65^0 20 mins	>0.0500
		65^0 10 mins	>0.0500
		65^0 20 mins	<0.0001
		65^0 30 mins	<0.0001
	65^0 10 mins vs	65^0 20 mins	<0.0001
	65^0 30 mins vs	65^0 10 mins	<0.0001
		65^0 20 mins	<0.0001
Acidity	Unprocessed vs	65^0 10 mins	<0.05
		65^0 20 mins	>0.05
		65^0 30 mins	>0.05
	65^0 10 mins vs	65^0 20 mins	>0.05
		65^0 30 mins	>0.05
	65^0 30 mins vs	65^0 10 mins	>0.05
		65^0 20 mins	>0.05

Table 1 (C): Effects of various processing temperature-time frames on the TSS and TA of tomato juice

Dependent variable	Temperature-time	Temperature-time	Significance
BRIX	Unprocessed vs	65^0 10 mins	<0.01
		65^0 20 mins	>0.05
		65^0 30 mins	<0.05
	65^0 10 mins vs	65^0 20 mins	<0.05
	65^0 30 mins vs	65^0 10 mins	>0.05
		65^0 20 mins	>0.05
Acidity	Unprocessed vs	65^0 10 mins	>0.05
		65^0 20 mins	<0.05
		65^0 30 mins	>0.05
	65^0 10 mins vs	65^0 20 mins	>0.05
		65^0 30 mins	>0.05
	65^0 30 mins vs	65^0 10 mins	>0.05
		65^0 20 mins	>0.05

In pawpaw juice (A), significant difference ($P < 0.05$) existed between the unprocessed samples and processed in BRIX at 65 ^{0}C, 10 minutes and 20 minutes and in TSS, at 65 ^{o}C, 20 minutes. In soy milk (B) there was significant difference between the unprocessed and processed samples ($P < 0.05$) significant difference ($P < 0.05$) existed between the unprocessed samples and processed in BRIX at 65 ^{0}C, 10 minutes and 20 minutes and in TSS, at 65 ^{o}C, 10 minutes. In tomato juice, there was significant difference ($P <0.05$) between the unprocessed and processed in BRIX at 65 ^{0}C, 10 minutes and 30 minutes and in TSS, at 65 ^{o}C, 20 minutes. When different processing times were compared at 65^0 there was no significance difference ($P > 0.05$) at all instances in the TA. The absence of significant difference at all instances in the TA of tomato juice would mean that processing tomato juice at the set temperatures time frames would not have significant effects on the taste of the juice product, unlike the other two products. Multiple comparisons of the effects of high temperature-short time and high temperature-long time on the TSS and TTA contents of the three liquid foods is represented in table 2. There were significant differences ($P < 0.05$) in the TSS at 90 ^{o}C, 6 seconds and in the TA at 140 ^{o}C, 2 seconds.

Table 2: Multiple comparisons of the effects of high temperature-short time and ultra-high temperature-short time on the TSS and TTA of the three liquid foods

Parameter	Processing temperature and time	Pawpaw juice (n=3)		Soya milk (n=3)		Tomatoes juice (n=3)	
		Std. Error Mean	P value	Std. Error Mean	P value	Std. error mean	P value
BRIX	Unprocessed	.00882		.03844		.08413	
	90^0 6 secs	.01000	<0.0001	.03512	<0.0001	.01764	<0.01
	140^0 2 secs	.01155	<0.0001	.02404	<0.0001	.14526	>0.05
Acidity	Unprocessed	.01202		.01333		.02309	
	90^0 6 secs	.02000	>0.05	.00577	<0.05	.00333	>0.05
	140^0 2 secs	.00882	<0.0001	.02603	<0.05	.02028	<0.05

4. CONCLUSION

Identifying an ideal preservation temperature that would minimally affect the organoleptic property of fruit juice is critical in food processing technology. The three liquid foods studied are increasingly emerging in Nigeria as functional foods because of their numerous nutritional benefits and are commonly available in the food combination of many families. However, to maximize their culinary acceptability and health benefits there is need to process these foods within a temperature-time frame that will minimally affect the critical organoleptic properties. From the results of this study it is concluded that: low temperature-long time favoured the total soluble solids content of pawpaw juice and would therefore cause retention of most of its raw taste; high temperature-short time frame (90 ^{o}C, 6 seconds) favoured soy milk processing as there was an increase ^{O}BRIX and would mean improved taste, mouth feel and general acceptability, as well as better bench life; low temperature-long time decreased titratable acidity of tomato juice, which would also be interpreted as favouring TSS/TA ratio and hence improvement in the organoleptic property of taste. The absence of significant difference at all instances in the TA of tomato juice at low temperature-long time frame would mean that processing tomato juice at the set temperatures time frames would not have significant effects on the taste of the juice product, unlike the other two products. High temperature-short time processing technique favoured pawpaw juice and soy milk more than tomato juice. In this period when consumption of mixed juice is advocated, understanding the ideal processing technique is necessary. The result of this study will be instructive for industrial and domestic formulations of mixed blend of plant-based liquid foods.

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST

This manuscript is not associated with any conflict of interest.

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