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Production of wine from the fruit pulp of African star apple (*Chrysophyllum albidum* G.Don,)

[1*]Jimoh S.O, [1]Adeniyi T.E. and [2]Oladele A.T.
[1]Department of Forest Resources Management, University of Ibadan, Nigeria
[2]Department of Forestry and Wildlife Management, University of Port Harcourt, Nigeria

*****Correspondence: jimohsaka@yahoo.com

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ABSTRACT
African star apple Chrysophyllum albidum G.Don, (Sapotaceae) is an important forest tree species and valued for its fruits among forest dwellers across West and Central Africa. Utilization efficiency of the fruit pulp in Nigeria is limited to consumption as fruit snack during its season. Hence there are a lot of wastages of fruits which are not marketed within few days of harvesting. Processing of the fruit pulp for industrial development may promote better utilization efficiency and sustainable management of the species. The study therefore investigated the potentials of the fruit pulp of the species in wine production. Fruits used for the study were collected from old and young trees at Laniba, Akinyele Local Government Area, Ibadan, Nigeria. Ripe fruits were plucked from young and old trees and the juice extracted from the fruit pulp. The wine was prepared by fermenting the juice, using graded levels of sucrose to produce dry and sweet wines. Chemical, microbial, heavy metals and sensory properties of the wine were determined. Heavy metals concentrations were within the WHO limits. Young and old trees fruit wines contain: Cr (22.74ppm/mg, 20.46ppm/mg), Pb (8.4ppm/mg, 2.4ppm/mg) and Mn (10.8ppm/mg, 9.6ppm/mg) respectively. The ascorbic acid contents were higher in old tree and sweet wine samples than young tree and dry wine samples (3.28 and 3.59%) and (2.06 and 2.11%) respectively. African star apple has good potentials as a raw material for fruit wine production. Food industries may consider the adoption of this indigenous species for fruit wine production.

Keywords: Fruit, Wine, *Chrysophyllum albidum*, Nutritional elements, Heavy metals

INTRODUCTION

Non-timber Forest Products (NTFPs) including fruits, nuts, seeds, berries, mushrooms, oils, foliage, medicinal plants, fuel-wood and forage are obtained from forest or similar ecosystems for household consumption or for commerce. They play a major role in sustainable forest management (Arnold, 2002) and support household livelihoods, hence can be used to raise the perceived value of forest ecosystems. In many developing countries, most rural households and a large proportion of urban households depend on NTFPs to meet parts of their nutritional, health, housing and income needs (Houessou *et al*., 2012). Therefore, NTFPs form an integral part of the rural economy especially around the forest resource base; where the majority of the rural populations live.

However, the full potential of many of them are yet to be tapped due to the crude methods of processing and utilization. This has implications for the sustainability of the species. Hence they are often overlooked in most forest management priorities compared to timber production. The wastage of these resources during harvesting and lack of appropriate preservation and processing techniques have led to their inability to sustainably contribute to the national income. Thus, it is essential that the inherent potentials of these resources be unlocked. Various products could be derived from NTFPs such as sweetener from *Thaumatococcus danielli*; juice from *Parkia biglobosa*, dye from *Lonchocarpus cyanensis;* food colourant from *Pterocarpus osun* and wine from *Chrysophyllum albidum.* This will not only promote efficient utilization and sustainable management of the species concerned; but will also enhance the economic value of the resources and improve the welfare of the people whose livelihoods depend on such resources.

Chrysophyllum albidum G. Don, (Sapotaceae) is a tree of high commercial value in Nigeria. Its local names include: *Agbalumo* (*Yoruba*) and *Udara* (*Igbo)*. The fruit (Plate 1) is commonly sold in both urban and rural markets during the months of December to April. The fleshy pulp of the fruit is eaten as snack and relished by both young and old. The fruit contributes to the nutritional needs of the people as an important source of vitamins (Ureigho and Ekeke, 2010). However the level of this contribution is limited by the lack of value addition and storage facilities. Hence a lot of fruits are wasted during the fruiting season once they are not marketed within few days of harvesting.

The aim of this study therefore, was to produce wine from the fruit pulp of *Chrysophyllum albidum* with a view to minimizing the usual wastage of the fruits during the peak period of harvesting; enhancing its contribution to the rural economy and ultimately promoting its sustainable management.

METHODOLOGY

Study Area

The fruits used in the study were collected from Laniba, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria. Laniba is located on longitude 03^{o} 53.237' E and latitude 07^{o} 25.721' N (Figure 1). Its elevation is 207 m above sea level.

The area is characterized by two seasons, the dry season which is brought about by the North-East trade wind lasts from late October to early March. The wet season has two peaks which are July and September. The vegetation is a relic of tropical rain forest with large tall trees, mixed with thick undergrowth. The characteristic species include: *Albizia zygia, Antiaris toxicaria, Phyllantus discoides, Newbouldia laevis, Elaeis guineensis, Leucanea leucocephala, Phyllantus mulerianus and Alchornea cordifolia.*

Sample collection: The young and old trees were chosen after a reconnaissance survey and oral interviews of the people residing in the area regarding the relative ages of the trees from which the fruits were collected.

WINE PREPARATION

Pulp Extraction: This was done by separating the epicarp (outer cover), mesocarp (pulp), and seeds into different lid containers (Plate 2). These different parts of the fruits were weighed and recorded. Fruit pulp yields from the old and the young trees were obtained and recorded in order to compare fruit pulp yields from them.

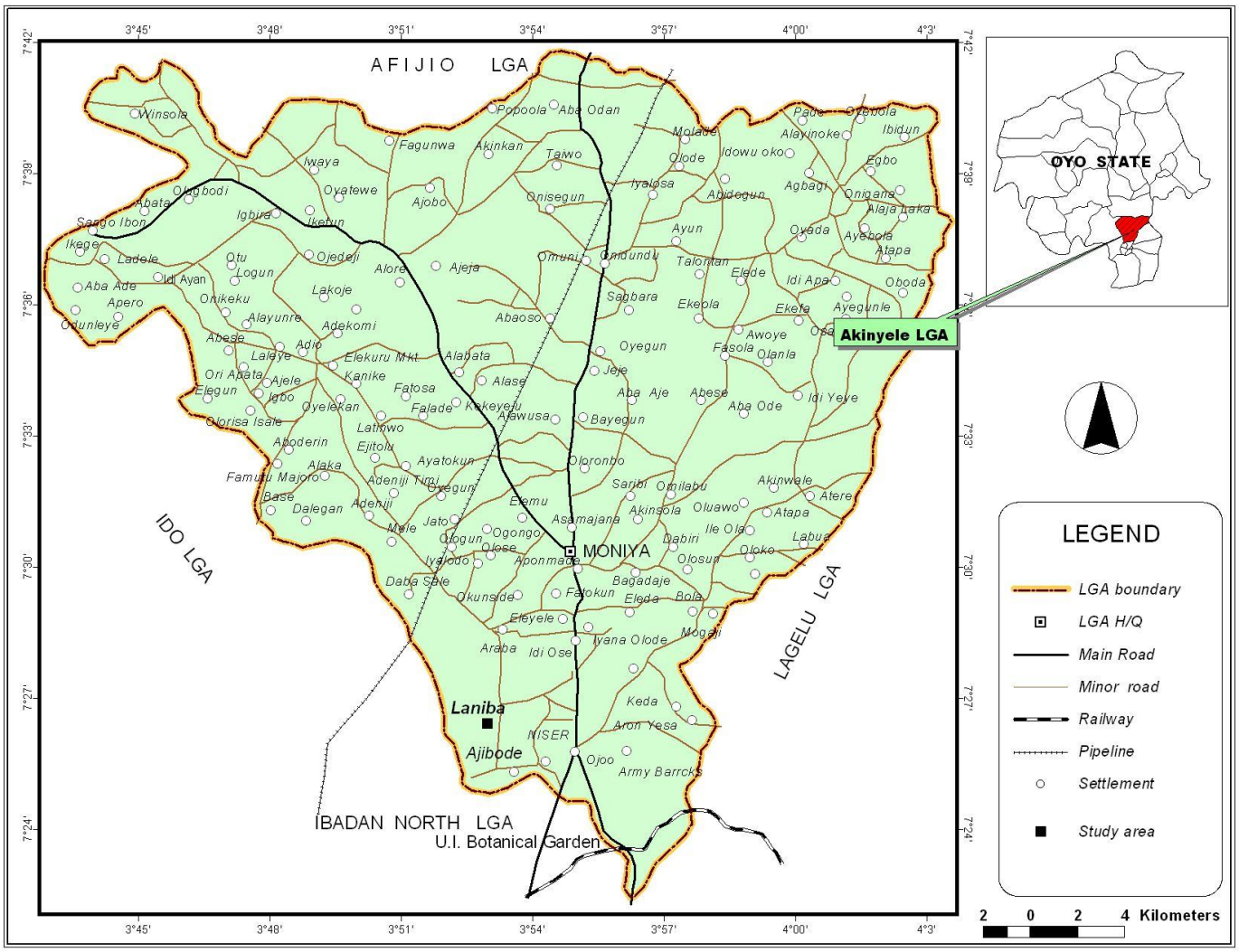

Figure 1: Map of Akinyele LGA showing fruit collection site

Source: Department of Geography, University of Ibadan, Nigeria.

Plate 1: Fresh ripe fruits of *C. albidum*

Plate 2: Fruit Mesocarp (pulp)

Plate 3: Plate 4: Fruit juice

Crushing: This was done by squeezing the pulp manually in a cloth sieve so as to extract the juice content (Plate 3).

Fermentation: Prior to fermentation, different quantities of sugar were added to fruit juices from both the old and young trees in order to produce dry and sweet wine types. 200g and 300g of sugar were added to 0.9litres of each of the juices to produce dry and sweet wines respectively. Next, 0.05kg of raisin and 0.155g of sodium metabisulphite were added to each of the juices. Then, 6.1g of baker's yeast (*Saccharomyces cerevisiae*) was added after 45hours. Sodium meta-bisulphite was added to the fruit juice to sterilize the fruit juice so that any wild yeast cells in the mixture were eliminated first before adding baker's yeast. At this stage, the juices were set on open fermentation. Kegs containing the juices were slightly opened to admit oxygen for the multiplication of the yeast at 28^0C. The juices were set on secondary fermentation for 48hours by transferring the juices into air tight kegs following Randy (2006).

Racking and Clarification: Racking separates the sediments from the wine blend fluid. The method of Randy (2006) was adopted for this process. Racking was done weekly for two weeks , after fermentation. This process was done in order to remove the sediments (dead yeast) formed at the base of the liquid completely. The juice was clarified by adding 2.5g of calcium bentonite solution to the juice at a temperature of 21^oC and mixed properly for two minutes.

Wine Aging: The wine was allowed to age for eight weeks at 10^oC to improve the taste and aroma(Perez-Coello and Diaz-Maroto, 2009). The aging regime adopted was governed by the style of wine desired which is white wine. This requires only a short period to develop and generally do not benefit from prolonged maturation and aging.

Wine sweetening: 1.5g of sucrose was added to 20ml of wine with high quantity of sucrose and 0.4g of sucrose to 20ml of wine with low quantity of sucrose following the method of sweetening dessert wine by Savin *et al*. (2011).

PARAMETERS MEASURED

Determination of Pulp and Juice Yields

The pulp yield was obtained using a sensitive weighing balance to weigh the fruit pulp while the yield of the juice extracted from fruit pulp was measured using a measuring cylinder and each weight recorded.

Determination of Microbial Count

Microbial count was carried out to check for the presence of wild yeast before and after adding sodium meta-bisulphite which was for the purpose of reducing wild yeast. This was determined using the pour plate count method (Fankhauser, 2010). 1ml of the juice sample was diluted with distilled water using ten folds of serial dilution. Empty Petri dishes were inoculated with the diluted juice samples. Melted nutrient agar and potato dextrose agar were poured into different inoculated Petri dishes. The Petri dishes were covered and the contents mixed thoroughly by tilting and swirling gently. They were then placed on a flat surface undisturbed for about 10 minutes allowing the agar to completely gel. The Petri dishes were inverted and incubated at 28^0C and 32^0C for 24 hours and 48 hours each. The colonies of the coliform and yeast were then counted.

Determination of pH: Electronic pH meter was used to determine the pH of the raw juice and the wine samples. This was determined by dipping a pH electrode into a 50ml beaker containing the samples using

the pH meter with 7.0 and 4.2 buffer solutions.

Determination of Alcohol Content: Alcohol content was estimated following (Honneyman, 2009). This was done by measuring the initial specific gravity of 140ml of wine in volume. The sample was then poured into a beaker and boiled until it was half the original volume. Distilled water was added to the boiled sample to fill to the exact initial volume. The sample was cooled and the final specific gravity was determined. Spirit indication = Final Specific gravity – Initial Specific gravity

Determination of Heavy Metals Content: The samples were digested and read for the mineral elements on Buck 200 Atomic absorption spectrophotometer (AAS). Concentration in ppm or % was obtained by using the formula below:

Ppm (metal) = meter reading of sample x average gradient x dilution factor

% (metal) = ppm (metal) / 10000

Determination of Total Soluble Solid: Total soluble solid for the wine samples was determined as prescribed by Goose and Binsted (1973).

Determination of Fat Content: Fat content was determined by weighing 1ml of the sample into a labelled porous thimble. The porous thimble was covered with clean white cotton wool and placed in a condenser. 200ml of petroleum ether was poured into a dried 250ml extraction flask. The soxhlet extractor was set up and the sample was extracted for about 5-6 hours.

Determination of Ascorbic Acid
The Ascorbic acid content was determined as described by Ruck (1969).

Determination of Proximate Composition
The Association of Official Analytical Chemists' Method of Analysis (A.O.A.C., 1995) was used to determine the proximate composition of the wine.

Determination of Moisture Content: The moisture content was determined using the formula below:

$$\% \text{ moisture} = \frac{Mo}{M_i} \times 100$$

M_o = Loss in weight (g) on drying
M_i = Initial weight of sample used (g)

Determination of Ash Content: 5g of dried fruit pulp was placed in clean, dried and weighed crucibles. The crucibles were placed in a muffle furnace at 525^{o}C and the sample incinerated for 5hours 30minutes to produce a white ash. The crucibles were cooled in a desiccator and re-weighed. The Ash (%) was determined as follows:

$$\text{Ash (\%)} = \frac{M_a}{M_s} \times 100$$

M_a = Mass of ash (g)
M_s = Mass of sample used (g)

SENSORY EVALUATION

Sensory evaluation of the samples was carried out among 21 panelists across different ages and sexes. Panelists were asked to score the samples based on the intensity of organoleptic quality attributes of: vision, olfaction and gestation i.e. colour, taste, aroma and flavor respectively. The old tree sweet wine, old tree dry wine, young tree sweet wine and young tree dry wine samples were coded as 101, 102, 103 and 104 respectively. Panelists were asked to

rate them according to their degree of likeness for each of the sensory attributes as follows: strongly like, like, strongly dislike, dislike and indifferent.

Data Analysis

The data generated were analyzed using descriptive statistics, proportions, t-test and analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Physicochemical composition of *C. albidum*

The fruit pulp yield from the old and the young trees were 39.45g/ 100g and 52.3g/ 100g respectively. T- test result showed significant difference (0.026, $p \leq 0.05$) in the fruit pulp yields of the two samples. The pulp yield of the young tree fruit is in consistence with Ige and Gbadamosi (2007) who observed that the pulp yield of *C. albidum* range between (52.5- 55.5%). Juice yields of fruits from the young and old trees were 57.05% and 64.7% respectively. No significant difference exists between the juice yields of the two trees (0.09, $p \leq 0.05$), hence age of tree has no effect on the fruit juice yields.

The fruit from both the old and the young trees of *C. albidum* had 70% moisture content each (Table 1). The t- test result shows no significant difference (2.776, $p < 0.05$) in the moisture contents of fruits from the two trees. This agrees with the findings of (Oyebade *et al.*, 2011) that the moisture content of *C. albidum* fruits is between 70-77.5%. The fruit juice from the old trees was slightly more acidic (pH = 2.99) than those of the young trees (pH =3.03). T-test showed significant difference in the pH of fruits from both trees (0.004, $p \leq 0.05$). The result corroborates Ige and Gbadamosi (2007) that pH of *C.albidum* juice is 3.3 while ascorbic acid content of the juice is about 49.4mg/100L. *C.albidum* has been described as having a pleasantly acidic pulp. Ige and Gbadamosi (2007) reported that the fruit contains nicotinic acid and ascorbic acid. Jellies and Jams produced from the fruit pulp were reported to be able to compete with raspberry jellies and jams from other sources (Chukwuemeka, 1981).

Microbial Analysis

Coliform count in the fruit juice samples increased with increase in time and decreased temperature (Table 2). Sodium meta-bisulphite (Na_2O_5S) reduced the microbial count in the juice. Reduction of microbial count allows yeast (*Saccharomyces cerevisiae*) to dominate the fermentation process of the juice.

pH

The young tree fruit wine with low 0.4g of sucrose (dry wine) had the pH of 3.08 and 3.33 before and after aging while samples with 1.5g of sucrose (sweet wine) had 3.08 and 3.34 before and after the aging respectively(Table 3). The old tree fruit wine with 0.4g of sucrose (dry wine) had pH values of 3.05 and 3.31 before and after aging while those with 1.5g of sucrose (sweet wine) had 3.01and 3.33 before and after aging respectively.

Table 1: Physicochemical composition of *C. albidum*

Samples	Moisture content (%)	Pulp weight (%)	pH	Juice yield (%)
Fruit from Old tree	70^a	39.4^a	3.03^b	57.05^a
Fruit from Young tree	70^a	52.3^b	2.99^a	64.7^b

Means in the same column with same superscripts are not significantly different at ($p \leq 0.05$)

Table 2: Mean Microbial count in *Chrysophyllum albidum* fruit juice

		24hrs		48hrs	
Sample	**Temperature**	**Coliform cfu/ml)**	**Yeast (cfu/ml)**	**Coliform (cfu/ml)**	**Yeast (cfu/ml)**
OTSa	Room temp (32^0C)	1.3	0.0	2.4	0.3
	28^oC	2.2	0.0	3.7	1.2
OTSb	Room temp (32^0C)	0.8	0.0	1.5	0.1
	28^oC	1.0	0.0	1.8	0.5
YTSa	Room temp (32^0C)	4.2	0.0	6.6	0.8
	28^oC	4.4	0.0	7.8	1.0
YTSb	Room temp (32^0C)	3.1	0.0	4.5	0.5
	28^oC	3.3	0.0	4.6	0.4

Note: OTSa- Old tree sample without Na_2O_5S, OTSb- Old tree sample with Na_2O_5S
YTSa- Young tree sample without Na_2O_5S, YTSb- Young tree sample with Na_2O_5S

Table 3: pH values of sweet and dry wines before and after aging

Samples	pH before Aging	pH after Aging
Old Tree Sweet Wine	3.01	3.33
Old Tree Dry Wine	3.05	3.31
Young Tree Sweet Wine	3.08	3.34
Young Tree Dry Wine	3.08	3.33

The low pH values obtained indicate that the wine would be more stable with age due to acid precipitation and ester formation. This agrees with the observation of Eutech(2013), that low pH inhibits bacteria, causes sugar fermentation to progress more evenly and makes malolactic fermentation easier to control.

Heavy Metals

The quantity of the elements detected from the laboratory examination of the wine produced from the fruit juices of the young and old trees of *C. albidum* and the WHO (2008) maximum allowable concentrations in human food are shown in (Fig.2) below. The result shows that the wine samples produced from *C. albidum* contains some biologically important elements for humans at allowable concentrations such as: Chromium (22.7ppm), Lead (8.4ppm) and Manganese (10.8ppm). Concentrations obtained for these heavy metals were far below the WHO allowable levels of 30ppm, 50ppm and 35ppm respectively for Chromium, Lead and Manganese. This indicates that *C.albidum* wine is safe for human consumption.

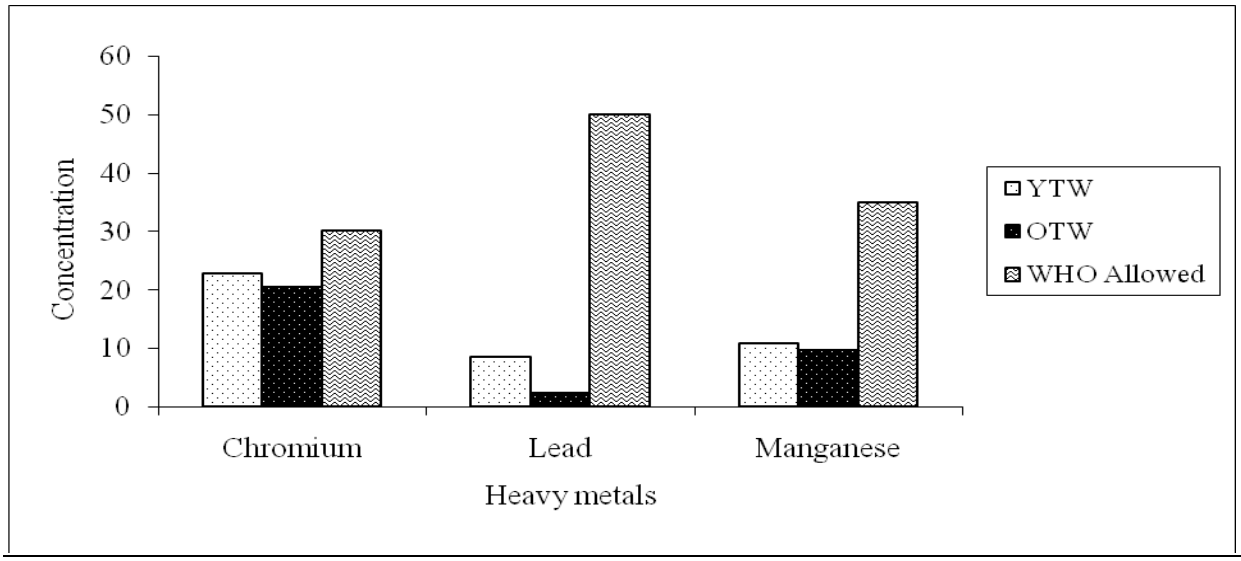

Fig. 2: Concentrations of heavy metals in fruit wine of *C.albidum* and UN/WHO Allowable Concentrations

Proximate composition of *Chrysophyllum albidum* fruit wine

The result of proximate analysis of wine samples is shown in (Table 4). Protein contents of dry and sweet wine samples in young and old trees are presented in table 4. ANOVA shows significant differences (0.0005**,** $p \leq 0.05$) in the protein contents. Young tree dry wine has the highest protein content. The protein content of the wine was lower compared to Amusa *et al.(* 2003) and Adepoju and Adeniji (2012) who reported the protein content of the fruit pulp to be between (8.02-8.8 %). The lower protein content could be attributed to the calcium bentonite that was added to clarify the wine. The fact that both the sweet and dry wine samples from the young tree had higher protein contents than those from the old tree could be attributed to differences in the ages of the trees and hence the rates of photosynthesis and respiration. This agrees with Nwoboshi (1982), who observed that younger tree parts photosynthesize more actively at higher rate than respiration which breaks down the food reserve. Hence younger trees are able to accumulate more food to feed the actively growing tissues. In the older tree however the rate of photosynthesis slows down with age while respiration increases. Since respiration breaks down the food reserve in parts of the older tree (including the fruits), such food substances including protein are likely to be lower in quantity in the older tree than the younger tree.

Fat contents in the dry wine and sweet wine for the young and old trees are as shown in Table 4. ANOVA shows significant difference (0.033, $p \leq 0.05$) in the fat contents with old tree sweet wine having the highest fat content. The fact that the fat content of the fruit wine from the older tree is higher than that of the younger plant may also be attributed to the effect of decreased metabolic activities in older plants (Pandey and Ojha, 2013). Younger plant will accumulate less fat as more of the fat will be converted for energy needed for physiological activities in the vigorously growing plant.

Values of ash contents in the dry wine and sweet wine for the young and old trees are as presented in table 4. ANOVA shows that there is no significant difference (0.125, $p \leq 0.05$) in the ash contents of all the samples.

CHEMICAL ANALYSIS

Total soluble solid (TSS) and Ascorbic acid contents for the dry wine and sweet wine samples for the young and old trees are shown in Table 5. The ascorbic acid content of the wine was lower than that of Ige and Gbadamosi (2007) who reported the ascorbic acid content of the fruit juice to be 49mg/100L. The lower ascorbic acid content could be attributed to the acid precipitation and ester formation that occurred during the process of wine aging (Murli, 2007). Ascorbic acid is very important for human health as an antioxidant. The World Health Organization's standard for ascorbic acid to be taken by an adult is 45 mg per day. The content of the ascorbic acid in *C.albidum* wine indicates that it could contribute to good health in humans.

Sensory Evaluation

Sensory evaluation analysis showed that: 71.4% of the panelists preferred the colour of the old tree sweet wine (Fig. 3), while 42.9% of the panelists preferred the taste of old tree sweet wine (Fig. 4). The flavour of old tree sweet wine and young tree sweet wine were preferred by 42.9% of the panelists (Fig. 5) followed by old tree dry wine (38.1%). In overall acceptability, 47.6% preferred young tree sweet wine, while 38.1% of the panelists preferred old tree sweet wine (Fig. 6). Based on the overall acceptability, 100% of the panelists preferred the young tree sweet wine.

Table 4: Proximate composition of *Chrysophyllum albidum* fruit wine

SAMPLE	PROTEIN (%)	FAT (%)	ASH (%)	MOISTURE CONTENT (%)
OTSW	0.35^{a}	0.21^{a}	0.13^{a}	90.04^{a}
OTDW	0.47^{b}	0.18^{a}	0.11^{a}	98.08^{b}
YTSW	0.68^{c}	0.11^{b}	0.18^{a}	97.06^{b}
YTDW	0.53^{b}	0.13^{b}	0.15^{a}	97.13^{b}

Means in the same column with same superscripts are not significantly different at ($p \leq 0.05$)

Note: OTSW- Old tree sweet wine, OTDW- Old tree dry wine, YTSW- Young tree sweet wine, YTDW- Young tree dry wine

Table 5: Total Soluble Solids and Ascorbic Acid Contents of *Chrysophyllum albidum* fruit wine

SAMPLE	TOTAL SOLUBLE SOLID (%)	ASCORBIC ACID (mg/100g)
OTSW	1.96^{a}	2.06^{a}
OTDW	1.92^{a}	2.11^{a}
YTSW	2.94^{b}	3.59^{b}
YTDW	2.87^{c}	3.28^{c}

Means in the same column with same superscripts are not significantly different at ($p \leq 0.05$)

Note: OTSW- Old tree sweet wine, OTDW- Old tree dry wine, YTSW- Young tree sweet wine, YTDW- Young tree dry wine

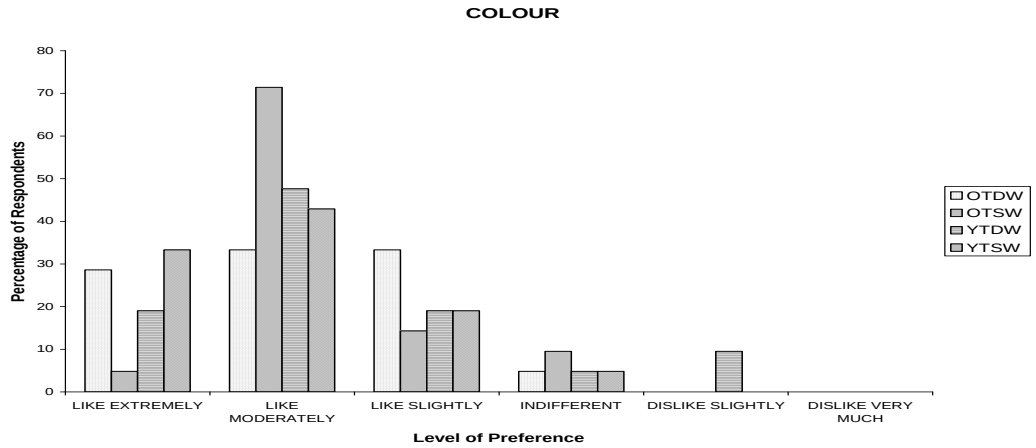

Fig. 3: Colour preference of *C.albidum* wine by panelists

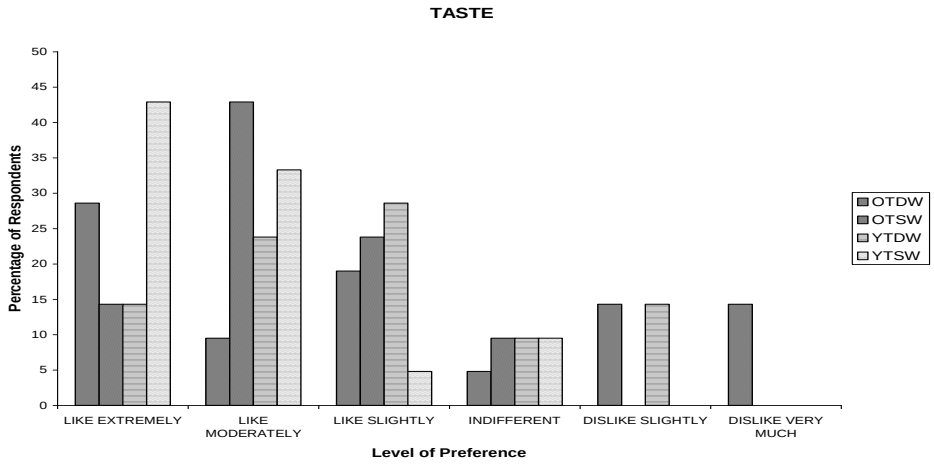

Fig. 4: Taste preference of *C.albidum* wine by panelists

Fig. 5: Flavour preference of *C.albidum* wine by panelist

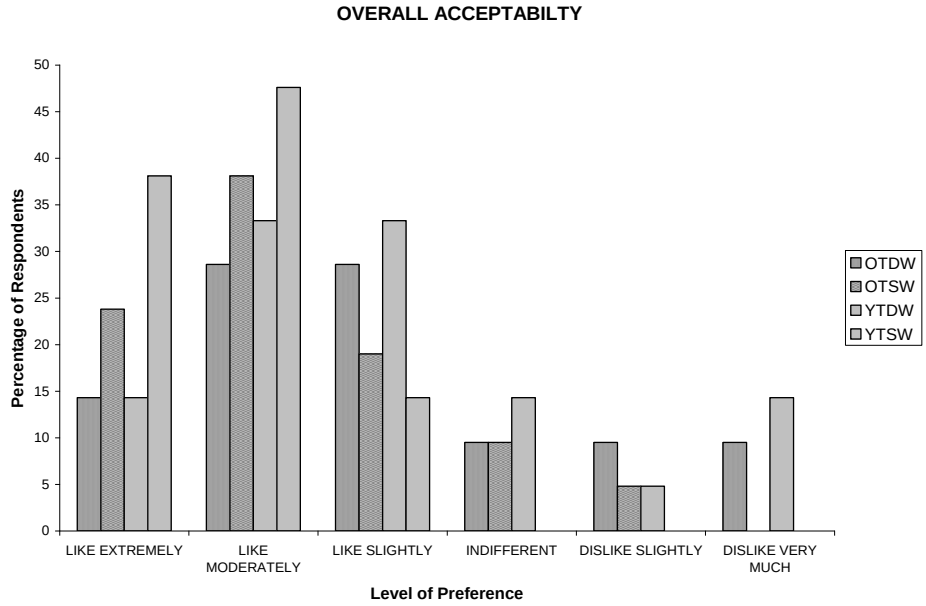

Fig. 6: Overall Acceptability of *C.albidum* wine by sensory evaluation panelist

CONCLUSION

The chemical analysis of the fruit pulp of African star apple shows that it is a good source of energy and vitamin C which are important in human nutrition. The concentrations of heavy metals such as Chromium, Lead and Manganese found in the wine are within the WHO allowable concentrations for human consumption. Age of the tree has no significant effect on their juice yield. However, it is better to collect fruits from the young trees considering; the pulp yield, mineral elements,protein and ascorbic acid contents which are higher in the young tree fruits. African star apple has good potentials to produce acceptable sweet wine. Hence wine industries may consider the adoption of this indigenous fruit tree. Further research and development efforts are required on fruit processing, improving the wine quality, storage and packaging.

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