Physico-chemical properties of beetroot (*Beta vulgaris* l.) wine produced at varying fermentation days

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**Abstract**

Beetroot is a crop with lots of nutritional and health benefits. The study investigated the effect of different fermentation days on the physicochemical and sensory qualities of wine made from beetroot. Beetroot wine was made by fermenting beetroot Must for 7, 14 and 21 days, and the physicochemical and sensory properties of the wines were analysed by standard methods. Results showed that the acidity increased as the number of fermentation days increased. The pH decreased from 5.51 in the Must to 3.37, 3.23 and 3.20 in the fermented wines for 7, 14 and 21 days respectively. In the fermented product, alcohol per volume of 12.2%, 13.5% and 13.6% were reported for the 7, 14 and 21 days of fermentation. The results showed organic acids (0.40 to 0.71%), alcohol by volume (12.20 to 13.6%) as well as phenolic content (2587.48 to 4286.17 mg/L GAE) increased as the fermentation progressed, while the reducing sugar, total sugar and vitamin C content reduced significantly as the fermentation days was increased. The potassium and iron content of the wines ranged from 568.73 – 677.38 mg/l and 14.25 – 16.85 mg/l respectively. The colour parameters showed that the L* value (29.16 to 39.04), which signifies lightness, increased as fermentation progressed, as well as the b* axis (10.88 to 18.86), which is the yellow-blue coordinate. There were significant differences (p ≤ 0.05) in the taste, flavour and overall acceptability of beetroot wines fermented for 7 days, 14 days and 21 days. Moreover, beetroot wine fermented for 14 days was more preferred in terms of taste, aroma, flavour and overall acceptability than those of 7 and 21 days.

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**Introduction**

Wine is an alcoholic beverage made from fermented grapes or other fruits and plants. Fruit wines are described as undistilled alcoholic beverages which have undergone a period of fermentation and ageing. They are nutritive, tasty and act as mild stimulant [43]. Fruit-based fermented product contains most of the nutrients present in the original fruit juice and are more nutritious as a result of release of amino acids and other nutrients from yeast during fermentation [43]. Fermentation is a metabolic process that enhances release of energy from a sugar or other organic molecules, which do not require

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oxygen or electron transport system and use an organic molecule as the final electron acceptor [45]. Fermentation has been described as a viable method in the development of new products with modified sensory and chemical parameters [43].

Beetroot is the taproot portion of the beet plant. It is one of the several of the cultivated varieties of Beta vulgaris grown for their edible taproots and their leaves which are called beet greens. It is grown year round for its tender, succulent roots, and it has been reported to have more sugar than any other vegetable, its earthy taste and aroma comes from an organic compound called geosmin [30]. Beetroot has been reported to contain powerful antioxidants, such as betalain which helps prevent oxidative damage to cells, thereby reducing the risk of cancer and cardiovascular diseases [19]. According to Canvas et al., [8], beetroot has no fat, it is low in calorie, and it is a good source of fibre, folate, iron, potassium, flavonoids and vitamin C. Beetroot has lots of nutritional and health benefits. It is useful in the treatment of several health problems including anaemia, constipation, haemorrhoids, as well as heart problems [19].

Beetroot comes in different colors (red, yellow, white, multicoloured) sizes and shape (round, long cylindrical and huge sugar and mangle beets) [20]. Beetroot could be consumed fresh, as salad, made into fresh juice [29,40] could be used as colourant [14,24] and as medicine ([19]; Clifford et al [49]). Beetroot have been used for other products such as: wine from red pumpkin and sugar beet root [11], beverage from blend of beetroot and pineapple [35], beetroot juice treated with indigenous spices [16], wine from Ethiopian Beetroot [20], wine from sugarcane and beetroot [42], beetroot fortified cheese crackers [39], as well as other beetroot based products [15]. However, despite the nutritional and health benefits of beetroot, it is still an underutilized and unexploited crop in Nigeria, production of wine from beetroot is therefore a novel means of utilizing it industrially.

Fermentation process of wine can be extended for as long as possible, but a sweet wine is created by stopping the process before the complete conversion of all the sugar. In some products, the wine fermentation usually take about 10 days or more, however in novel products such as beet root wine there is paucity of information on the best fermenting period which will produce acceptable Beet root wine since authors reported different fermenting periods; Kingston et al., [27] reported 6–9 days for beetroot wine in India, Hailu and Mekonen [20], reported 14 days for Ethiopian Beetroot wine, while Ezenwa et al., [17] reported 21 days for Nigerian Beetroot wine, however these authors did not also report the method for halting the fermentation process. Therefore, this research is focused on production of beetroot wine produced at varying fermentation days in order to know the most appropriate fermenting period for good quality beet root wine, the best method for stopping the fermentation process and determination of physicochemical properties of beetroot wine produced at these fermenting periods.

Materials and methods

Materials

The raw materials used for this study were obtained from ShopRite supermarket, Ibadan, Oyo state. The raw materials include beetroot, sugar, active dry yeast and lime.

Methods

Wine preparation. The wine was prepared by the conventional wine preparation method, method of Ezenwa et al., [17] and ingredients were selected based on slight modification of the method of Hailu and Mekonen [20]. The flow diagram for wine preparation is shown in Fig. 1 a&b. The beetroot was sorted, washed, peeled and grated, about 3 L of water was added to 0.75 kg of the grated beetroot and blended using a warring blender (McConnell burg, PA, USA). The beetroot juice was extracted by filtering the beetroot slurry with a muslin cloth. The beetroot juice was pasteurized and left to cool. The pasteurized beetroot juice was sieved using a muslin cloth. 0.6 kg of sugar, 15 ml of lime juice, and pitched with about 0.0212 kg of yeast (Saccharomyces Cerevisiae) that has been proofed was added to the filtrate. The Must was stirred continuously till all the sugar was dissolved. It was then transferred into the fermenting bottles that had been sterilized with hot water. The fermenting bottles’ mouth were blocked with cotton wool and wrapped with aluminium foil. It was left in a cool dark place to ferment for 7, 14, 21 days respectively.

Determination of the best method to stop fermentation in beetroot wine. Cold shock and Pasteurization method were used to stop fermentation of the beetroot wine at the end of each fermentation period or days (7 &14 and 21 days respectively) Cold shock is the physiological response of the yeast to sudden cold, especially cold temperature. The beetroot wine in the fermenting bottle was kept at a temperature between 2–10 °C for 3–5 days and then filtered to remove the dead yeast cells which precipitated at the bottom of the bottle. The second method used is pasteurization. This is a heat process that kills microorganisms in food and drinks. The beetroot wine in the fermenting bottle was heated to 70 °C. This temperature was maintained for 10 min. It was then cooled to 10 °C as quickly as possible. The wine was clarified by racking (racking is a method of removing wine from one vessel to another leaving the settled yeast cells and other solids behind) pasteurized and packed in bottles.

Chemical analysis

The pH, specific gravity, alcohol content, total titratable acidity, total solids and ash content were determined using AOAC [2] (2019) method. Potassium, manganese, iron and zinc content were determined using atomic absorption spectrophotometer. Reducing sugar and total sugar test were carried out by Lane Enyon’s method, as described by James [23]. Total
Washing  
Peeling  
Grating  
Boiling (20 min.)  
Cooling  
Sieving  
Beetroot must  
Fermentation (7, 14, 21 days respectively)  
Clarification  
Packaging  
Beetroot wine

Sugar (0.6kg), Lime juice (15 ml) and proven yeast (2.12 g)

Beetroot

Fig. 1. a) Processing of beetroot wine. b) Processing of beetroot wine.
phenolic content was determined spectrophotometrically by Singleton et al. [41], Vitamin C content by the modified method of Mazunder and Majunder [32].

Colour analysis

Hunter colorimeter was used to measure the colour attributes (L*, a* and b*) of the CIE scale, after it was calibrated with a white tile [31]. *L* (lightness) axis: 0 is black, while 100 is white; *a* (red-green) axis: positive values are red while negative values are green and 0 is neutral; *b* (yellow-blue) axis: positive values are yellow, while negative values are blue and 0 is neutral. From the data obtained, delta Chroma (DC), colour intensity (DE) and hue angle were calculated according to Eqs. (1), 2 and 3, respectively [22].

\[
\Delta C = \sqrt{(\Delta a*)^2 + (\Delta b*)^2} \\
\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} \\
\text{Hue angle} = \tan^{-1}\frac{\Delta b*}{\Delta a*}
\]

Sensory evaluation

Sensory evaluation was carried out to know the acceptability of the wine by carrying out In-house consumer acceptability test using in-house panellists, according to the method of Meilgard et al., [33]. Sensory evaluation was carried out by 20 untrained panellists who were selected based on their availability, objectivity and being conversant with wine tasting. The sensory attributes evaluated were colour, aroma, taste/ mouth feel, flavour and overall acceptability, on a 5-point hedonic scale (where 1 represents dislike very much and 5 represents like very much). The wine samples were served in clean plastic cups to individual panellist in a booth in a well-lit environment where there was no interference for bias expression.

Statistical analysis

Data were analysed using SPSS package for analysis of variance (ANOVA) and means separation.

Results and discussion

Method of stopping fermentation

On the completion of the fermenting periods (7,14,21 days respectively), fermentation were stopped in the wine by subjecting the beetroot wine to either cold shock or pasteurization respectively. It was observed that both methods were effective in stopping the fermentation, however, stopping the fermentation by means of pasteurization resulted in colour change from 'purplish-red' to 'reddish-brown'. This implies that the method of fermentation may affect or determine the final colour of the beetroot wine.

Physico-Chemical properties of Must

The Physico-chemical properties of Must and beetroot wines are presented in Table 1. The properties of the Must may determine the quality of the fermented wine. The pH of the Must was 5.51: this is slightly acidic. The pH of the Must observed is lower than pH of 6.45, reported by Emelike et al., [16] for beetroot juice, but higher than 4.2 – 4.8 pH reported by Haliu and Mekonnen [20] for beetroot Must and 4.20 reported by Owolade and Aruveya [35] for beetroot juice. These variations could be as a result of differences in the variety of crop, maturity level of the beetroot fruit used, processing techniques, wine storage, as well as other ingredients that might have been added prior to fermentation [37]. Bobai et al. [7] reported a pH of 3.64 and 3.55 for grape and orange Must respectively. The specific gravity of the Must was 1.080, the density of the Must is largely dependent on the sugar content of the Must. Decline in sugar content and the presence of ethanol will reduce the density of the Must. Alcohol content of the Must was 0.0% since fermentation has not begun. The

### Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Must (at 7 days)</th>
<th>Wine (at 14 days)</th>
<th>Wine (at 21 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>5.51 ± 0.01</td>
<td>3.37 ± 0.01a</td>
<td>3.23 ± 0.01b</td>
</tr>
<tr>
<td>Malic acid (%)</td>
<td>0.25 ± 0.01</td>
<td>0.40 ± 0.01a</td>
<td>0.53 ± 0.01b</td>
</tr>
<tr>
<td>Tartaric acid (%)</td>
<td>0.29 ± 0.01</td>
<td>0.44 ± 0.01a</td>
<td>0.59 ± 0.01b</td>
</tr>
<tr>
<td>Alcohol by volume (%)</td>
<td>0.00 ± 0.00</td>
<td>12.20 ± 0.00a</td>
<td>13.5 ± 0.00b</td>
</tr>
<tr>
<td>Total solids (%)</td>
<td>17.53 ± 0.03</td>
<td>0.72 ± 0.25a</td>
<td>0.94 ± 0.40b</td>
</tr>
<tr>
<td>Ash content (%)</td>
<td>1.49 ± 1.06</td>
<td>0.32 ± 0.06b</td>
<td>0.27 ± 0.02bc</td>
</tr>
<tr>
<td>Reducing sugar (%)</td>
<td>0.92 ± 0.04</td>
<td>0.74 ± 0.02c</td>
<td>0.57 ± 0.02bc</td>
</tr>
<tr>
<td>Total sugar (%)</td>
<td>8.65 ± 0.03</td>
<td>6.74 ± 0.22c</td>
<td>4.89 ± 0.12bc</td>
</tr>
<tr>
<td>Vitamin C (mg/100 ml)</td>
<td>22.71 ± 0.56</td>
<td>16.80 ± 0.32c</td>
<td>11.08 ± 0.00b</td>
</tr>
<tr>
<td>Phenolic content (mg/L GAE)</td>
<td>1411.07</td>
<td>2587.48a</td>
<td>4161.55b</td>
</tr>
</tbody>
</table>

*a* Means with the same superscript within the row are not significantly different (*P* > 0.05).
total solid of the Must was 17.53%, which is in close range to 19.82% observed by Emelike et al., [16] and 15.5 to 18.0% observed by Halii and Mekonnen [20] for beetroot juice, while the vitamin C content of the Must was 22.71 mg/100 ml. The Must had phenolic content of 1411.07 mg/L GAe; this was lower than that reported by Tugba et al. [46] for red beet. Reducing sugar of the Must was 0.92% while total sugar is 8.65%. Sugar is very important for wine production as it serves as food for the yeast and can also dictate the final alcohol content and the body and mouthfeel of the wine [38].

Physico-Chemical properties of wine
The physicochemical properties of the wine showed that pH ranged between 3.20 to 3.37 (strongly acidic) this showed a decrease in pH as fermentation progressed. This implied that acidity of the wine increased as fermentation days progressed. This reported range of pH is similar to reports on pH of wines reported by Halii and Mekonnen [20] for beetroot wine: 2.89 – 3.53; Akingbala et al. [1] for mango wine: 3.70; Soibam et al., [42] for sugarcane-beetroot wine: 3.45 – 3.8. However, high pH values of 4.10 to 4.20 were reported for honey-coconut wines produced by 21 days fermentation [4]. pH plays important roles in wine making and stability. This include solubility of tartrate salts, effectiveness of Sulphur dioxide, ascorbic acid, solubility of proteins and effectiveness of bentonite, polymerisation of the colour pigment as well as oxidative and browning reaction Rajkovic et al., [37]. The level of pH of wine has an important implication on the taste of wine; as wine taste are usually classified based on their pH; low pH wine will taste tart and crisp, while higher pH wines will taste weak and flabby, and it will increase it susceptibility to microbial growth.

The organic acid content in wine, majorly malic acid and tartaric acid, increased as the fermentation days increased (Table 1). Volschenk et al. [47] stated that when organic acid is in balance with other components of wine, it contributes positively to the organoleptic characteristics of wine. Malic acid increased from 0.25% in the Must to 0.4, 0.53 and 0.64% for the 7, 14 and 21 days fermented wine respectively. The same trend of increase was also reported for tartaric acid, increasing from 0.29% in the Must, to 0.44%, 0.59% and 0.71% for 7 days, 14 days and 21 days of fermented wine. The growth and vitality of yeast during fermentation is greatly influenced by malic acid and tartaric acid [5]. Increased acidity of wine has been reported to be as a result of the production of succinic acid during the fermentation process of alcohol, which is an important non-volatile acid produced [38]. According to Coote and Kirsop [13] increase in acidity and decrease in pH can be attributed to absorption of basic amino acids and release of organic acid. Preservation and sensory characteristics of wine is greatly attributed to its acid content, and this can vary depending on the variety of fruit, degree of ripeness, climatic conditions during ripening, soil type, processing technique, vineyard position and wine storage [37]. Volschenk et al. [47] stated that acidity and pH of wine also influences the visible attributes of wine such as wine colour, clarity and microbrial stability of wine.

The alcohol per volume reported for the fermenting periods (7, 14 and 21 days) were 12.2%, 13.5% and 13.6% respectively also increase significantly fermentation days increased. The increase in the alcohol content as fermentation days progressed was due to increase in ethanol production from acetaldehyde, which was produced from pyruvates which resulted from glucose by the process called glycolysis [28,45]. Despite the short period of fermentation, compared with some other fermented fruits, beetroot produced wine with higher alcohol content than banana wine and pawpaw wine (10% and 9.8% respectively) [3] as well as sugarcane-beetroot wine (8.2 – 11.7%) [42], but similar alcohol content was reported by Bobai et al. [7] for grape wine (14.6%) and orange wine (12.6%); Chilaka et al. [12] for passion fruit, water melon and pineapple wine (10.14 – 12.8%); Akingbala et al., [1] for Mango wine (13.82%), including beetroot wine by Halii and Mekonnen [20] (9.7 – 15.7%). Beetroot wines could be referred to as natural wines, since its alcohol content ranged between 9 – 14% [43], with most natural wines being in the range of 12.5 – 14.5%.

The total solid content of the wine increased with increase in the days of fermentation, ranging through 0.72%, 0.94% to 0.99%, as the solid content is composed of constituents of the Must and the yeast strain used in the fermentation. Total solid has been described to indicate sweetness, it influences the preference and choice of fruit juice products, as well as altering the physico-chemical characteristics of wine (Joshi et al., [50] and [35]). There was a rapid decrease in the total solid content of beetroot wine after the first seven days of fermentation, which showed significant breakdown in the starch and sugar content of the Must to alcohol, by the action of yeast. Moreover, same method of clarification was employed at the end of the fermentation process, but there was significant difference (p ≤ 0.05) in the total solid of wine fermented for 7 days and those of 14 and 21 days. This implies that the major break down of starch, and action of yeast was between the first seven days of fermentation, with little or no breakdown of starch between the 14th and 21st day of fermentation.

The ash content of the wine decreased with fermentation days, ranging between 0.20 – 0.32%. However, there was no significant difference (P ≥ 0.05) in the ash content of the wine despite differences in the fermentation days. Hence, the reduction in the ash content of the Must as fermentation progresses may imply that there was significant reduction in the inorganic compounds of the Must as the breakdown of sugar and other organic components took place. Similar observations of ash content were made for pawpaw wine (0.30%) [3], mango wine (0.27 g/100 g) [1], but higher values have been reported for banana wine (0.7%) [3]. This implies that wines are significantly low in minerals, as ash content could indicate mineral contents.

The sugar content of the wine samples reduced significantly with increase in fermentation days. Wine fermented for 7 days had the highest reducing and total sugar content (0.74%, 6.74%), wine fermented for 14 days had 0.57% and 4.89% of reducing and total sugar, while wine fermented for 21 days had the lowest reducing and total sugar content (0.31%, 2.49%) respectively. The reduction in sugar content is as a result of increased breakdown of sugar to ethanol and carbon dioxide,
as the days of fermentation progressed. The sugar content of beetroot wines reported for this study were higher than those reported by Awe et al., [3] for banana wine (0.1 g/100 g) and pawpaw wine (0.2 g/100 g).

The vitamin C content of the wine significantly reduced during fermentation. There was significant decrease in the vitamin C content ranging from 16.80 mg/100 ml, 11.08 mg/100 ml to 4.62 mg/100 ml for 7 days, 14 days and 21 days of fermentation respectively, which implies that vitamin C degraded as the fermentation period was increased. Hande et al. [21] stated that degradation of vitamin C takes both aerobic and anaerobic pathways during processing or extraction (including boiling of beetroot), which could be affected by factors such as oxygen, heat, light, temperature as well as storage time. Similar vitamin C content for 7 days beetroot wine was reported for banana wine (15 mg/100 g) [3], with a lower vitamin C content (10 mg/100 g) reported for pawpaw wine [3].

The phenolic content of the wine increased as the fermentation days increased from 2587.48 mg/ L GAE, 4161.55 mg/L GAE to 4286.17 mg/ L GAE. The increase in the phenolic content as the fermentation progressed may be due to formation of polymeric pigments, which increases with time [44]. The formation of these polymeric pigments is influenced by proanthocyanins, other flavonols and oxygen [34]. Phenolic content in wine is composed of large group of chemical compounds, including phenolic acids, stilbenoids, flavanols, dihydroflavonols, anthocyanins, flavanol monomers (catechins) and flavanol polymers (proanthocyanidins), quercetin, all contributing to colour, mouthfeel and taste (Kennedy [51]). These chemical compounds could either be flavonoids or non-flavonoids. The flavonoids have high antioxidant activity and have many biological activities such as inhibition of platelet aggregation and cyclooxygenase activity, potent nitric oxide radical scavenging activity and exhibiting antibacterial, antiviral, anti-inflammatory and antiallergenic effects [6]. The phenolic content reported in the beetroot wines were higher than that of red wine reported by Robinson [38] - 2160 mg/L, red wine from four varieties of grape - 1283 – 2570 mg/L by Bin et al. [6], red wine-3630 mg/l by Bosanek et al. [52], white wine- 320 mg/l [38], rose wine- 820 mg/l, [38]. Variations in the phenolic contents of wines could be due to different factors including variations in the content of different fruits, species, varieties, season, soil conditions, climate, crop load as well as skin colour. The higher phenolic content of beet root wine could be due to the higher anthocyanin content, reflected in the deep red colour of the fruit, as compared with other sources of wine, which affected the production of the polymeric pigments, hence increased phenolic content.

Mineral contents of Must and wines

Mineral content of wines has been reported to be affected by factors such as mineral composition of soil, viticultural practices, environmental factors, fruit varieties, fermentation process and the procedure of storage conditions [26]. The potassium and iron content of the Must and fermented wines were reported in Table 2.

The Must gave a potassium content of 517.62 mg/l and iron content of 19.07 mg/l. Lower potassium content was observed by Owolade and Arueya [35] for beetroot juice (9.77 mg/100 ml). Potassium has been reported to be the most relevant cation in concentration, as it has greater effect on changes in acidity and pH of juice and its wine, by helping to neutralize acids in juice and in wine [48]. Iron has been regarded as one of the most abundant minerals in wine, which is said to be influenced by the iron content of soil used for growing the fruit [26].

There was decrease in the potassium content of the wine from 7 days through to 21 days, given 677.38 mg/l, 587.84 mg/l and 568.73 mg/l for wines fermented for 7 days, 14 days and 21 days respectively. However, lower potassium content was reported by Awe et al., [3] for banana wine (12.00 mg/l), pawpaw wine (21.00 mg/l) and red wine (35.00 mg/l). There was significant increase in the iron content of wine fermented for 7 days, 14 days and 21 days, observed as 14.25, 15.11 and 16.85 mg/l respectively (Table 2). These contents are in close range to those of grape wine reported by Karatás et al., [26] (9.14 – 29.64 mg/l). Low concentration of iron has been reported to play an important role in metabolism and fermentation processes, enzyme activator, stabiliser and functional protein component. However, iron content of wine above trace level could affect the sensory characteristics through oxidation, and as well participate in the formation of tannins and phosphates resulting in instabilities [36].

Table 2

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Must</th>
<th>Wine at 7 days</th>
<th>Wine (at 14 days)</th>
<th>Wine at (21 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium (mg/l)</td>
<td>517.62 ± 0.03</td>
<td>677.38 ± 0.03c</td>
<td>587.84 ± 0.04b</td>
<td>568.73 ± 0.06a</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>19.07 ± 0.01</td>
<td>14.25 ± 0.04a</td>
<td>15.11 ± 0.12b</td>
<td>16.85 ± 0.04c</td>
</tr>
</tbody>
</table>

*Means with the same superscript within the row are not significantly different (P ≥ 0.05).

**Effects of fermentation duration on the colour parameters**

The effect of fermentation duration on the colour attributes of beetroot wines, as presented by the L∗, a∗ and b∗ coordinates of the CIE scale from triplicate determinations are presented in Fig. 2. The L∗ values, which represents the lightness or luminance component increased as the fermentation process progressed. The Must had an L∗ value of 28.83, and fermentation process significantly (P ≤ 0.05) increased the lightness to 29.16, 33.89 and 39.04 at 7 days, 14 days and 21 days period of fermentation. The L∗ ranges from 0 (black) to 100 (white), hence the fermentation process led to increased lightness of the wine over the period of fermentation. Same trend of increased lightness was also reported over time for red wine by Garcia-Estevez et al., [18], which could be due to decrease in the total pigmen content. This was reported to be due to
loss of anthocyanins: however, addition of oenological tannin could increase the levels of anthocyanins, thereby stabilizing wine colour through co-pigmentation reactions. The oenological tannin protects anthocyanins against oxidation due to the presence of phenolic compounds, especially ellagitannins [18].

The $a^*$ coordinate, indicating the red-green (positive and negative values respectively) axis, are presented in Fig. 2. The results showed that the colour of both the Must and the beetroot wines tend towards red as observed from the positive $a^*$ values. However, Must had the highest $a^*$ value, that is redness, and then a decreasing red colour for the wines as the fermentation period was extended, which corroborates the $L^*$ results of increasing lightness as the fermentation periods increased. Beetroot contains a group of highly bioactive pigments called betalains, the betacyanin constituents, which gives beet root its attractive red colour, and possess an exceptionally high free radical-scavenging activity [9,10,25]. Swami et al., [43] observed that thermal treatment/processing led to colour degradation of beet root as measured by Hunter ‘$a/b$’, following time and temperature difference as well. Hence, the reduced redness, and increased lightness of beetroot wine could be as a result of breakdown of the betalain pigment during the pasteurization process and fermentation period.

The $b^*$ coordinate of the Must and beetroot wines also gave positive values, which showed that they tend towards yellow. The $b^*$ value of the Must was 9.13, followed by an increase in the yellow axis ($b^*$ value) as the fermentation duration was extended, ranging from 10.88, 15.94 to 18.86. The results of the CIE tristimulus evaluation of the beetroot wines fermented for different days showed that the wines became lighter as the fermentation progress, hence tending more away from red ($a^*$) and moving towards yellow ($b^*$).

The delta-chroma ($\Delta C$) results showed that there were significant differences in the beetroot wine samples as fermentation progressed, which ranged between 2.45 and 14.23. The colour intensity ($\Delta E$) shows that there was significant increase in the colour intensity as fermentation progressed, ranging from 2.48 – 17.52. The hue angle showed that there were significant differences in the beetroot wine samples, as the hue angle increases with days of fermentation, which ranged from 0.25 – 0.63. Hence, these calculated colour parameters showed that there was significant change in colour as fermentation progressed, resulting in significant breakdown of the colour pigments of beetroot Must, which is increase degradation of betalains, breakdown of sugar and subsequent increase in acidity as time progressed.

**Sensory properties of beetroot wine**

The sensory evaluation results of the beetroot wines are presented in Fig. 3. The result showed that beetroot wine fermented for 7 days was more preferred in terms of colour than others. There was no significant difference ($p \geq 0.05$) in the colour attributes of the wine fermented at 7 and 14 days, but the colour of the wine sample was significantly different from wine fermented for 21 days. This may imply that there was minimal degradation of betanin in the wine fermented for 7 and 14 days, with significant degradation in that of 21 days, hence since betanin is an antioxidant, wine fermented for 7 and 14 days respectively may have higher anti-oxidant activity. From the scores of the panellists they prefer the “purplish-red” colour of the wine fermented for 7 days to the “wine-red” colour of wine fermented for 21 days which received a lower
score. There was no significant difference in terms of colour by the panellists for wine fermented for both 7 and 14 days respectively.

There were significant differences \((p \leq 0.05)\) in the taste, aroma, flavour and overall acceptability between beetroot wines fermented for 7 days and other days (14 days and 21 days), with no significant difference between those of 14 and 21 days. Wine fermented for 7 days had low scores for taste and flavour. These may be adduced to the fact that the wine is not yet fully fermented, and body of the wine is not fully developed, hence has low acidity causing a weak and flabby taste with an earthy flavour which may be as a result of geosmin which is present beetroot. Wine fermented for 21 days had higher scores than that of 7 days fermentation, probably because the wine was dry with no perceptible sweetness which could be due to higher breakdown of sugar during fermentation which can also affect the flavour and aroma. However, beetroot wine fermented for 14 days was more preferred (Fig. 3) in terms of taste, aroma, flavour and overall acceptability than those of 7 and 21 days, which could be due to balance in the acidity and sweetness level. There was perceptible sweetness but not as much as in a sweet wine. However, the colour could be improved by the addition of oenological tannin, to reduce the degradation of the colour pigments.

**Conclusion**

Beetroot is a valuable and nutritious fruit, which can be fermented to produce acceptable quality wine. The duration of fermentation affected the sensory and physicochemical properties of the wine. The study showed that fermenting beetroot Must for 14 days produced wine that was nutritious and better accepted by consumers. However, wine fermented for 21 days produced dry wine which may be the preferred choice of some consumers. The fermentation period can thus determine the type of wine (sweet or dry) wine that can be produced from beetroot. Both cold shock and pasteurization method were effective in stopping the fermentation process in beetroot wine, however stopping the fermentation period by pasteurization affected the colour of the beetroot wine, hence the method employed in stopping fermentation process can also influence the colour of the final product.

**Declaration of Competing Interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**References**
