INTRODUCTION

Food insecurity and malnutrition are threatening issues in both the developed and developing world. Despite all the efforts to combat them (Chikwendu et al., 2014). Global nutrition survey reveals that most dietary deficiencies are of protein with high biological value (Latham, 1997). Consequently, legumes and cereal grains have received great attention lately. The high level of wastage of ripe pawpaw and pineapple fruits encourages the disposal of these fruits coupled with their low level of industrial utilization in developing countries such as Nigeria therefore calls for great concern. Hence, fermenting the juices of these fruits into wine would contribute immensely to the fast-growing food need in the world, forestall wastage and also enhance the nutrient intake of the consumers. Fermentation of foods has been recognized as an important tool for enhancing food security through food preservation, improving livelihoods, nutrition and social well-being of millions of people around the world, particularly the marginalised and vulnerable (Holzapfel, 2002). According to Etsuynkpa et al. (2015), anti-nutrients are natural or synthetic compounds that interfere with the absorption of nutrients by reducing the body’s ability to absorb or use essential nutrients like vitamins and minerals, and are found in all plant foods, although the types and amounts vary tremendously from food to food. However, the traditional method of food preservation such as fermentation has been observed to have positive cumulative health benefits. Pawpaw and Pineapple have well-known nutritive and health benefits. This study evaluated the role of fermentation on the nutritional and anti-nutritional compositions of pawpaw-pineapple juice blends using single and mixed starter cultures. Fermentation of pawpaw-pineapple juice blends in varying ratios: 1:1, 1:3 and 3:1 tagged Samples A, B, and C respectively was performed for five days after which the nutritional and anti-nutritional compositions were analyzed using standard methods. The findings revealed an increase in the concentration of all the proximate parameters except carbohydrate. The results also showed that sample A was better in nutritive quality than sample B and C by 8.55% and 3.92% respectively. The mono-cultural fermentation of sample A by Saccharomyces cerevisiae yielded the highest nutritional value (30.12%) as compared to mixed (25.35%) and single culture fermentation of Lactobacillus delbrueki (23.40%) and Leuconostoc mesenteroides (21.13%). The mineral composition of sample A (37.60%) with respect to organism was also observed to be significantly higher than sample B (28.82%) and C (33.58%). Overall, the single culture of S. cerevisiae gave the highest mineral output in all the blended ratios. The levels of the anti-nutrients were better reduced by a single culture of S. cerevisiae. Furthermore, the monocultural fermentation of sample A by S. cerevisiae produced the highest alcoholic content. Mono-cultural fermentation of pawpaw-pineapple juice in ratio 1:1 by S. cerevisiae is most efficient in obtaining the highest nutritional value and alcoholic content in pawpaw-pineapple wine.

Keywords: Pawpaw-Pineapple Wine, Food Insecurity, Malnutrition, Fermentation, Nutrient, Pilot Scale
Nevertheless, success stories have been documented on the utilization of fruits other than grape (Awe, 2011) to produce wine; however, there is limited information on the combination of these fruits in wine production. Considering the important properties of these fruits, it is of more advantage to have blends of the fruits for wine production as it will enhance and improve the properties of the wine (Ajit et al., 2018). Apart from the limited information on pawpaw-pineapple wine, ascertaining the concentrations of the nutrients and anti-nutrients in the wine is considered vital as it will help to justify the potential ability of the wine in mitigating food insecurity and malnutrition in both the developed and developing world. Hence, this study was conducted to determine the role of fermentation on the nutritional and anti-nutritional compositions of pawpaw-pineapple juice blends using single and mixed starter cultures.

MATERIALS AND METHODS

Collection of Fruits

Apparently healthy fruits with intact protective skin of pawpaw and pineapple were purchased from Oye-Ekiti main market and transported to the Food Science and Technology Laboratory, Federal University Oye-Ekiti, Ekiti State for authentication before further investigation at Microbiology Laboratory of the same University.

Isolation of Starter Cultures

Pawpaw and pineapple juices were subjected to natural fermentation for 5 days at 30 °C and 37 °C. At every 24 hours of the processes, samples were taken for microbial isolation. Dilution factor 3 and 5 were cultured on Nutrient and Potato Dextrose agar respectively. The dominant microorganisms were subsequently identified using standard biochemical methods (Fawole and Oso, 2001). The pure cultures of these organisms were stored on agar slant and thereafter used as starter cultures.

Preparation of Microorganisms

Each of the test organisms from the slant was inoculated in nutrient broth and incubated for 18 hours at 37 °C. The 18 hours old broth culture was centrifuged to pellet cells and the supernatant was discarded. Pellet cells were washed with phosphate buffer saline 3 times to remove debris. The washed cells were resuspended in buffered saline and diluted to specific cell density using 0.5 Mcfarland for the fermentation processes. The yeast was prepared by culturing on potato dextrose agar slant for 10 days for sporulation to occur. The spores were collected after shaking the slant with sterile peptone water (0.2%, w/v) and then filtered through Whatman No. 2 to remove hyphal fragment (Magnusson and Schnurer, 2001). The yeast concentrations were then determined using a Buckner haemocytometer and thereafter diluted to specific cell density for the fermentation processes.

Preparation of Samples

The fruits were sorted out to remove any unhealthy ones among them. The fruits were washed thoroughly in the laboratory before their usage to remove dirt and other contaminants attached to the surface of the fruits. The fruits were peeled and the flesh was sliced into a dry cleaned jar. Different samples were prepared. The first category (Sample A) contains blended mixture of fruit samples in the same proportion (100 g each). The second category contains 50 g of pawpaw and 150 g of pineapple (Sample B), while the third category contains 150 g of pawpaw and 50 g of pineapple (Sample C) (Table 1). After blending, the juice was thereafter extracted by juice extractor for further processes.

| Table 1 Formulation of pawpaw-pineapple juice blends |
| Sample | Pawpaw (g) | Pineapple (g) | Determination of Anti-Nutritional Content |
| A(1:1) | 100 | | |
| B(1:3) | 50 | | |
| C(3:1) | 150 | | |

Fermentation of Fruit Juice Blends Using Starter Cultures

Each sample was added into 500 ml of sterile distilled water in a bioreactor and treated with 44 mg campden tablet of Sulphur dioxide (SO₂) and stirred. The samples were then heated for 3 minutes at 60 °C. Each sample was aseptically inoculated with single or mixed starter cultures at an initial cell density of 2 OD₆₆₀. The samples were made to undergo controlled-liquid state fermentation for 5 days under sterile conditions at 4 °C (Fig. 1). Un-inoculated treated samples were used as control. Samples were collected from each bioreactor and the proximate, mineral, and anti-nutrient compositions of the wine were determined.

The wine was produced using the method of Ogunbanwo and Ogunsanya (2012).

1. **Pawpaw and Pineapple Fruits**
2. **Sorting, Washing, Peeling and Slicing**
3. **Preparation of samples in varying proportions (1:1, 1:3 and 3:1)**
4. **Juice Extraction**
5. **Filtering**
6. **Addition of each Proportion into 500 ml of sterile distilled water in a bioreactor**
7. **Treatment of sample with campden tablet of Sulphur dioxide (SO₂)**
8. **Stirring**
9. **Aseptic Inoculation of each proportion with Starter Cultures at initial cell density of 2 OD₆₆₀**
10. **Fermentation at 4 °C (0, 24, 48, 72, 96, 120 h)**
11. **Pasteurization**
12. **Cooling**
13. **Storage**

The tannin content was determined by measuring 20 milliliters each of the juice and indigo solution into 1 L conical flask. Distilled deionized water (ddH₂O) was thereafter added into the flask to make the volume 800 milliliters. 0.1 N KMnO₄ was used for the titration until blue colour appeared green. Few drops were then carefully added until solution turns golden yellow. Standard solution of indigo was prepared by dissolving 6 g of indigo carmine in 500 milliliters of ddH₂O by heating, after cooling 50 milliliters of 95% H₂SO₄ was added, the solution was thereafter diluted to 1 L and filtered. For blanks, 20 milliliters of indigo and 760 milliliters of ddH₂O was titrated. The tannin content was calculated as:

\[ T = \left( \frac{V-V_0}{g} \right) \times 0.004157 \times 250 \]

where:
- \( T \) = tannin content (mg/g)
- \( V \) = volume at which titration was completed (mL)
- \( V_0 \) = volume of ddH₂O added (mL)
- \( g \) = weight of juice sample (g)

Figure 1: Production flowchart of Pawpaw-Pineapple wine
T: Tannin content; V: volume of 0.1 N aqueous solution of KMnO₄ for sample titration; Vc: volume of 0.1 N aqueous solution of KMnO₄ for blank titration; 0.004157: Tannins equivalent in 1 milliliter 0.1 N aqueous solution of KMnO₄; g: mass of the sample taken for the analysis; 250: volume of the volumetric flask (Anttanasova, 2009).

Oxalate

Oxalate was determined by titration using the method of Association of Official Analytical Chemists (AOAC, 2000). Two milliliters of the sample was weighed into 100 ml conical flask and 50 ml of 1.5 N H₂SO₄ was added and stirred intermittently with a magnetic stirrer (Heated gathering type, Model number DF 101S) for 1hr, and then filtered (Whatman N01). The filtrate (25 ml) was transferred into another conical flask and filtrated at high temperature (80-90 °C) against 0.1 N KMnO₄ solution until a faint colour appearance that persist for at least 30 seconds.

Oxalate = (Titer value x 0.9004) mg.

Determination of Proximate and Mineral Composition

The moisture, ash, crude fibre, fat, protein, and carbohydrate contents, and mineral composition of the samples were analyzed using the standard methods of AOAC (AOAC, 2000).

Determination of Percentage Alcohol

To a 150 ml graduated cylinder, 150 ml of the sample was added. The content was transferred to a 200 ml boiling flask for distillation. A graduated cylinder (250 ml) was placed under the output of the condensers to collect the distillate. The contents were allowed to cool to room temperature. Distilled water was added to the distillate until the volume reached 150 ml (the same volume as the original sample). A specific gravity hydrometer was used to measure the specific gravity of the distillate at room temperature. The following equation was then applied to convert specific gravity to percentage alcohol (Ferguson 2000).

Percentage of alcohol = ((1.05 x (OG - TG)) / TG) / 0.79

Where OG = Original gravity, TG = Terminal gravity

Statistical Analysis

This was carried out using Statistical Package for Social Sciences (SPSS) 15.0 for windows evaluation version by using Analysis of Variance (ANOVA) and Duncan’s Multiple Range Test for the separation of means at 95% Confidence Interval.

RESULTS

Effects of Single and Mixed Starter Cultures on the Proximate Composition of Sample A (1:1)

The findings revealed an increase in the level of all the proximate parameters as compared to the control except carbohydrate level that was observed to decrease with increased fermentation time. It was also observed that the maximum protein content value in sample A was produced by a single culture of L. mesenteroides (10.33±0.58%), followed by S. cerevisiae (9.33±0.58%). The fermentation of sample A, using a single starter culture of L. delbruekii and S. cerevisiae yielded the highest ash content value of 4.67±0.58%. However, L. mesenteroides was observed to produce the highest fiber (6.00±0.00%) and carbohydrate (14.67±0.58%) values at the end of the fermentation process. In the same vein, the proximate analysis of sample A depicted that the fermentation processes of the mixed culture of L. delbruekii and L. mesenteroides enhanced the concentration of all the proximate parameters except carbohydrate (Fig. 2a).

Effects of Single Starter Cultures on the Proximate Composition of Sample B (1:3)

All the fermenting organisms increased the level of all the proximate parameters, excluding carbohydrate. The fermentation process of a single culture of S. cerevisiae in sample B produced the maximum protein and ash content values (8.00±0.00% and 4.00±0.00%) respectively. Moreover, the sample that was fermented with a single culture of L. delbruekii was found to yield the highest fiber (2.67±0.58%) and fat (8.00±0.00%) contents on the last day of the fermentation process. The exploitation of a single culture of L. mesenteroides in fermenting sample B produced the maximum moisture content value (76.33±0.58%). After the fifth day of fermentation, the highest carbohydrate content value was recorded in sample fermented with a single culture of S. cerevisiae (11.67±0.58%) (Fig. 2b).

Effects of Single Starter Cultures on the Proximate Composition of Sample C (3:1)

At the end of the fermentation process, only carbohydrate level was observed to decrease as compared to the control. The maximum protein (5.67±0.58%), ash (3.00±0.00%), and fat (7.33±0.58%) content values were observed in the sample fermented with a single culture of S. cerevisiae. Samples fermented with a single culture of L. mesenteroides and S. cerevisiae exhibited the maximum fiber content value of 3.67±0.58%. Moreover, L. mesenteroides was observed to produce the highest carbohydrate value (6.67±0.58%) at the end of the fermentation process (Fig. 2c).

Figure 2 A Effects of single and mixed starter culture on the proximate composition of sample A (1:1), B. Effects of single starter culture on the proximate composition of sample B (1:3), C. Effects of single starter culture on the proximate composition of sample C (3:1), after the fifth day of fermentation. Three parallel flasks are tested for each organism. Error bars represent deviations (n=3). Statistically significant differences (P<0.05) were determined by student’s t test. L. delbruekii= Lactobacillus delbruekii, L. mesenteroides= Leuconostoc mesenteroides, CHO= Carbohydrate.
Effects of Single and Mixed Starter Cultures on the Mineral Composition of all the Blended Ratios

The results revealed a high amount of sodium, potassium and calcium in all the blended ratios. However, sample A gave the highest mineral composition with respect to organism after the fermentation processes. There were variations in the mineral outputs of both single and mixed starter cultures. Overall, a single starter culture of *S. cerevisiae* produced the highest mineral output in all the blended ratios. For instance, mono-cultural fermentation of sample A by *S. cerevisiae* produced sodium, potassium and calcium output values of 560±0.00 mg/ml, 2600±0.00 mg/ml and 650±0.00 mg/ml while mixed culture fermentation gave 750±0.00 mg/ml, 2000±0.00 mg/ml and 640±0.00 mg/ml respectively (Table 2).

Table 2: Effects of single and mixed starter cultures on the mineral composition of pawpaw-pineapple juice blends in varying proportions after 5 days fermentation

<table>
<thead>
<tr>
<th>Samples</th>
<th>Minerals (mg/100ml)</th>
<th>Control</th>
<th>L. delbruekii</th>
<th>L. mesenteroides</th>
<th>S. cerevisiae</th>
<th>L. delbruekii+ L. mesenteroides</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Na</td>
<td>600±0.00a</td>
<td>700±0.00a</td>
<td>600±0.00a</td>
<td>800±0.00a</td>
<td>750±0.00a</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>1400±0.00a</td>
<td>1800±0.00a</td>
<td>1600±0.00b</td>
<td>2600±0.00a</td>
<td>2000±0.00a</td>
</tr>
<tr>
<td></td>
<td>Ca</td>
<td>500±0.00a</td>
<td>620±0.00a</td>
<td>610±0.00b</td>
<td>650±0.00a</td>
<td>640±0.00b</td>
</tr>
<tr>
<td>B</td>
<td>Na</td>
<td>600±0.00a</td>
<td>550±0.00a</td>
<td>580±0.00c</td>
<td>620±0.00a</td>
<td>600±0.00c</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>1400±0.00a</td>
<td>1200±0.00a</td>
<td>1300±0.00a</td>
<td>1700±0.00a</td>
<td>1500±0.00b</td>
</tr>
<tr>
<td></td>
<td>Ca</td>
<td>500±0.00a</td>
<td>510±0.00c</td>
<td>550±0.00c</td>
<td>550±0.00c</td>
<td>590±0.00c</td>
</tr>
<tr>
<td>C</td>
<td>Na</td>
<td>600±0.00a</td>
<td>600±0.00a</td>
<td>550±0.00c</td>
<td>600±0.00a</td>
<td>620±0.00c</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>1400±0.00a</td>
<td>1600±0.00a</td>
<td>1800±0.00a</td>
<td>2200±0.00c</td>
<td>1800±0.00c</td>
</tr>
<tr>
<td></td>
<td>Ca</td>
<td>500±0.00a</td>
<td>500±0.00c</td>
<td>500±0.00c</td>
<td>630±0.00c</td>
<td>540±0.00c</td>
</tr>
</tbody>
</table>

**Keys:** *L. delbruekii* = *Lactobacillus delbruekii*, *L. mesenteroides* = *Leuconostoc mesenteroides*, *S. cerevisiae* = *Saccharomyces cerevisiae*, Na = Sodium, K = Potassium, Ca = Calcium

Effects of Single and Mixed Starter Cultures on the Anti-Nutritional Composition of all the Blended Ratios

In all the blended ratios, both the single and mixed starter cultures considerably reduced the levels of the examined anti-nutritional factors. However, there was a variation in the extent to which the organisms affected the anti-nutrient compounds present in the sample. The reduction of the anti-nutritional factors in all the blended ratios was observed to be more pronounced on a single starter culture of *S. cerevisiae* than mixed and single culture of *L. delbruekii* and *L. mesenteroides*. For example, the 33.00±0.00 mg/100 ml tannin compound found in sample A was reduced to 24.50±0.00 mg/100 ml, 26.00±0.00 mg/ml, 29.10±1.73 mg/100 ml and 30.00±0.00 mg/ml by single culture of *S. cerevisiae*, mixed and single culture of *L. delbruekii* and *L. mesenteroides* respectively (Table 3).

Table 3: Effects of single and mixed starter cultures on the anti-nutritional components of pawpaw-pineapple juice blends in varying proportions after 5 days of fermentation

<table>
<thead>
<tr>
<th>Samples</th>
<th>Anti-nutrients (mg/100ml)</th>
<th>Control</th>
<th>L. delbruekii</th>
<th>L. mesenteroides</th>
<th>S. cerevisiae</th>
<th>L. delbruekii+ L. mesenteroides</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tannin</td>
<td>33.00±0.00a</td>
<td>29.10±1.73c</td>
<td>30.00±0.00d</td>
<td>24.50±0.00e</td>
<td>26.00±0.00f</td>
</tr>
<tr>
<td></td>
<td>Oxalate</td>
<td>10.50±0.00a</td>
<td>10.00±0.00a</td>
<td>10.00±0.00a</td>
<td>9.40±0.58a</td>
<td>9.50±0.00a</td>
</tr>
<tr>
<td>B</td>
<td>Tannin</td>
<td>33.10±1.73c</td>
<td>33.10±1.15c</td>
<td>33.00±0.00c</td>
<td>30.00±0.00c</td>
<td>31.00±0.00e</td>
</tr>
<tr>
<td></td>
<td>Oxalate</td>
<td>11.00±0.00c</td>
<td>10.00±0.00c</td>
<td>10.90±0.00d</td>
<td>8.50±0.00a</td>
<td>9.30±0.00b</td>
</tr>
<tr>
<td>C</td>
<td>Tannin</td>
<td>32.40±0.00a</td>
<td>32.00±0.00a</td>
<td>30.60±0.58c</td>
<td>29.40±1.15c</td>
<td>30.00±0.00c</td>
</tr>
<tr>
<td></td>
<td>Oxalate</td>
<td>11.00±0.00c</td>
<td>10.00±0.00c</td>
<td>10.10±1.00c</td>
<td>9.40±0.00a</td>
<td>9.60±2.65c</td>
</tr>
</tbody>
</table>

**Keys:** *L. delbruekii* = *Lactobacillus delbruekii*, *L. mesenteroides* = *Leuconostoc mesenteroides*, *S. cerevisiae* = *Saccharomyces cerevisiae*

Effects of Single and Mixed Starter Cultures on the Alcoholic Content of Pawpaw-Pineapple Juice Blends

The findings revealed that both single and mixed culture fermentation processes resulted in the production of a considerable amount of alcohol in all the blended ratios. However, single starter culture of *S. cerevisiae* was observed to produce the highest percentage of alcohol, most especially on sample A (Table 4).

Table 4: Effects of both single and mixed starter cultures on the alcoholic content of blended fruits mixed in different proportion after 5 days of fermentation.

<table>
<thead>
<tr>
<th>Samples</th>
<th>L. delbruekii</th>
<th>L. mesenteroides</th>
<th>S. cerevisiae</th>
<th>L. delbruekii+ L. mesenteroides</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (%)</td>
<td>1.57±0.06a</td>
<td>1.73±0.06b</td>
<td>3.00±0.00c</td>
<td>2.33±0.12d</td>
</tr>
<tr>
<td>B (%)</td>
<td>1.20±0.00a</td>
<td>1.00±0.00b</td>
<td>2.47±0.06c</td>
<td>1.77±0.06c</td>
</tr>
<tr>
<td>C (%)</td>
<td>1.30±0.06a</td>
<td>1.50±0.00c</td>
<td>2.60±0.00c</td>
<td>1.93±0.06c</td>
</tr>
</tbody>
</table>

**Keys:** *L. delbruekii* = *Lactobacillus delbruekii*, *L. mesenteroides* = *Leuconostoc mesenteroides*, *S. cerevisiae* = *Saccharomyces cerevisiae*

**DISCUSSION**

The use of starter culture in wine production has been found to be more productive than natural fermentation, owing to its advantages such as reduction in fermentation time and enhancement of nutritive quality in wine (Omofuvbe et al., 2002). Moreover, wines from the combination of two or more local fruits have been observed to have a positive cumulative health benefits than single fruit wines (Asuk et al., 2011). In view of this, efforts had been made towards the production of varieties of wine from the combination of different local fruits; however, the benefits associated with pawpaw-pineapple wine with respect to alleviation of malnutrition and food insecurity are yet to be unravelled. The combination of local fruits for wine production could probably result in an additional increase in anti-nutritional factors, whose excess consumption has been linked with health disorders such as infertility problems, kidney irritation,
liver damage (Lilian, 2003) etc. Consequently, Ifemeje et al. (2014) advocated moderate consumption of these phytochemicals to forestall them from serving as anti-nutrients to our bodies. On this note, we envisaged based on the reported abilities of some microbes to use anti-nutrients for metabolic activity (Etsuyanpka et al, 2020), that the fermenting organisms utilized in the present study will reduce the levels of the anti-nutrients, leading to the liberation of nutrients that form complexes with them and hence, achieving wine with little or no anti-nutritional factors and improved nutritive quality. In agreement with our expectation, the fermenting organisms significantly reduced the anti-nutrients analyzed in the exam. (Chukwendu et al., 2014). However, the anti-nutrients were better reduced by a single culture of \textit{S. cerevisiae}. This finding contradicts that of Sindhu and Khetarpaul (2014), where mixed culture fermentation was observed to be more effective in reducing anti-nutritional factors than a mono-cultural fermentation, although this mixed culture fermentation involved lactobacilli and yeast. An exploration into the proximate and mineral compositions of the wines produced from all the blended ratios revealed that samples mixed in ratio 1:1 (sample A) gave the highest nutritional value, most especially the sample that was fermented with a single starter culture of \textit{S. cerevisiae}. This suggests that nutrients and anti-nutrients in sample A were probably more readily available for the metabolic activity of the culture than samples mixed in ratio 1:3 and 3:1 (sample B and C respectively). Moreover, the use of a mono-cultural fermentation on sample A was found to be more productive with respect to enhancing the proximate composition of wine than mixed culture fermentation. The observed less productivity of the mixed culture fermentation may be due to the synergistic effect of these organisms in respect to acid production, which might further enhance their sensitivity to the antimicrobial effect of SO2 that was added to the juice (Quiro’s et al., 2012), however, further work is needed to ascertain this phenomenon.

The observed increase in protein in the present study could be linked to the increased activity of the microbial proteolytic enzymes that released more free amino acids into the fermenting medium (Chukwendu et al., 2014). Furthermore, the augmentation of the crude fat by the fermenting organisms could be as a result of extensive breakdown of large molecules of fat into simple fatty acids (Jokatgaba et al., 2015). The increased levels of dietary fibre in the fermented pawpaw-pineapple wine indicates that the wine would offer protection against cardiovascular disease, obesity and colon cancer and promote the effective functioning of the human digestive tract as reported by Ubom (2007). The observed increase in moisture content of all the blended ratios may be attributed to the availability of free bond water in the fermentation medium, the autolysis action of the microorganisms and presence of large volume of water in the matrix (Adeleke, B. S., 2014). The increase in ash content may be due to contribution by fermentation microorganisms in the breakdown of the organic components of the fruit samples during the period of fermentation (Oladele and Oshodi, 2008) while the ability of microbes to metabolize carbohydrate as carbon source to synthesize cell biomass could be attributed to the observed decrease in carbohydrate content of all the blended ratios (Ojokoh et al., 2013). The use of anti-nutrients by microorganisms for metabolic activity usually results in the release of nutrients, including minerals that form complexes with them, although this ability varies from organism to organism, and so do amount of nutrients released differs. This may therefore be attributed to the variations in the mineral outputs of the fermenting organisms observed in the present study. Indirectly, the increase in ash content of the wines produced from all the blended ratios revealed highest percentage of alcohol in the sample that was fermented with a single starter culture of \textit{S. cerevisiae}. This finding complies with that of Okunowo et al. (2005), who stated that fruit wines with alcoholic content above 2% are comparable with moderate grape wines.

The current data in the present study strongly imply that the mono-cultural fermentation of pawpaw-pineapple juice in ratio 1:1 by \textit{S. cerevisiae} will not only greatly improve the safety of the wine by reducing anti-nutritional factors, but it will also contribute immensely to mitigating food insecurity and malnutrition in both developed and developing world.

CONCLUSIONS

The results indicated that the concentrations of the proximate parameters, including the protein, ash, fibre, moisture and fat contents were enhanced by the fermentation process with a reduction in carbohydrate content. The wine produced from sample A using a single starter culture of \textit{S. cerevisiae} was observed to be more nutritious than those produced from sample B and C using a single culture of \textit{S. cerevisiae}, mixed single and single culture of \textit{L. delbrueckii} and \textit{L. mesenteroides}. It can therefore be concluded that the mono-cultural fermentation of pawpaw-pineapple juice in ratio 1:1 by \textit{S. cerevisiae} is most efficient in obtaining the highest nutritional values and content in pawpaw-pineapple wine. Hence, it is recommended that the industrial utilization of pineapple and pawpaw fruits in wine production should involve the combination of pawpaw-pineapple juice blends in the same ratio and fermenting with a single starter culture of \textit{S. cerevisiae}.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

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