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Production of Wine and Vinegar from Cashew (*Anacardium occidentale*) "Apple"

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Authors' contributions

The present work was result of the efforts of all authors. The lead author SL designed the experimental and wrote the first draft of the manuscript. Author DY performed the experiments and all analytical methods used in study. Authors KW and CKAB reviewed the experimental design and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To prepare commercial-grade wine from cashew apples using less expensive household materials and vinegar production by natural spontaneous fermentation.
Study Design: Cashew wine was prepared by fermenting cashew apple juice with *Saccharomyces cerevisae*. Various parameters viz., time, pH, temperature, density and vinegar concentration was monitored.
Place and Duration of Study: Biochemistry Division and New Product Development Unit, Cocoa Research Institute of Ghana, between February 2009 and July 2013.
Methodology: Progress and quality of fermentation were carried out by using various biochemical tests. Acceptability of products was determined by sensory analysis.
Results: Physico-chemical analyses of the wine during fermentation showed a decrease in specific gravity and pH, and a corresponding increase in titratable, fixed and volatile acidity. The ageing wine was amber, dry (12.58±0.24%^{v}/v alcohol content), slightly acidic in taste (titratable acidity of 0.79±0.02 g tartaric acid/100 mL and pH of 3.84±0.04) and had high phenolic content (406.10±4.56 mg/100 mL) and a distinct cashew apple juice smell. Microbiological assay of the wine showed no microbial growth. Sensory evaluation showed no significant differences (*P*>.05) between the

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cashew wine and a commercial grape wine with respect to clarity, colour, taste, astringency and aftertaste. However, in terms of aroma, the grape wine was found to be significantly superior (P<.05) to the cashew wine. Vinegar was produced by natural spontaneous acetic acid fermentation of the cashew wine. Chemical monitoring of the acetic acid fermentation showed a decline in both alcohol and pH from 7.14±0.04%^{v}/v to 0.00±0.04%^{v}/v and 4.23±0.03 to 2.40±0.27 respectively over a period of 29 days. Conversely, volatile acidity increased from 0.01±0.01 g acetic acid/100 mL to 6.85±0.03 g acetic acid/100 mL over the same period. The characteristics of the cashew vinegar met the standard specifications for vinegar.

Conclusion: This study shows that ordinary household materials could be used to commercially exploit the underutilised cashew apples in Ghana through the production of wine and vinegar to conserve foreign exchange and increase the income of farmers in the country.

Keywords: Cashew; pH; vinegar; wine; physico-chemical; underutilized.

1. INTRODUCTION

Wines are alcoholic beverages made from a variety of fruit juices by the fermentative action of selected yeast adapted to a particular type of wine followed by an ageing process [1]. Fermentation of the wine, using acetic acid bacteria, converts alcohol to acetic acid thus resulting in the product known as vinegar [2]. Vinegar is an important preservative and condiment and it has a variety of industrial, medical, and domestic uses.

Traditionally, wines and vinegars are produced from grape, berry, apples and other pome fruits. The wines and vinegars from these fruits are products of Europe, Far East, Middle East, America, South and North Africa [3] but not of tropical countries like Ghana where these crops do not thrive. The nation is thus compelled to import wines and vinegars which result in loss of foreign exchange. There is therefore the need to identify traditional fruits in the country that can serve as raw materials for the production of wines and vinegars. Researchers have so far been successful in developing commercially viable wines and vinegar from cocoa pulp juice [4].

The cashew plant (*Anarcadium occidentale*) is a tree crop generally considered to be native to northern part of South America and it is now found in many tropical countries including Ghana. The *"Ghana Cashew Industry Study"* conducted by Ministry of Food and Agriculture (MOFA) in 1998, estimated that the total land area under cashew plantations in Ghana is 18,000 hectares, which is scattered in various parts of the country [5]. It is grown as a cash crop in the coastal belt (Central, Greater Accra, and Volta Regions), the transitional belt (north of Ashanti, Brong-Ahafo) and Guinea savanna and Sudan belts (Northern, Upper West and East regions) [6]. The cashew fruit consists of a soft succulent apple and a hard nut surrounded by a double shell. The apple has a sugar content of about 10% (mostly invert sugar) and a content of vitamin C (250 mg/100 g of juice) usually about 4-5 times higher than that of citrus fruits. It is also rich in vitamins A and B, tannins, proteins and minerals [7,8].

Cashew tree cultivation is an agricultural activity directed at the production of cashew nuts. The nuts represent only 10% of the total fruit weight, and large amounts of cashew apples are lost in the field after nut removal. The expected yield for the cashew tree under rainy conditions is approximately 1 t/ha of raw cashew nut and 10 t/ha of cashew apple. Under irrigated conditions, it may reach 3.8 t/ha of raw cashew nut and 30 t/ha of cashew apple [9]. The average yield of juice extraction is approximately 85% (^{v}/w) [7], thus the juice productivity can reach 25.5×10^{3} m^3/ha. By considering the size of Ghana's cashew plantation, about 45.9×10^{7} m^3 of cashew juice are lost or underutilized during every yielding period. Attempts were made to salvage the situation through the development of jams, brandy, gin, fresh drink and animal feed from the apple [10,6]. Considering the huge quantity of cashew apples that go to waste, there is the need to explore other alternative ways of utilizing the apple. Earlier laboratory studies indicate that cashew apples could serve as a good raw material for the production of wine and vinegar [1,2,11,12]. This study thus sought to prepare commercial-grade wine from cashew apples using less expensive household materials and vinegar production by natural spontaneous fermentation.

2. MATERIALS AND METHODS

2.1 Extraction of the Juice

Ripe undamaged cashew fruits of red varieties were harvested from the Cocoa Research Institute of Ghana's cashew plantation at Bole in the Northern Savanna Zone of Ghana in February 2009. The nuts were detached from the apples and the apples sorted and washed with sodium metabisulfite solution (350 ppm) to remove any contaminant. One hundred kilograms of the apples were weighed and the juice squeezed out using a locally manufactured screw press.

2.2 Preparation of Juice (must)

The juice was pasteurised using a pasteurizer (Alvan Blanch) at 80℃ for 10 minutes. Sucrose was then added to bring the fermentable sugars to 24%. The must (juice) was poured into three 30 L drums each drum containing 23 L of the must, covered tightly and allowed to cool. To each drum, 0.15 g/L of sodium metabisulfite and 0.15 g/L of ammonium phosphate were added and stirred.

2.3 Preparation of Yeast Starter

Seven hundred and fifty millilitres of the must (30℃) was used as the culture medium. Five grams (5 g) of powdered commercial wine yeast, *Saccharomyces cerevisae* (Lallemand), was dissolved in the must and allowed to stand for one hour at a temperature of 28℃.

2.4 Fermentation Process

Two hundred and fifty millilitres (250 mL) of the yeast starter was dispensed into each must (23L) and then stirred gently. Each barrel was loosely closed and fermentation was carried out at 22℃. During fermentation, pH, titratable acidity, nonvolatile (fixed) acidity, volatile acidity, specific gravity and temperature were monitored daily. The wine was allowed to rest for a week before racking.

2.5 Clarification and Aging

Each wine was racked (siphoned) into a sterilized 23 L plastic container and then clarified with pectinase (Biocon) (20IU/L), bentonite (0.4 g/L), polyvinylpyrrolidone (0.18 g/L) and gelatin (0.09 g/L). The wines were closed tightly with lids affixed with fermentation locks and allowed to stand for four weeks at a temperature of 17℃. About 14 L of each wine was racked into clean 23 L capacity specially designed plastic containers for vinegar production and the rest racked into 4 L conical flasks. The flasks where tightly closed with stoppers affixed with fermentation locks and placed in a dark room at a temperature of 17℃ and allowed to age for another four weeks.

2.6 Vinegar Containers

Three empty 23 L capacity gallons with two opposite rectangular openings of dimension 10 cm (length) x 5 cm (height) created at the upper sides of each gallon were used. For each gallon, one opening was covered with a plastic mesh and the opposite opening was covered with a transparent glass. The pores of the plastic mesh used in this experiment were small enough to prevent vinegar flies and other small insects from passing through. Finally, both interior and outer parts of the gallons were rinsed with hot water.

2.7 Acetic Acid Fermentation

Fourteen litres of wine was racked from each wine barrel, four weeks after fining, into corresponding vinegar container. Each wine was diluted with distilled water to an alcohol concentration of seven percent. Each container was covered with cotton wool and placed in an airy room at room temperature. The wines were allowed to be naturally inoculated with Acetic acid bacteria (vinegar flies*).* The mesh prevented the flies, which were drawn to the setup by the wines' fermentative smell*,* from having direct contact with the wine but allowed the AAB associated with them to fall into the wine. The acetification process was daily monitored until all the ethanol was exhausted.

2.8 Bottling of Wine and Vinegar

Both wines and vinegars were centrifuged (MISTRAL 6000) at a speed of 4000 rpm at -5℃ for 25 minutes. Sodium metabisulfite (0.05 g/L) and potassium sorbate (0.22 g/L) were added to each wine after which they were each filtered and pasteurised at a temperature of 68℃ for 10 minutes. The wine was bottled hot in dark green-coloured glass bottles (net content of 750 mL) which were sterilized in 0.25% sodium metabisulfite solution and then covered with wooden corks. The vinegars were bulked and diluted to an acetic acid concentration of about 4.5%^{v}/v. Sodium metabisulfite (0.22 g/L) and potassium sorbate (0.18 g/L) were added after

which the vinegar was pasteurised at a temperature of 65℃ for 30 minutes. The vinegars were bottled hot in translucent white plastic bottles (net content of 250 mL) which were sterilized in 0.25% sodium metabisulfite solution. A commercial dry wine made out of grapes (brand name: "Tassenberg", South Africa) was procured from a local wine shop and used as a "standard" for comparison of sensory and quality attributes of the cashew apple wine.

2.9 Specific Gravity Determination

The specific gravity was measured according to AOAC (2007)'s method. About 90 mL of the wine sample was placed in a transparent 100 mL glass cylinder and gently inverted five times, allowing gas to be given off each time the cylinder was uprighted. The temperature of the sample was noted after which the specific gravity was measured with a glass hydrometer. The measured specific gravity was corrected using the appropriate temperature correction factor.

2.10 Alcohol Content Determination

Ethanol production during fermentation was monitored through the measurement of the specific gravity and the corresponding potential alcohol content extrapolated from the relation:

% Potential alcohol by volume = 1000 x (Starting specific gravity – Final specific gravity) ÷ 7.36 [13]

The actual alcohol content of the finished wine and vinegar was determined by distillation [14]. The test sample (100 mL) was diluted with 50 mL of distilled water and the solution was neutralized with 1 M NaOH solution. The sample was then distilled at 100℃ until 100 mL of distillate was obtained. The percentage alcohol by volume was determined using an alcohol hydrometer.

2.11 pH and Titratable Acid Determination

The pH of both wine and vinegar was measured by using a pH meter (Mettler Toledo AG). The titratable acid was determined according to the method of AOAC [14] with slight modification. Carbon dioxide was first removed from the test samples by heating 25 mL of the sample to incipient boiling after which it was held 30s, swirled and cooled. Five millilitres degassed test portion was titrated with 0.1 M NaOH using 1%^{w}/v phenolphthalein as indicator. Titratable acid was calculated as g tartaric acid/100 mL wine by using the formula:

Titratable acid = milliliters of NaOH used x molarity of NaOH x 0.075 x 100/5.

2.12 Fixed and Volatile Acid Determination

The methods described by AOAC [14] were used in these determinations. Twenty-five millilitres of the test sample was carefully evaporated on a hot plate (Ikamag Reo) until the volume had reduced to 5-10 mL. Twenty-five millilitres of hot distilled water was added and the solutions again evaporated to a final volume of 5-10 mL. The process was repeated two more times after which the residue was cooled and diluted to 50 mL with distilled water. This was titrated with 0.1 M NaOH using phenolphthalein as indicator. The fixed acid was expressed as g tartaric acid/100 mL wine by using the titratable formula. The volatile acid was determined by subtracting the fixed acid value from the titratable acid value. The volatile acid was expressed as g acetic acid/100 mL.

2.13 Assay of Total Phenolic Content

The phenolic content of the wines was determined by Folin-Ciocalteu's method [15]. Tannic acid was used as the standard phenolic compound. Each sample (0.1 mL) was added to 4.2 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent. After 1 minute of mixing, 1 mL of an 80% solution of sodium carbonate and 4.2 mL of distilled water were added. The mixture was left 2 h at room temperature in the dark and the absorbance at 760 nm was measured on a UV-VIS spectrophotometer (CE 7400, Cecil Instruments, Cambridge, England). The total phenolic content was determined from an equation that was obtained from tannic acid calibration curve and the values were expressed in terms of tannic acid equivalent (mg/100 mL) of wine.

2.14 Determination of Density and Test for Solubility of Vinegar

The density of vinegar was determined according to the method described by Lethbridge [16]. Hundred millilitres of vinegar was weighed and the density was determined by dividing the weight (grams) by the volume (millilitres). The solubility of vinegar in three solvents, namely

water, ethanol and acetone was determined. Fifty millimetres of each solvent was placed in separate 250 ml conical flasks after which 50 mL of the vinegar was poured onto each of them. Each flask was swirled for few seconds and allowed to stand at room temperature (28℃). Mixtures were then observed for possible separation.

2.15 Microbiological Analysis

Yeasts and moulds in the wine were enumerated using Rose Bengal Agar containing Dichloran and Chloramphenicol (DRBC Agar) (CONDA) and the plate count of bacteria was done using Casein-peptone Dextrose Yeast Agar (Plate Count Agar) (Fluka). Twenty millilitres of the wine samples were pipetted into 225 mL of Peptone Saline Diluent (Fluka). One millilitre of the solution was serially diluted up to 10^{-3} dilution. The spread plate technique was used during inoculation where 100 uL of the diluted samples were spread on the appropriate media. The DRBC plates were incubated at 30℃ for 5 days whiles the Plate Count Agar plates were incubated at 30℃ for 3 days.

2.16 Sensory Evaluation Assay

A total of 20 respondents were used for the sensory evaluation. Sensory attributes of wine (clarity, colour, aroma, taste, astringency and aftertaste) were evaluated using a 5-point Hedonic scale (where 1 = dislike extremely and 5 = like extremely) according to Mohanty's method [17]. Samples were served in labelled transparent glasses (tumblers). Questionnaires and water for mouth rinsing between each tasting were provided. Prior to evaluation, a session was held to familiarize panelists with the product. The panelists were asked to read through the questionnaires, and the meaning of each attribute (clarity, colour, aroma, taste, astringency and aftertaste) was explained to the panelists to avoid any misinterpretation. Tasters were not allowed to discuss their scores with one another during the evaluation session. The cashew wine along with a selected commercial brand of grape wine (Tassenberg) was presented to the trained panel of sensory analysts.

2.17 Statistical Analysis

Values were expressed as mean ± standard deviation of three replications. The sensory evaluation data were presented as means of the panelist's score. Comparisons between scores were performed using SPSS (version 17.0, SPSS Inc.) to determine statistical significance. The 0.05 level of probability was used as the criteria of significance in all instances.

3. RESULTS AND DISCUSSION

Monitoring of the fermentation process (Fig. 1) showed that specific gravity decreased relatively slowly during the first 3 days from 1.090 to 1.085±0.00 before gaining pace until the 19th day where it became stable to day 21 with a constant reading of 0.990±0.00. A similar trend was observed in the potential alcohol content of the must. It increased relatively slowly from 0.00±0.00% on day 1 to 0.73±0.16% on day 2 after which it showed a relatively faster increase until day 19 when it became stable to the end of the fermentation at 13.59±0.00%. These phenomena confirmed two generally understood sequence of yeast activity and these are yeast multiplication in aerobic condition during which only few fermentable sugars are converted to ethanol and fermentation under a blanket of CO_2 during which there is mass production of ethanol [18,19]. The yeast multiplication appeared to have occurred during the first three days of fermentation judging from the slow reduction in the specific gravity. This initial activity may also be responsible for the rise in temperature of the cashew must during the initial stage of the fermentation process from 23±0.0℃ on day 1 to a peak value of 25±0.6℃ on days 3 and 4. This finding is consistent with what Chilaka [20] observed in an experiment aimed at evaluating the efficiency of yeast isolates from palm wine in diverse fruit wine production. During the final days of the fermentation, yeast activity became absent and the specific gravity remained constant. This may be due to the unavailability of sugars [19].

Titritable and fixed acidity (Fig. 2) progressively increased during the fermentation period from 0.38±0.00 g tartaric acid/100 mL to 0.85±0.01 g tartaric acid/100 mL and 0.37±0.01 g tartaric acid/100 mL to 0.79±0.03 g tartaric acid/100 mL respectively. Conversely, pH dropped from 4.59±0.02 to 3.92±0.05 at the end of fermentation. High acidity is known to give fermenting yeasts competitive advantage in natural environments [20]. There was also a brief rise in volatile acidity from 0.01±0.01 g acetic acid/100 mL to 0.025±0.02 g acetic acid/100 mL during the initial stages of the fermentation (Fig. 2). This may be due to the activity of AAB and other bacteria which, being ubiquitous in nature, were able to convert some of the alcohols

into volatile acids (mostly acetic acid) [21]. AAB generally have alcohol tolerance of 7 to 9% [22], thus their continuous activity was suppressed as the fermentation progressed (Fig. 2).

The composition of must and bottled four months old wine prepared from cashew apple as well as that of a commercial grape wine is presented in Table 1. Generally, the cashew wine appeared to be more acidic than the grape wine used in this study. Whilst the grape wine had fixed acidity of 0.49±0.01 g tartaric acid/100 mL, the cashew wine had 0.72±0.01 g tartaric acid/100 mL. Fixed acidity of wines depends on the type and concentration of organic acids present in the particular fruit used for the production [19]. Organic acids differ in concentration and type from fruit to fruit and they are also influenced by the degree of ripening of the fruit [18]. These factors may have accounted for the differences in the fixed acidity as well as the titratable acidity of both wines. Nonetheless, titratable acidity of wine is expected to be between 0.5% and 1.0% [23] and that of the cashew wine which was 0.79±0.02 g tartaric acid/100 mL fell within this limit. The pH of the cashew wine (3.84±0.04) was however comparable to that of the grape wine (3.71±0.01) and was quite consistent with the acidity (tritratable, fixed and volatile) of the wine. The pH results obtained in this work agree with a similar work [1] that found the pH of cashew must and wine to be 4.80 and 4.21 respectively.

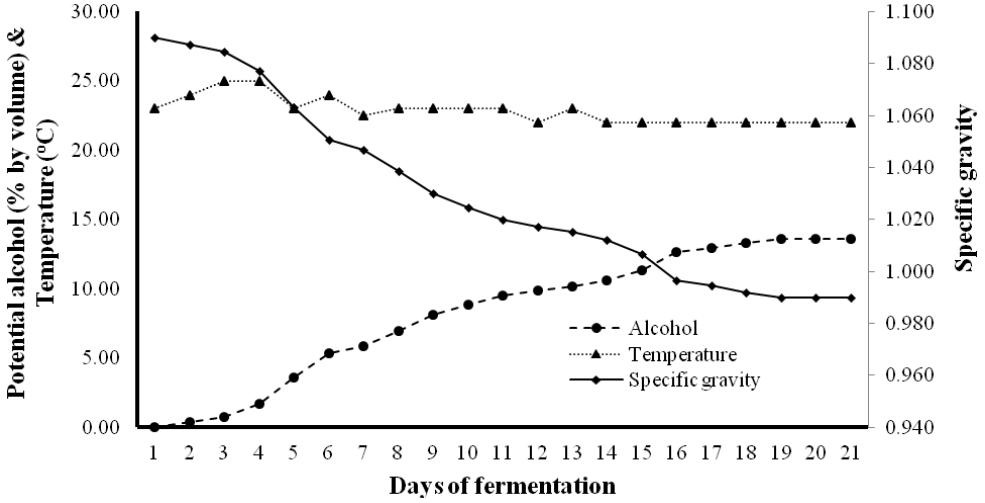

Fig. 1. Variations in specific gravity, temperature and potential alcohol during cashew must fermentation

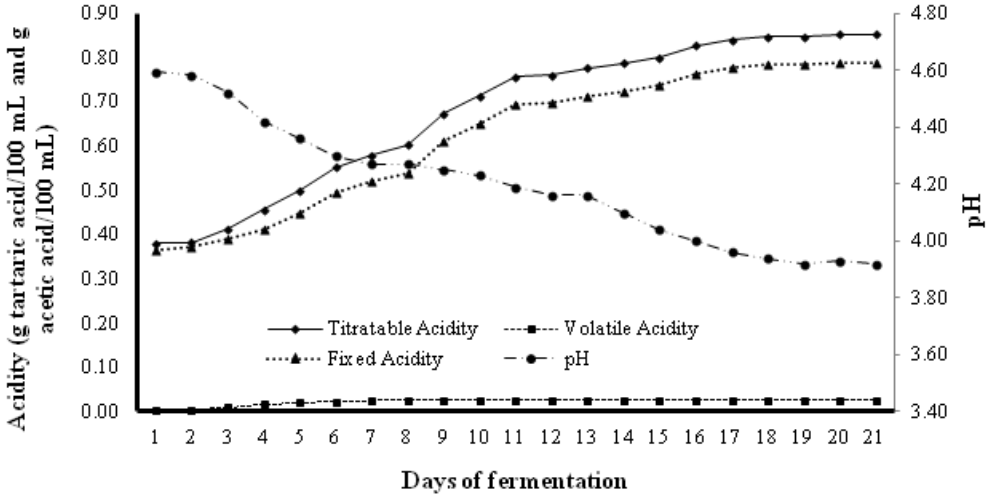

Fig. 2. The trend of total titratable, fixed and volatile acidity and pH during cashew must fermentation

Table 1. Chemical composition of cashew must and wine and commercial grape wine

Parameters	Cashew must	Cashew wine	Grape wine
Specific gravity	1.090±0.00	0.990±0.00	0.992±0.00
Alcohol (%)	0.00±0.00	12.58±0.24	12.47±0.01
pH	4.59±0.02	3.84±0.04	3.71±0.01
Titratable acidity (g tartaric acid/100 mL)	0.38±0.00	0.79±0.02	0.52±0.01
Fixed acidity (g tartaric acid/100 mL)	0.37±0.01	0.72±0.01	0.49±0.01
Volatile acidity (g acetic acid/100 mL)	0.01±0.01	0.03±0.02	0.01±0.01
Total phenolic content (mg/100mL)	410.83±0.12	406.10±4.56	210.65±0.07

Values are means ± SD of three determinations

The specific gravity of the must decreased from 1.090±0.00 to 0.990±0.00 in the wine and correspondingly, the alcohol content (%) increased from 0.00±0.00 in the must to 12.58±0.24 in the wine (Table 1). The reduction of the specific gravity of the cashew must to a level below 1.000 in the bottled wine indicates that, virtually all the fermentable sugars were converted to ethanol by the yeasts. Theoretically, the resulting alcohol (by volume) from this fermentation should be 13.59% (Fig. 1) but this is generally not attainable due to factors such as evaporation and oxidation of alcohol to volatile acids, production of higher alcoholic compounds, yeast biomass and energy for metabolism [24].

The total phenolic content decreased from an initial level of 410.83±0.12 mg/100 mL in the must to a final level of 406.10±4.56 mg/100 mL in the wine (Table 1). This disparity may be as a result of the activity of the fining agents that were added to reduce the astringency of the wine. Tannins are phenolic compounds reported to be responsible for the astringency of cashew apples thus any fining to reduce the astringency would directly influence the tannin concentration. A similar phenomenon was reported by Mohanty [17] who observed a decrease in both total phenolic (g/100 mL) and tannin (mg/100 mL) contents from 0.13±0.01 and 2.2±0.13 respectively in cashew apple must to 0.12±0.03 and 1.9±0.22 respectively in the cashew wine. However, the cashew wine maintained a higher total phenolic content than the grape wine which contained 210.65±0.07 mg/100 mL. This is not surprising since cashew apple juice is known for its high tannin content [25]. Phenolic compounds, known to be antioxidants, are capable of protecting cell membranes from free-radical mediated oxidative damage which has been implicated in diverse pathological conditions [26]. Thus the huge presence of these compounds in cashew wine may be beneficial.

The physical and microbial examination (Tables 2 and 3 respectively) of the cashew wine showed that the wine had acceptable characteristics. The absence of growth on both the DRBC and Plate Count Agar indicated that the wine fermented and aged without any microbial spoilage. This may be due to the high alcohol content (12.58±0.24%) of the wine which inhibited the growth of the microorganisms [27]. The absence of sugars in the wine also served as an annihilation factor for some of the organisms [16]. These observations concur with that of Akinwale [11] who matured cashew wine for 6 months at 10℃.

The sensory evaluation of the cashew and grape wines showed that, the panelists have comparable likeness (P>.05) for both wines in terms of clarity, colour, taste, astringency and aftertaste (Table 4). However, they preferred the aroma of the grape wine to that of the cashew (P=.05) possibly because most of them were not familiar with the natural cashew apple smell.

Table 2. Physical examination of cashew wine after 2 months aging at 17℃

Attribute	Condition of wine
Condition when opened	Still
Appearance	Bright and clear (no sediment)
Colour	Amber
Odour	Distinct and peculiar of cashew apple juice
Taste	Dry and slightly acidic

Table 3. Microbiological characteristics of cashew wine after 2 months aging at 17℃

Attribute	Result
Growth on DRBC Agar*	No growth
Growth on Plate Count Agar†	No growth

**DRBC Agar: Rose Bengal Agar containing Dichloran and Cloramphenicol, †Plate Count Agar: Casein-peptone Dextrose Yeast Agar*

Table 4. Sensory evaluation of the cashew wine

Attributes *	Cashew wine	Grape wine
Clarity	4.1±0.64	4.1±0.85
Colour	3.0±0.73	3.6±0.50
Aroma	2.55±0.51	3.55±0.60
Taste	2.05±0.60	2.55±0.60
Astringency	1.8±0.62	2.4±0.68
Aftertaste	3.2±0.70	2.85±0.49

*Values are means ± SD of the panelists' scores. n = 20, *1= dislike extremely; 2 = like moderately; 3 = like much; 4 = like very much; 5 = like extremely*

The conversion of the alcohol in the wine to acetic acid due the activity of AAB progressed uninterrupted. There was constant decrease in pH from 4.23±0.03 to 2.40±0.27 as alcohol content decreased from 7.14±0.04% to 0.00±0.04% at the end of the acetic acid fermentation (Fig. 3).

The volatile acidity however increased from 0.01±0.01 g acetic acid/100 mL to 6.99±0.03 g acetic acid/100 mL on the 27th day of fermentation. The end of the fermentation was signaled by the over-oxidation which occurred after the 27th day of fermentation leading to a decrease in volatile acid content to 6.85±0.03 g acetic acid/100 mL on the 29th day. Some strains of AAB are known to be over-oxidizers and they tend to convert acetic acid to carbon dioxide and water in the absence of ethanol [28]. The optimum growth temperature of AAB, 25 – 30℃, [29] was maintained throughout fermentation period (Fig. 4).

Generally, the properties of the vinegar produced in this study were similar to the standard vinegar properties stated by Raji [30]. Though the acetic acid content (measured as volatile acid, (Table 5)) was slightly higher than 4.5% stated by Raji [30], it fell within the range required by most countries [30].

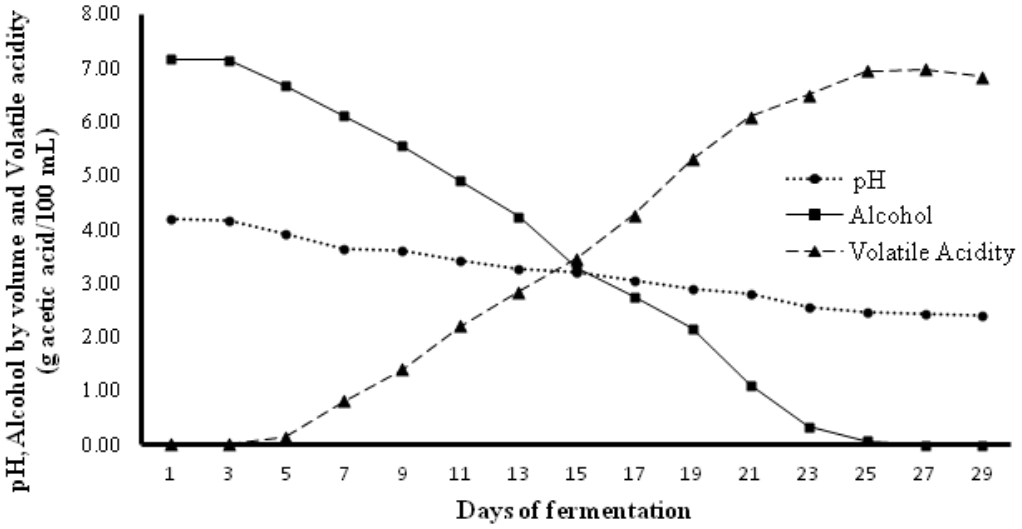

Fig. 3. Variations in pH, alcohol and volatile acidity during acetic acid fermentation

Table 5. Measured properties and standard values

Property	Measured	Standard
Density	1.01±0.01 gcm^{-3}	1.01 gcm^{-3}
Solubility in water	fully miscible	fully miscible
Solubility in ethanol	fully miscible	fully miscible
Solubility in acetone	fully miscible	fully miscible
pH	2.45±0.06	2.4
Volatile acidity (g acetic acid/100 ml)	4.59±0.01	4.5

Values are means ± SD of three determinations

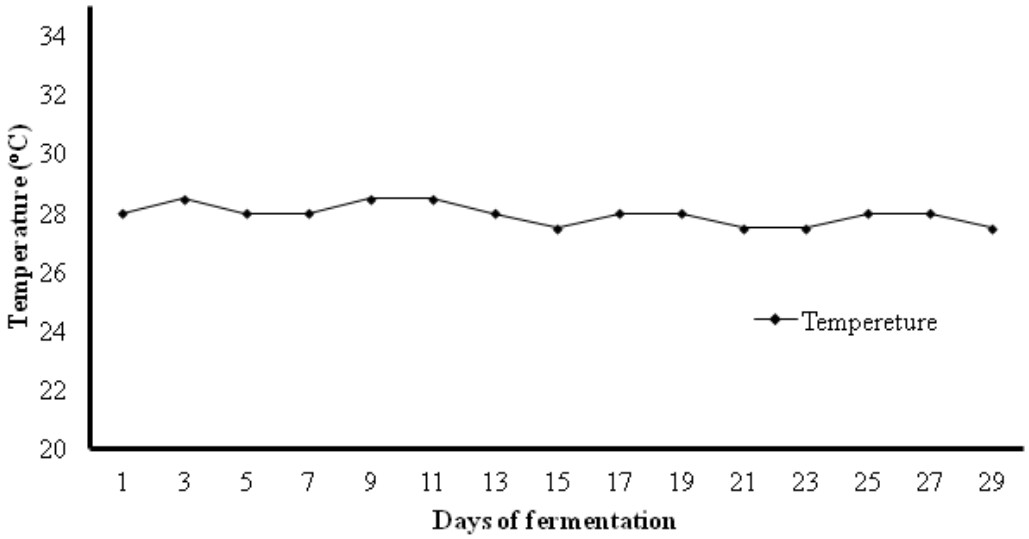

Fig. 4. Variations in temperature during acetic acid fermentation

4. CONCLUSION

Cashew wine could compete favorably with existing commercial grape wines on the market. It has relatively high phenolic content. These characteristics could give it a more competitive advantage over some of the commercial wines in the market as well as maximize the producers' income due to shorter production period. Spontaneous fermentation method, which requires no complex or expensive equipment was used to produce quality cashew vinegar with attributes which conform to generally accepted standards. Commercial grade wine and vinegar production often requires the use sophisticated fermentation tanks which are often too expensive for small scale producers in a developing country such as Ghana. This study shows that ordinary household materials could be used to commercially exploit the underutilised cashew apples in Ghana through the production of wine and vinegar. This may eventually conserve foreign exchange and also increase the income of farmers in the country.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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