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## Studies on Industrially Processed Fruit Juice and Freshly Prepared Fruit Juice Sold in Enugu State, Nigeria

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## Abstract

The sugar and mineral levels of industrially processed fruit juices (mainly 100% and 50% fruit juices) sold to consumers in Enugu state, Nigeria were determined and compared with that of freshly prepared fruit juices. The fruit juices tested included apple, orange, pineapple and red grape juices. The industrially processed and the freshly prepared fruit juices were tested for total soluble solid (TSS) content, fructose, glucose, sucrose, minerals such as sodium, potassium, magnesium, calcium, phosphorus, iron and heavy metals such as copper, zinc, arsenate and lead. Findings from the analysis of the TSS content of fruit juice samples demonstrated no significant ($p > 0.05$) difference between the industrially processed and freshly prepared fruit juices; however, differences in sugar and mineral levels between industrially processed and freshly extracted fruit juices were significant ($p < 0.05$). Industrially processed fruit juices contained higher glucose, sucrose, sodium, calcium, phosphorus, copper and zinc contents, and lower fructose, potassium and magnesium contents when compared to freshly prepared fruit juices. There was no significant ($p > 0.05$) difference in iron and arsenate contents of industrially processed fruit juices when compared with the freshly extracted juices. Lead (Pb) was not detected in any of the samples. This study demonstrated no quality issues of concern in relation to the products because all the parameters considered in the study were within the standard acceptable range for fruit juices and nectar.

**Keywords:** Fruit juice, sugar content, mineral content, heavy metals, Enugu State

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**INTRODUCTION**

Fruit juices are becoming important part of modern diet in many communities. Their consumption is popular in Nigeria because of their health and invigorating benefits (Ndife *et al*., 2013). They act as nutritious beverages and play significant parts in healthy diets because they offer good taste and varieties of nutrients found naturally in fruits (Hossain *et al*., 2012). In Nigeria, different kinds of seasonal fruits are available including apple, orange, pineapple, and grape which provide an abundance of vitamins, minerals, antioxidants and fibers, all of which are essential for human health (Jasmine, 2012). Fruit juice intake is a convenient way by which people receive the benefits of various fruits when whole fruit is not readily available or desired (Nitu *et al*., 2010). Properly extracted juices are very similar to the fruit; they contain most substances which are found in the original ripe and sound fruit from which the juice was made. Fruit juices are always 100% fruit product and should not be confused with soft drinks or other refreshing drinks (Landon, 2007). Juices are available either in their freshly prepared form or industrially processed form. In either case, it is expected to be free from contaminants and contain most substances which are found in the original ripe and sound fruit from which the juice is extracted, with no added sugar or preservative (Hassan *et al*., 2014). Fruit juices contain water and varying concentrations of carbohydrates such as sucrose, fructose, glucose and sorbitol (Oranusi *et al*., 2012). They are rich in phytochemicals, minerals and vitamins; contain small amount of protein, no fat, cholesterol and fiber (Pao *et al.,* 2000). The micronutrients and phytochemicals contained in fruit juices are responsible for the several health benefits associated with its consumption; however, excessive consumption in recent time has been associated with the development of type 2 diabetes, dental caries and obesity which are all attributed to its sugar content (Cashwell *et al*., 2009). The minerals contained in fruit juices including sodium, potassium, magnesium, phosphorus, calcium and iron are essential for good health if present in adequate concentration (Ofori *et al*., 2013) and harmful when in excess or deficient, hence the need for their proper representation. The liquid nature of juice and availability of several raw fruit materials offers many mixing options and a blending opportunity leading to a variety of fruit juice products. This versatility of juice as well as the ease with which it can be altered with sugar, contaminants, water or inferior juices has continued to attract unethical suppliers; however, valid data are not available on the extent to which the commercial fruit juices and drinks available in Nigeria market are either mislabeled, adulterated or of inferior quality (Dosumu *et al*., 2009; Oranusi *et al*., 2012). Excessive sugar consumption, micronutrient malnutrition and heavy metal contamination are ongoing public health concerns (Nzeagwu and Onimawo, 2010; Jasmine, 2012; Ofori *et al*., 2013); in part to address these concerns, there has been a recent campaign of fruit juices with “100% natural” and “no sugar added” label by manufacturers. It is therefore necessary to validate this claim by scrutinizing these trendy commercial fruit juices made available to consumers in Nigeria with an aim to determine and compare their sugar and mineral level with that of freshly prepared fruit juices. Validation of this information will help consumers to make an informed decision on the safety, quality and the amount of juice to consume

## MATERIALS AND METHODS

### Collection of Samples

The fresh fruits used for this study were apple (*Malus domestica*), orange (*Citrus sinensis*), pineapple (*Ananas comosus*) and red grape (*Vitis vinifera*). Industrially processed fruit juices (100% and 50%) from four different companies (A, B, C and D) were purchased from Shoprite and other local grocery stores in Enugu State of Nigeria. Some of the fresh and ripe fruits used in this were purchased from Ogige market in Nsukka Local Government Area, and others from Shoprite, both located in Enugu State of Nigeria. The industrially processed fruit juices purchased were within expiry date. The fresh fruits used were identified in the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka.

### Experimental Design

A total of 20 samples (juices) were used for the study; four (4) of which were freshly extracted juices of apple, orange, pineapple and red grape (designated 1). Eight (8) were industrially processed 100% fruit juices (designated 2) and the other 8 were industrially processed 50% fruit juices of apple, orange, pineapple and red grape origin (designated 3). There were four groups (apple, orange, pineapple and red grape juices). Each group had five fruit juice samples (of the same fruit origin) comprising one freshly prepared fruit juice, two industrially processed 100% fruit juices from companies A and B, and two industrially processed 50% fruit juices from companies C and D.

### Extraction of Juice from Fresh Fruits

Extraction of juice from the fresh fruits was carried out using the method of Nzeagwu and Onimawo (2010).

### Determination of the Total Soluble Solids (TSS) Contents of Fruit Juice Samples

The total soluble solids content of the fruit juice samples was determined using a refractometer as described by Jasmine (2012) and Hossain *et al.* (2012).

### Determination of Sugar Contents of Fruit Juice Samples

Fructose, glucose and sucrose levels of each of the fruit juice samples were determined. The fructose content of fruit juice samples was determined by resorcinol reagent method as described by Buba *et al*. (2013). The glucose content was determined by Folin-Wu method as described by Plummer (1987). The concentration of sucrose in each of the samples was determined by the method described by Buba *et al*. (2013).

### Determination of the Mineral Contents of Fruit Juice Samples

Fruit juice samples were digested prior to mineral determination using the method described by AOAC (2000). A quantity, 5 ml of each of the fruit juice samples was accurately measured into appropriately labelled conical flasks after which concentrated $HNO_3$ (20 ml) and $H_2O_2$ (20 ml) were added. The preparations were heated in a furnace at a temperature of 500ºC until the $HNO_3$ and $H_2O_2$ had evaporated. The digested samples were afterwards tested for mineral contents.

Sodium (Na) and potassium (K) contents of digested samples were determined by flame photometric method as described by AOAC (2000) and Ndife *et al.* (2013). Magnesium (Mg) and calcium (Ca) contents were determined by complexometric titration using EDTA as described by Okoye and Ibeto (2009). Phosphorus (P) and iron (Fe) contents of digested samples were determined by spectrophotometric method as described by AOAC (2000).

### Determination of Heavy Metal Contents of Fruit Juice Samples

Each of the digested samples was screened for contaminations with heavy metals using the method of Ndife et al., 2013.

### Statistical Analysis

Data obtained from this study were analyzed using Statistical Product and Service Solutions (SPSS) version 18. Least Significant Difference (LSD) and Duncan were used to compare mean values. Data were reported as mean±standard deviation. Mean values were considered statistically significant at $p < 0.05$.

## RESULTS

### Total Soluble Solids Contents of Fruit Juice Samples

The total soluble solids content (in degree Brix) of the industrially processed fruit juice samples ranged from 10.60 ± 0.58 to 11.40 ± 0.58, 10.00 ± 0.10 to 11.00 ± 0.12, 10.00 ± 0.05 to 12.00 ± 0.10 and 15.33 ± 0.15 to 16.00 ± 0.03 for apple, orange, pineapple and red grape juices, respectively. These values were lower than the TSS of the freshly extracted apple (12.00 ± 0.10), orange (11.00 ± 0.00) pineapple (12.30 ± 0.58) and red grape (16.00 ± 0.10) juices. Of the commercial samples, the orange juice samples had lowest TSS contents while the red grape juice samples had highest TSS content (Table 1).

**Table 1**: Total soluble solids (TSS) contents (ºBrix) of fruit juice samples

| **Groups (Juices)** | **Samples** | | | | |
|---|---|---|---|---|---|
| | **1** | **2A** | **2B** | **3C** | **3D** |
| Apple | $12.00 \pm 0.10^a$ | $10.67 \pm 0.58^a$ | $11.40 \pm 0.58^a$ | $10.60 \pm 0.58^a$ | $11.00 \pm 1.00^a$ |
| Orange | $11.00 \pm 0.12^b$ | $11.00 \pm 0.06^b$ | $11.00 \pm 0.10^b$ | $10.00 \pm 0.10^a$ | $10.33 \pm 1.00^a$ |
| Pineapple | $12.30 \pm 0.58^c$ | $12.00 \pm 0.10^b$ | $10.00 \pm 0.05^a$ | $10.00 \pm 1.00^a$ | $12.00 \pm 0.10^b$ |
| Red grape | $16.00 \pm 0.10^b$ | $16.00 \pm 0.03^b$ | $15.33 \pm 0.15^a$ | $15.77 \pm 0.05^{ab}$ | $15.33 \pm 0.53^a$ |

Values are mean ± SD for three replicates (n=3). Means with different superscripts across rows are significant at $p < 0.05$. Where; 1 = freshly extracted fruit juice, 2A= Commercial 100% fruit juice from company A, 2B= Commercial 100% fruit juice from company B, 3C= Commercial 50% fruit juice from company C, 3D= Commercial 50% fruit juice from company D.

**Sugar Contents of Fruit Juice Samples**

The fructose, glucose and sucrose contents of fruit juice samples are stated in Table 2. The fructose content of all industrially processed fruit juice samples was significantly (<0.05) lower than those of freshly extracted juice samples. However, the glucose and sucrose contents of industrially processed fruit juice samples were significantly ($p<0.05$) higher than those of freshly extracted juice samples (Table 2). The order of sugar concentrations in the commercial fruit juices was fructose>sucrose>glucose. While in fresh juice samples, the order was fructose> glucose> sucrose (Table 2).

Of the commercial samples, the red grape samples had the highest sugar contents when compared to the other fruit juice samples analyzed while the orange juice samples had the lowest.

Table 2: Sugar contents of fruit juice samples

| | | Parameters (g/100 ml) | | |
|---|---|---|---|---|
| Groups | Samples | Fructose | Glucose | Sucrose |
| Apple juice | 1 | $6.87 \pm 0.06^{d}$ | $2.11 \pm 0.02^{a}$ | $2.57 \pm 0.15^{a}$ |
| | 2A | $6.07 \pm 0.04^{c}$ | $4.50 \pm 0.01^{c}$ | $3.16 \pm 0.17^{b}$ |
| | 2B | $6.12 \pm 0.06^{c}$ | $4.76 \pm 0.01^{c}$ | $2.61 \pm 0.22^{a}$ |
| | 3C | $4.05 \pm 0.63^{a}$ | $4.12 \pm 0.33^{b}$ | $4.29 \pm 0.18^{c}$ |
| | 3D | $4.98 \pm 0.03^{b}$ | $4.65 \pm 0.02^{c}$ | $4.73 \pm 0.12^{c}$ |
| Orange Juice | 1 | $6.59 \pm 0.04^{e}$ | $1.26 \pm 0.01^{a}$ | $3.11 \pm 0.15^{a}$ |
| | 2A | $5.02 \pm 0.04^{c}$ | $3.71 \pm 0.01^{b}$ | $3.56 \pm 0.12^{b}$ |
| | 2B | $6.07 \pm 0.04^{d}$ | $4.61 \pm 0.01^{c}$ | $3.67 \pm 0.21^{b}$ |
| | 3C | $3.79 \pm 0.04^{a}$ | $4.61 \pm 0.03^{c}$ | $4.18 \pm 0.19^{c}$ |
| | 3D | $4.54 \pm 0.03^{b}$ | $3.76 \pm 0.02^{b}$ | $4.23 \pm 0.23^{c}$ |
| Pineapple Juice | 1 | $7.12 \pm 0.05^{d}$ | $1.22 \pm 0.03^{a}$ | $1.76 \pm 0.12^{a}$ |
| | 2A | $6.59 \pm 0.04^{c}$ | $2.22 \pm 0.02^{c}$ | $3.79 \pm 0.15^{c}$ |
| | 2B | $6.43 \pm 0.03^{c}$ | $2.72 \pm 0.03^{d}$ | $2.97 \pm 0.19^{b}$ |
| | 3C | $5.54 \pm 0.19^{a}$ | $1.72 \pm 0.02^{b}$ | $4.29 \pm 0.17^{d}$ |
| | 3D | $5.99 \pm 0.18^{ab}$ | $2.08 \pm 0.08^{bc}$ | $3.47 \pm 0.09^{c}$ |
| Red grape juice | 1 | $8.64 \pm 0.05^{c}$ | $2.01 \pm 0.02^{a}$ | $1.45 \pm 0.17^{a}$ |
| | 2A | $8.60 \pm 0.03^{c}$ | $3.61 \pm 0.01^{c}$ | $2.51 \pm 0.09^{b}$ |
| | 2B | $7.77 \pm 0.52^{b}$ | $2.77 \pm 0.05^{b}$ | $2.18 \pm 0.42^{b}$ |
| | 3C | $7.01 \pm 1.73^{a}$ | $4.37 \pm 0.02^{d}$ | $3.33 \pm 0.15^{c}$ |
| | 3D | $7.43 \pm 0.24^{ab}$ | $3.89 \pm 0.24^{c}$ | $3.08 \pm 0.21^{c}$ |

Values are mean ± standard deviation for three replicates (n=3). Means with different superscripts across rows are significant at $p < 0.05$.

**Mineral Contents of Fruit Juice Samples**

The results of the Na, K, Mg, Ca, P and Fe contents of the fruit juice samples were expressed as mean ± standard deviation in Table 3. The studies on the mineral content of fruit juice samples showed that the Na, Ca, P levels in industrially processed fruit juice samples were significantly ($p<0.05$) higher when compared with freshly prepared juices, which K and Mg level in commercial juices were significantly ($p<0.05$) lower when compared with freshly prepared juice (Table 5). The difference between commercial samples and freshly prepared samples in their Fe contents was not significant at $p < 0.05$. The order of mineral concentrations was Na > K > Mg > P > Ca > Fe in freshly prepared fruit juice and Na > Ca > P > Mg > K > Fe in industrially processed fruit juices. In general, the mean concentration of Na was the highest with Fe having the least mean concentration in all samples (Table3).

Table 3: Mineral contents of fruit juice samples

| Fruit Juice Samples | Mineral Contents (mg/100 ml) | | | | | |
|---|---|---|---|---|---|---|
| | Na | K | Mg | Ca | P | Fe |
| 1(Apple juice) | 670.33 ± 6.01$^{a}$ | 52.45 ± 7.51$^{b}$ | 118.23 ± 6.76$^{d}$ | 91.60 ± 5.54$^{a}$ | 81.65 ± 1.33$^{a}$ | 2.81 ± 0.20$^{a}$ |
| 2A | 713.00 ± 5.22$^{b}$ | 29.77 ± 3.46$^{a}$ | 75.64 ± 6.94$^{c}$ | 92.26 ± 14.01$^{a}$ | 87.47 ± 1.26$^{b}$ | 2.83 ± 0.08$^{a}$ |
| 2B | 711.67 ± 5.18$^{b}$ | 32.51 ± 4.61$^{a}$ | 79.67 ± 9.03$^{c}$ | 109.33 ± 9.32$^{b}$ | 150.43 ± 1.62$^{c}$ | 2.99 ± 0.23$^{a}$ |
| 3C | 696.23 ± 9.02$^{ab}$ | 30.78 ± 3.80$^{a}$ | 45.33 ± 5.47$^{a}$ | 139.90 ± 9.87$^{c}$ | 85.98 ± 1.92$^{b}$ | 2.95 ± 0.08$^{a}$ |
| 3D | 700.67 ± 6.53$^{b}$ | 49.56 ± 0.01$^{b}$ | 67.88 ± 10.32$^{b}$ | 102.21 ± 11.20$^{b}$ | 209.33 ± 1.34$^{d}$ | 2.77 ± 0.12$^{a}$ |
| 1 (Orange Juice) | 651.13 ± 5.01$^{a}$ | 120.34 ± 6.51$^{c}$ | 111.97 ± 17.21$^{c}$ | 45.65 ± 9.44$^{a}$ | 102.76 ± 1.76$^{a}$ | 1.84 ± 0.20$^{a}$ |
| 2A | 782.10 ± 2.11$^{c}$ | 60.23 ± 4.06$^{ab}$ | 94.98 ± 5.93$^{b}$ | 49.98 ± 5.60$^{a}$ | 105.54 ± 2.11$^{a}$ | 1.76 ± 0.20$^{a}$ |
| 2B | 699.23 ± 5.64$^{b}$ | 49.20 ± 3.81$^{a}$ | 75.83 ± 4.96$^{a}$ | 53.79 ± 9.06$^{b}$ | 269.76 ± 2.32$^{c}$ | 2.02 ± 0.16$^{b}$ |
| 3C | 711.33 ± 2.51$^{b}$ | 81.67 ± 6.71$^{b}$ | 75.12 ± 6.18$^{a}$ | 139.12 ± 5.61$^{c}$ | 130.67 ± 2.00$^{b}$ | 1.94 ± 0.23$^{a}$ |
| 3D | 696.96 ± 6.02$^{b}$ | 77.65 ± 5.04$^{b}$ | 72.54 ± 9.11$^{a}$ | 140.33 ± 9.17$^{c}$ | 143.51 ± 1.65$^{b}$ | 2.50 ± 0.25$^{b}$ |
| 1(Pineapple juice) | 690.23 ± 5.62$^{a}$ | 450.33 ± 3.45$^{d}$ | 165.32 ± 6.51$^{d}$ | 40.55 ± 3.07$^{a}$ | 105.98 ± 1.65$^{a}$ | 2.33 ± 0.24$^{a}$ |
| 2A | 745.43 ± 4.05$^{b}$ | 65.44 ± 2.01$^{b}$ | 97.80 ± 3.33$^{bc}$ | 43.67 ± 5.65$^{a}$ | 184.61 ± 1.36$^{c}$ | 2.25 ± 0.28$^{a}$ |
| 2B | 789.56 ± 6.82$^{c}$ | 100.65 ± 3.61$^{c}$ | 82.97 ± 4.81$^{a}$ | 53.98 ± 5.33$^{b}$ | 224.32 ± 1.11$^{d}$ | 3.56 ± 0.19$^{b}$ |
| 3C | 702.55 ± 9.11$^{a}$ | 39.45 ± 5.81$^{a}$ | 94.46 ± 3.98$^{b}$ | 128.10 ± 8.11$^{d}$ | 163.45 ± 1.32$^{b}$ | 2.21 ± 0.19$^{a}$ |
| 3D | 694.25 ± 7.55$^{a}$ | 50.10 ± 1.81$^{a}$ | 90.45 ± 15.22$^{b}$ | 69.96 ± 9.89$^{c}$ | 161.54 ± 2.61$^{b}$ | 2.68 ± 0.16$^{a}$ |
| 1(Red grape juice) | 687.33 ± 6.51$^{a}$ | 114.67 ± 3.71$^{c}$ | 131.56 ± 5.11$^{e}$ | 75.77 ± 9.61$^{a}$ | 174.69 ± 2.00$^{a}$ | 1.33 ± 0.16$^{a}$ |
| 2A | 715.23 ± 5.21$^{b}$ | 49.67 ± 6.57$^{a}$ | 101.45 ± 5.76$^{d}$ | 96.99 ± 5.60$^{b}$ | 179.43 ± 1.21$^{ab}$ | 1.30 ± 0.16$^{a}$ |
| 2B | 750.11 ± 4.04$^{c}$ | 52.34 ± 4.81$^{a}$ | 93.98 ± 6.23$^{c}$ | 101.55 ± 46.31$^{c}$ | 178.56 ± 2.01$^{ab}$ | 1.47 ± 0.09$^{a}$ |
| 3C | 700.51 ± 3.22$^{ab}$ | 60.04 ± 1.01$^{b}$ | 77.87 ± 10.11$^{a}$ | 129.76 ± 58.23$^{d}$ | 175.67 ± 1.56$^{a}$ | 1.61 ± 0.16$^{ab}$ |
| 3D | 699.83 ± 2.82$^{a}$ | 55.96 ± 4.58$^{ab}$ | 83.65 ± 11.55$^{b}$ | 101.87 ± 9.60$^{c}$ | 335.87 ± 2.32$^{c}$ | 1.83 ± 0.10$^{b}$ |

Values are mean ± std for three replicates (n=3). Mean with different superscripts across column of each group are significant at $p < 0.05$.Where; 1= Freshly prepared juices, 2A= Commercial 100% fruit juice from company A, 2B= Commercial 100% fruit juice from company B, 3C= Commercial 50% fruit juice from company C, 3D= Commercial 50% fruit juice from company D.

### Heavy Metal Contents of Fruit Juice Samples

The result of the heavy metal content of the juice samples showed that the level of Zn and Cu in the industrially processed juice were significantly ($p<0.05$) higher than the level in freshly prepared juice (Table 4). Traces of contamination with arsenic ranging from 0.01 ± 0.01 to 0.02±0.01 mg/100 ml were observed in all samples. Lead (Pb) fell below detectable limit in all the fruit juice samples analyzed. The order of heavy metal concentrations in terms of magnitude was Zn > Cu > As for both freshly extracted and industrially processed fruit juices. In general, the mean concentration of Zn was the highest, with arsenic having the least mean concentration in all samples (Table 4).

Table 4: Heavy metal contents of fruit juice samples

| | | Parameters (mg/100 ml) | | |
|---|---|---|---|---|
| **Groups** | **Samples** | **Zn** | **Cu** | **As** |
| **Apple juice** | **1** | 0.27 ± 0.12[a] | 0.14 ± 0.01[a] | 0.02 ± 0.01[a] |
| | **2A** | 0.53 ± 0.12[b] | 0.16 ± 0.01[a] | 0.02 ± 0.01[a] |
| | **2B** | 3.40 ± 0.35[c] | 0.18 ± 0.01[ab] | 0.02 ± 0.01[a] |
| | **3C** | 0.73 ± 0.23[b] | 0.37 ± 0.01[c] | 0.02 ± 0.01[a] |
| | **3D** | 0.93 ± 0.23[b] | 0.32 ± 0.01[c] | 0.02 ± 0.01[a] |
| **Orange Juice** | **1** | 2.53 ± 0.46[b] | 0.25 ± 0.02[a] | 0.02 ± 0.01[a] |
| | **2A** | 4.07 ± 0.12[c] | 0.27 ± 0.01[a] | 0.02 ± 0.01[a] |
| | **2B** | 0.53 ± 0.12[a] | 0.25 ± 0.02[a] | 0.01 ± 0.01[a] |
| | **3C** | 4.27 ± 0.23[c] | 0.37 ± 0.01[b] | 0.02 ± 0.01[a] |
| | **3D** | 2.67 ± 0.23[b] | 0.27 ± 0.00[a] | 0.02 ± 0.01[a] |
| **Pineapple Juice** | **1** | 1.40 ± 0.10[a] | 0.46 ± 0.01[a] | 0.01 ± 0.01[a] |
| | **2A** | 1.73 ± 0.23[ab] | 0.50 ± 0.01[b] | 0.02 ± 0.01[b] |
| | **2B** | 4.20 ± 0.35[c] | 0.47 ± 0.01[a] | 0.01 ± 0.01[a] |
| | **3C** | 2.13 ± 0.12[b] | 0.53 ± 0.01[b] | 0.02 ± 0.01[b] |
| | **3D** | 2.00 ± 0.40[b] | 0.60 ± 0.01[c] | 0.02 ± 0.01[b] |
| **Red grape juice** | **1** | 1.07 ± 0.46[a] | 0.18 ± 0.01[a] | 0.01 ± 0.01[a] |
| | **2A** | 1.73 ± 0.23[b] | 0.37 ± 0.01[b] | 0.02 ± 0.01[b] |
| | **2B** | 2.40 ± 0.40[c] | 0.35 ± 0.01[b] | 0.02 ± 0.01[b] |
| | **3C** | 1.87 ± 0.61[b] | 0.49 ± 0.01[d] | 0.02 ± 0.01[b] |
| | **3D** | 1.47 ± 0.23[a] | 0.40 ± 0.01[c] | 0.02 ± 0.01[b] |

Values are mean ± SD for three replicates (n=3). Means with different superscripts across column of each group are significant at $p < 0.05$.

## DISCUSSION

In the present study, the sugar and mineral contents of industrially processed fruit juices sold in Enugu state, Nigeria were determined and compared with those of freshly extracted fruit juices. The variation in total soluble solids (TSS) contents between industrially processed and freshly extracted fruit juices could be as a result of variation of fresh fruits used for extraction. Soluble solids are a large fraction of the total solids in fruits, of which soluble sugars (mainly fructose and glucose) and fruit acids are the largest contributors (Anthon *et al.,* 2011; Tilahun, 2013). Total soluble solid content of fruit is significantly influenced by the combined effects of stages of maturity and ripening conditions at harvest (Moneruzzaman *et al*., 2008). Ripening occurs through biosynthetic process or degradation of polysaccharides. It involves the breaking down of starch into sucrose and other sugars (Tilahun, 2013). Fruits which store starch switch from starch synthesis during development to starch hydrolysis during ripening. Moneruzzaman *et al*.

(2008) and Tilahun (2013) reported an increase in TSS content as fruit maturity and ripening stages advanced, which was also accompanied by a decrease in starch content. Hence, the lower TSS contents of some of the industrially processed fruit juice samples when compared with the freshly prepared juices could be due to the use of immature and unripe fruits. The lower TSS contents of the commercial juices could also be due to microbial fermentation of the sugar contained in fruit juice during storage. Juices are slightly acidic and are therefore a suitable medium for the growth of yeasts which rapidly convert fruit sugars into ethanol (Di Cagno *et al*., 2013). Sugar and fruit acids are the main contributors to the total soluble solid (TSS) contents of fruit juices, however, pectins, glycosidic materials and the salts of metals (Na, K, Mg and Ca) when present also register a small influence on TSS content (Tilahun, 2013). Adulteration by dilution with water so as to increase yield could also be responsible for the lower TSS content observed in commercial fruit juice samples when compared with the freshly extracted fruit juices. The total soluble solid contents (in degree Brix) of all samples including industrially processed and freshly prepared juice samples ranged from 10.60±0.58 to 12.00±0.10, 10.00±0.10 to 11.00±0.12, 10.00±0.05 to 12.30±0.58 and 15.33±0.15 to 16.00±0.10 for apple, orange, pineapple and red grape juices respectively, and did not go below the standard minimum brix values for apple (10.0), orange (10.0), pineapple (10.0) and red grape juices (16.0) as contained in general standards for fruit juices and nectar (CODEX STAN, 2005).

The relatively low concentration of fructose and high concentrations of glucose and sucrose in commercial juice samples when compared with the freshly extracted juices could be as a result of adulteration by addition of water and subsequent addition of sugar or sweeteners in the form of glucose and sucrose syrup or crystalline sugar. Even though, human metabolism does not distinguish between sugars that are added to foods and sugars that occur naturally in foods because they are chemically identical, frequent intake of high sucrose and glucose-containing beverages such as fruit juices and carbonated soft drink is hazardous to health (Benelam, 2009; Cashwell 2009). Sugar-sweetened beverages will not only affect diabetic patients and cause tooth decay in children but will also lead to insensitivity of insulin-producing gland (pancreas) and the subsequent development of type 2 diabetes in non-diabetic individuals (Palmer *et al*., 2008). The high glycemic load of sugar-sweetened beverages (especially glucose- and sucrose- sweetened, and not fructose) increases insulin demand and in the long run, may lead to beta cell failure (Palmer *et al*., 2008). Fructose has a low glycaemic index and it is predominantly metabolized in the liver, and unlike glucose it does not require insulin in order to be utilized by the body (Frank, 2009). Epidemiologic studies reported that a higher dietary glycaemic load, with low intake of cereal fibre, significantly elevates long term risk of type-2 diabetes (Palmer *et al*., 2008; Frank, 2009). Hence, the relatively low fructose and high glucose and sucrose content of the industrially processed fruit juice implies that the freshly prepared fruit juices are healthier from the nutrition point of view.

The higher sugar content of the industrially processed fruit juices when compared with the freshly extracted fruit juices could also be due to enzyme treatment of the industrially processed fruit juices to give a clearer and more desirable juice (Sharma *et al*., 2014). Fruit juices are naturally cloudy, though in different degrees, due to the presence of polysaccharides (pectin, cellulose, lignin, and starch), proteins, tannins and metals (Vaillant *et al*., 2001). During juice clarification, enzymes degrade these polysaccharides, thereby increasing its sugar content.

Findings from the analysis of the mineral contents of fruit juice samples showed no significant ($p > 0.05$) difference in iron (Fe) and arsenic (As) contents of industrially processed fruit juice samples when compared with the freshly extracted juices. However, differences in mean concentrations of Na, K, Mg, Ca, P, Cu and Zn between the industrially processed and freshly extracted fruit juices were significant ($p < 0.05$). The industrially processed fruit juice samples (both 50% and 100%) had higher amount of Na, Ca, P, Cu, and Zn, and lower amount of K and Mg than the the freshly extracted samples. All samples showed traces of contamination with arsenic (0.01±0.01 to 0.02±0.01) while Pb was not detected in any of the samples. As indicated, the amount of sodium is slightly elevated in the industrially processed fruit juices relative to the freshly extracted fruit juices. According to Maireva *et al.* (2013), excess sodium in fruit juices can be derived from the addition of preservatives such as sodium benzoate and sodium metabisulphite. The higher sodium content in commercial samples could also be as a result of addition of sodium-containing sweetness enhancers such as sodium chloride and sodium saccharin or the use of unsuitable water for reconstitution. A small amount of sodium is needed to keep the body working properly. In humans, sodium is an essential nutrient that regulates blood volume, blood pressure, osmotic equilibrium and pH (Soetan *et al*., 2010). The minimum physiological requirement for sodium is 500 milligrams per day while the maximum is 2.3 grams per day, the threshold which could lead to hypertension when exceeded (Agrawal *et al*., 2008). Research shows a strong dose-dependent relationship between high sodium consumption and raised levels of blood pressure (Geleijnse *et al.,* 2004).

The low level of potassium and magnesium observed in industrially processed fruit juices when compared with the freshly prepared fruit juices is a clear indication of adulteration by dilution with water (Maireva *et al.,* 2013). More water than required was probably used to reconstitute the fruit juice so as to increase yield which conversely affected the levels of potassium and magnesium present. Fruits, unlike green vegetables, are naturally low in calcium; hence, a higher content of calcium in industrially processed than the freshly prepared fruit juice is an indicator of adulteration. Voldrich *et al*. (2002) revealed that higher calcium content is an indicator of adulteration resulting from higher pulp wash content in juice because pulpwash contains substantially more calcium than juice. Higher calcium can also be due to use of unsuitable water for reconstitution. Reconstitution water with high content of calcium such as hard water could be responsible for the increased calcium content observed in industrially processed samples when compared with the freshly-prepared samples. Calcium is essential for bone and teeth development. Calcium also plays a role in muscle (including cardiac muscle) contraction, neurotransmitter secretion, blood coagulation (clotting) and digestion (Theobald, 2005; Soetan, 2010). However, chronic toxicity can occur due to constant exposure to lower levels of excess calcium. Toxicity of calcium causes anorexia, aphasia, memory loss, muscle weakness, psychosis, fat intolerance, gastric ulcers, hypertension, kidney disease and liver impairment (Maireva *et al*., 2013). The UK reference nutrient intake (RNI) for calcium for adults over 19 years of age is 700 mg/day; requirements are higher during childhood, adolescence and during lactation (Theobald, 2005). Fresh fruits and vegetables are low in phosphorus and iron, hence the high phosphorus content of the industrially processed samples when compared with the freshly prepared samples could be due to addition of phosphates additives (e.g phosphoric acids). Phosphorus is essential for life. It is a mineral that works together with calcium to keep the bones healthy. It also helps keep blood vessels and muscles working (Soetan *et al*., 2010). However, phosphate intakes in excess of the nutrient needs of the healthy population may significantly disrupt hormonal regulation of phosphorus, calcium, and vitamin D, contributing to disordered mineral metabolism, vascular calcification, impaired kidney function, and bone loss (Hruska, 2007). Phosphorus intake from food and drinks should be less than 900 mg per day. Mild elevation of serum phosphorus within the normal range is also associated with the risk of cardiovascular disease (Uribarri and Calvo, 2013). There was no significant ($p > 0.05$) difference in Fe content of industrially processed fruit juices when compared to freshly extracted fruit juices. However, the slightly elevated level of Fe found in industrially processed fruit juices could be from the water used for reconstitution. The use of various iron salts as coagulating agents in water-treatment plants as well as the use of cast iron, steel, and galvanized iron pipes for water distribution in some places impact the iron level of such water (Soetan *et al*., 2010). Concentrations of iron in drinking-water are normally less than 0.3 mg/litre. The minimum daily requirement of iron depends on age, sex, physiological status, and iron bioavailability and ranges from about 10 to 50 mg/day. Drinking-water containing 0.3mg /litre contributes about 0.6 mg to the daily intake (WHO, 2003). Low iron levels may lead to low levels of haemoglobin in the blood, hence anaemia leading to tiredness and an increased risk of infection. The effects of toxic doses of iron include depression, rapid and shallow respiration, coma, convulsions, respiratory failure, cardiac arrest and risk of colorectal cancer (Senesse *et al*., 2004). Sadrzadeh and Saffari (2004) in their review related iron accumulation to some neurologic disorders such as Alzheimer disease, Parkinson disease and type-1 neuro-degeneration.The relatively high concentration of Zn and Cu in all the products could be a reflection of the quality of the raw materials, processing equipment, environment, packaging materials and the personnel in the production process. Contaminations from environment as well as equipment used during the extraction process could impact the juices negatively with respect to Zn and Cu level. More so, metallic containers used in preparation and packaging of the fruit juices could contribute to high concentration of Zn and Cu. High levels of Zn and Cu in fruit juice could also result from the soil where the plants bearing the fruits were grown due to dumping of domestic and industrial waste. The higher copper content in industrially processed 50% juice samples when compared to other samples could be as a result of copper contamination of the water used for dilution. The copper content of juice is highly influenced by plumbing systems of water used for reconstitution (or dilution) as well as the industrial exposure to copper dusts, fumes and mists (Araya *et al.,* 2006). Copper and zinc are essential elements for growth, although emetic in large doses (Valko, 2005). They impair shelf life and decrease fruit juice quality hence fruit juice is expected to contain low levels of these metals. Excessive copper intake can cause nausea, vomiting, abdominal pain and cramps, headache, dizziness, weakness, diarrhea (Silvestre, 2000). Toxicity due to excessive intake has also been reported to cause liver cirrhosis, dermatitis and neurological disorders. Intentional high uptakes of copper may cause liver and kidney damage and even death (Osredkar and Sustar, 2011). Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches (Soetan *et al*., 2010). Intakes of 150-450 mg of zinc per day have been associated with such chronic effects as low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins (Osredkar and Sustar, 2011). The maximum concentration of copper and zinc determined (0.54±0.01 mg/100 ml and 4.27±0.23 mg/100 ml respectively) are within the safe limit set by WHO which is 3 mg/100 ml and 75 mg/100 ml for Cu and Zn, respectively and so do not pose a threat to public health. Traces of contamination with arsenic (0.01±0.00 to 0.02±0.01 mg/100 ml) seen with all samples could be from the fresh fruits from which the juices were extracted, or water used during the extraction process. Arsenic is more acutely toxic than other metallic compounds and continual low-level exposure to arsenic is associated with skin, vascular and nervous system disorders (Mandal and Suzuki, 2002). The order of heavy metals concentrations in terms of magnitude was Zn > Cu > As > Pb for all samples. Generally, with respect to sugar and mineral contents, it was also observed that the 100% commercial fruit juice samples were closer in quality to the 50% fruit juice samples than they were to the freshly extracted fruit juice samples. All the chemical compositions analyzed were within the standard acceptable range as contained in the 2008 standard specification of Standard Organization of Nigeria (SON, 2008).

## Conclusion

The present study demonstrated that industrially processed fruit juices sold to consumers in Enugu state, Nigeria are lower in quality when compared to freshly prepared fruit juices. This is because the industrially prepared juices had higher amounts of sugar, Na, P, Fe and heavy metals such as Cu and Zn, and lower in very essential minerals such as K and Mg when compared to freshly prepared fruit juices. However, they can still be regarded as safe because all the parameters considered in this study were within the standard acceptable range for fruit juices and nectar as stated in CODEX STAN (2005) and standard specifications of Standard Organization of Nigeria (SON) (2008). This study demonstrated no quality issues of concern in relation to the products; however, good manufacturing practices (GMP) and effective hazard analysis and critical control points (HACCP) should be enforced to ensure consumers safety because continuous intake of low levels of heavy metals and added sugar may accumulate far above tolerable limits and thus elicit hazard to consumers' health.

## Conflict of Interest

Authors have no conflict of interest to declare.

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