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**RESEARCH ARTICLE**

# Valorization of pineapple produced in Benin: Production and evaluation of wine quality parameters

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## *Abstract*

This study aims valuing pineapple cultivated in Benin. It consisted in conversion of the juice extracted from the latter into wine. The wine has been produced by a technology similar to that of white wine production. The physico-chemical (soluble solids, density, pH, titratable acidity, alcohol content), microbiological (total flora, moulds, yeasts, coliforms, *Staphylococcus aureus*) and organoleptic (clarity, color, flavor intensity, impressions, pineapple aroma, residual sugar, acid taste, length in mouth, alcohol) parameters were used to analyze the quality of the juice, wort and wine during the production and maturation. Results showed that the 'abacaxi' variety of pineapple in Benin, because of its composition (pH, sugar content and aroma) is a good substrate for the production of fruit wine. The wine produced has a pH of 3.80 ± 0.6, a titratable acidity of 8.20 ± 0.5%, a sugar content of 13.80 ± 0.5%, a density of 995.00 ± 0 2 and an alcohol content of 3.80 ± 0.4%. Microbiological analysis showed absence of pathogenic flora. This wine has been well accepted for all sensory quality attributes by adults wine consumers, with 25 to over 45 and the average wine consumption once per month.



## INTRODUCTION

The pineapple (*Ananas comosus*) is a specie of the Bromeliaceae families, widely cultivated for its juicy and sweet fruit. In Benin, the pineapple is available in all seasons of the year. In 2012, Benin was ranked 17th in world for pineapple production and third largest producer in Africa. Production during this year was estimated to 375 636 tons (FAOSTAT, 2014). More than a third of the pineapple produced in Benin is exported toward the sub-region and Europe. The rest of the production, reserved for the local market, is unfortunately subject to significant post-harvest losses due to the highly perishable nature of the fruit. Many technics are used to reduce post-harvest losses in Benin. Among these, is the transformation in pasteurized juices, syrups, jams and dried pineapple slices. Despite these transformations, a huge amount of this fruit rotten every year. It then proves essential to seek other methods for this fruit conservation. However, the production of wine through controlled fermentation of sugar content of pineapple in ethanol may be another way of conservation. This method which allows improvement of the nutritional value and

flavor of fruit is practiced on various tropical fruits such as orange (Okunowo and Osuntoki 2007; Okunowo et al, 2005), banana (Byarugaba-Bazirake, 2008. Isitua and Ibeh, 2010), mango (Joshi et al., 2000; Adeyemo, 2012) or pineapple (Gomes et al., 2009; idise, 2012) in many countries including Brazil, India, Thailand, China and Nigeria. The fermentation is spontaneous or controlled by introducing commercial yeast strains. The composition of the obtained wine is complex and the concentration of compound products varies according to the fruit used and the fermentation parameters (Amerina et al., 1980). Many studies have been conducted in recent years to show the potential of pineapple in wine production. In Thailand, Nanthaporn and Niorn, (2013) focused their work on yeasts kinetics growth during pineapple juice fermentation. In India, Roodagi *et al.*, (2012) studied the effect of various sugars contents on pineapple wine quality. Chanprasartsuk, *et al*., (2012) reported the fermentation profile of wine from pineapple "Queen" variety by various yeast species. Chilaka et al. (2010) investigated the potential of the pineapple as a substrate for wine production, and the efficiency of yeasts isolated from indigenous palm wine, compared to the commercial yeast Saccharomyces cerevisiae. Unlike those many countries, the production of pineapple wine is inexperienced in Benin, yet ranked among the twenty (20) first pineapple producers in the world (FAOSTAT, 2014). The pineapple wine is found only very few commercially in the form of classic presentation accorded to wines and very consumers didn't know this drink. In addition, little research has been conducted on wine production from pineapple variety " abacaxi " which is currently the main variety produced in Benin and this is the objective of this study which aims to produce reproducible healthy and acceptable sensory quality wine from this pineapple variety.

## Material and Methods

### Production of pineapple wine

### Extraction of pineapple juice and pasteurization

Four (04) productions were made. These different unit operations were used for wine production:

#### Collection of raw material

Pineapples were purchased at Ouando market (Porto-Novo, latitude / longitude: 6 ° 29 '50' 'north / 2 ° 36' 18 " east). After acquisition of pineapples, fruits were weighed and subjected to strict control of their characteristics in order to verify the acceptability of the raw material. Good bonding between mecanic strength and maturity was essential parameters for pineapples selection.

#### Parage, washing and topping / tailing

Pineapples for processing were uncrowned. It is checked after removing the crown if the contact surface between the latter and the fruit has no viscous liquid and if the heart does not have the fruit rot. The pineapple stem was removed if it is too high. Pineapples were then washed with water under pressure, to remove dust, dirt and foreign matter before being placed horizontally on the cutting table thoroughly cleaned beforehand. Both ends of each pineapple were trenched in the widthwise direction with suitable dimensions knife. This operation was done neatly to reduce yield losses.

#### Cutting, grinding and pressing

Pineapples previously headed and trimmed were placed on a clean surface of the cutting table and then cut into coarse pieces. They were ground and the ground material was collected in plastic barrels carefully washed before being plated in pressing bags used membrane filter, and then put into the wooden crate. The raw juice extract from the ground material is collected in a carefully washed barrel.

#### Filtration and juice pasteurization

The press juice was filtered to separate the raw juice of pineapple to debris or other foreign matter passes through the pressing bags. Filtration was carried out using a pouch poplin and pineapple juice was collected in barrels. The filtered juice was then pasteurized at 80 ° C for 30 minutes in order to significantly reduce microbial flora influence on the juice.

**Juice characteristics correction**
**pH and sugar content**

As the minimum wine alcohol content is 10% vol.alc, it was necessary to determine juice initial sugar content to ensure that it will allow achieving a suitable degree of alcohol. In addition, the mash's pH is a very important parameter in the conduct of fermentation. A pH of 4 is the optimum for the growth of fermentative yeast. This also inhibits the development of undesirable microbial flora. The sugar content of the juice was determined by measuring its refractive index (expressed in Brix) using a refractometer (ATAGO, Japan).

**Chaptalization and sulfitation**

Sugar deficiency in juice was corrected by adding sufficient sugar to achieve the desired alcohol level (13.5 ± 0.5% voltaic.). This operation called "chaptalization" was made with cane sugar, commercially available. Added sugar quantity was determined by the formula below:

$$Qs = 17 * (alc.f-alc.i) * Qj$$

With: Qs = added sugar quantity; Qj = Juice for chaptalize quantity, alc.i = alcohol potential degree of non-chaptalized juice; alc.f = desired alcohol degree (13.5% vol.alc.)

We then proceed to the juice sulfitation in order to inhibit endigenous flora proliferation and increase the efficiency of the inoculated strain. Metabisulfite sodium used dose was 40 mg/l. Wort enrichment has been done by adding commercial nutrients essential for yeast growth. Nutrients were then dissolved in 500mL of juice before adding this later to total juice, according to manufacturer's instructions.

**Fermentation**

The yeast *Saccharomyces cerevisiae* var cerevisiae was used for juice fermentation. 100ml of pineapple juice at 30 ° C were introduced in 1 L carboy previously sterilized before and 0.3 grams of yeast was added. The mixture was shaken vigorously for its homogenization before being stored at 30 ° C for 30 minutes. Yeast multiplication induces swelling of the carboy swelling due to $CO_2$ production. The carboy was stirred occasionally and lid slightly open to release gaz. The rehydrated yeasts are added to the wort in the fermentation carboy which was stirred for a good dispersion of yeasts.

**Post-fermentation treatments**

The post-fermentation treatments were necessary to ensure good conservation and presentation of produced pineapple wine.

**Sulfiting, rearing and wine clarification**

Pineapple wine was sulfited after fermentation with 40 mg of metabisulfite sodium per liter. It was kept during five (05) weeks after the fermentation in the fermenter room at temperature (about 30 ° C) to promote natural yeast flocculation to the bottom of the carboy and obtaining a less turbid wine. Prolonged contact between wine and lees in fermenter room aims to refine its taste. It was then clarified by clarifying agent addition (gelatin mixture 2mL/10L + kieselsol 2mL/10L + isinglass 1mL / 10L) in order to precipitate suspended particles responsible of its cloudy appearance. The mixture was homogenized before being stand for 3 days. Finally, ascorbic acid (0.5 g / 10L) was added to the wine after clarification to enhance the metabisulphite antioxidant action.

**Filtration, packaging and maturing in bottles**

Clarified pineapple wine was filtered with a cartridge filter of 0.20 µm diameter. Filtered pineapple wine was then packaged in 75cl bottles closed with corks. The bottles were previously washed after being soaked in a sodium hydroxide solution and then drained after rinsing. They were disinfected few minutes before use by rinsing in water containing metabisulfite and citric acid respectively in an amount of 2g / L and 0.5g / L of water. The stoppers were rinsed in clear water and soaked in a disinfecting permanganate solution for about 1 hour. The bottles (75cL) were filled and cork stoppers were inserted using a manual corker wine. After conditioning, wine bottles were kept lying

motionless in a crate at room temperature for three months. Diagrams of figures 1 and 2 showed the manufacturing process of pineapple wine production.

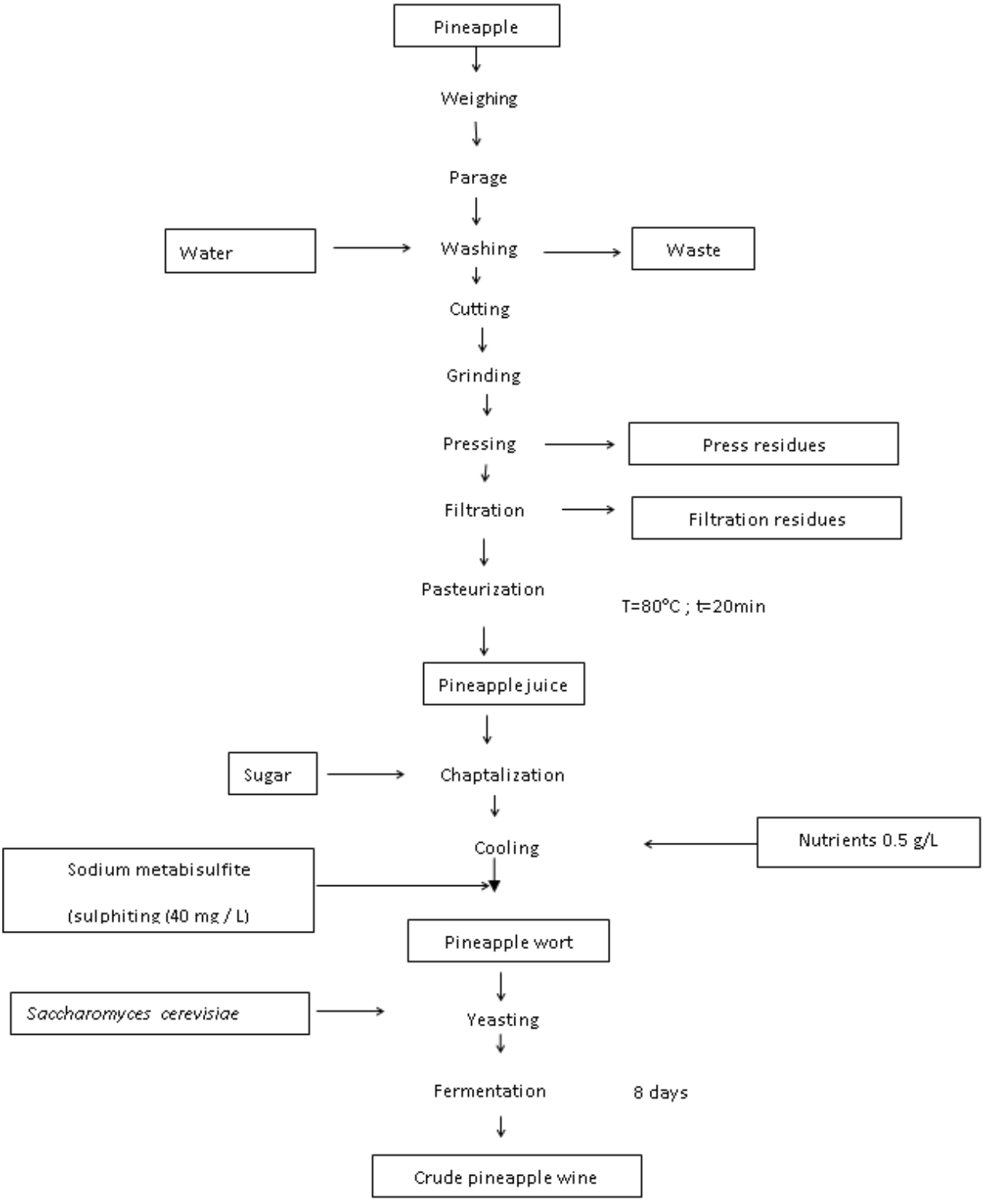


Figure 1. Technological diagrams of pineapple wine production

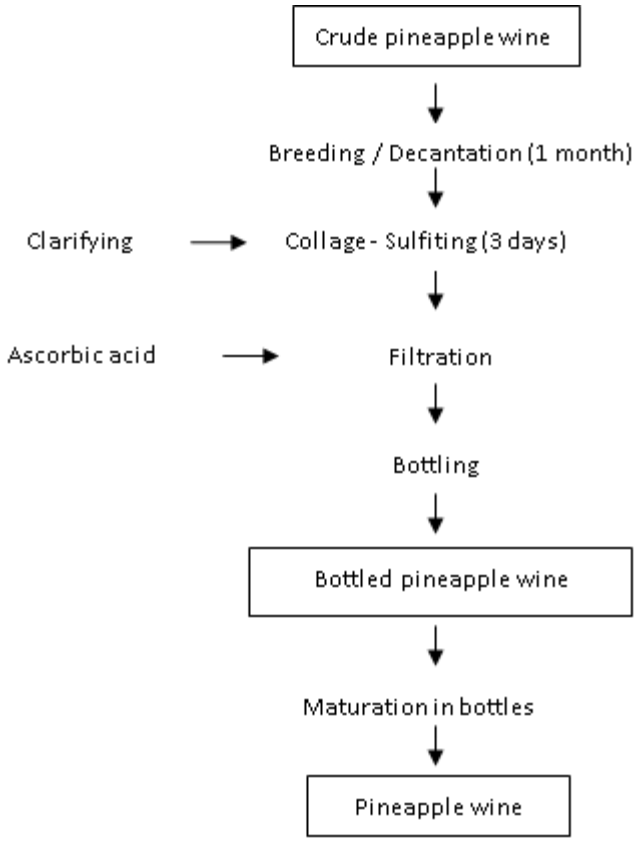


Figure 2. Post -fermentation treatments of the crude pineapple wine

**Produced wine's physico-chemical analysis**

Wort sugar content was determined using a refractometer (ATAGO, PLGA Brix 0-32%) at 20 ° C. Samples density was measured with a hydrometer (VINOFERM) (konfo *et al*., 2014) while pH was determined using a digital pH meter (HANNA test, Hi 98130) previously calibrated at pH 4 and 7. The titratable acidity was measured according to the AOAC, (1975) method by sample total acid neutralization with a 0.1N NaOH solution. The evolution of neutralization was monitored using a color indicator (phenolphthalein).

**Fermentation temperature and alcohol**

The fermentation was carried out at room temperature. This was measured with a thermometer every 12 hours during fermentation. Juices and wort samples potential alcohol content were determined from the initial and final of wine obtained by the formula below:

Degré d'alcool = (densité initiale – densité finale) / 7,6

Potential alcohol content was calculated taking as a basis a final density of 995, corresponding to the average density of white wines.

**Pineapple wine's microbiological analyses of**

Some parameters such as total aerobic mesophilic germs (NF V08-051, 1999), yeasts and moulds (NF V08-059, 2002), coliform (NF V08-050, 1999) and *Staphylococcus aureus* (NF EN ISO 6888-1/A1, 2004), were determined respectively with Plate Count Agar medium (PCA OXOID CM0463), sabouraud dextrose agar medium (OXOID CM0041), Violet Red Bile Agar (VM 012) and Baird-Parker.

**Sensory analysis**

Acceptability tests of pineapple wine were performed using a questionnaire to a panel of 30 tasters. These tests have been focused on sensory characteristics wine, to assess its overall acceptability by tasters already accustomed to wine and in order to consider their opinions.

**Statistical analyses**

The collected data were analyzed using Microsoft Excel 2010. The variance analysis using the Statistics software SPSS 12.0 was used to compare the averages for different variables studied. The test was considered statistically significant if $p < 0.05$.

## Result and Discussion

**Physical and chemical characteristics of juice wort**

Table 1. Physicochemical characteristics of juice, wort and pineapple wine

| Parameters | Pineapple raw juice | Wort (chaptalized pineapple juice ) | Bottled pineapple wine | Pineapple wine (03 months after bottling ) |
|---|---|---|---|---|
| Juice extraction yield (%) | 59.55±3.7 | ND | ND | ND |
| pH | 3.80±0.01 | 3.80±0.01 | 3.70±0.5 | 3.80±0.6 |
| Titratable acidity (% citric acid) | 0.67±0.01 | 0.67±0.01 | 8.00±0.3 | 8.20±0.5 |
| Brix) | 15.00±0.10 | 25.00 ± 0.10 | 13.60±0.7 | 13.80±0.5 |
| Specific Gravity (SG) | 1066.00±1,0 | 1100.00 ± 1,0 | 995.00±0.2 | 995.00±0.2 |
| Potential alcoholic / Level Alcohol (%vol.alc.) | 9.30*±0.10 | 13.80 ± 0.10 | 3.80±0.2 | 3.80±0.4 |

* Value determined by calculation, ND = not determined

Table 1 showed the physicochemical characteristics of juice, wort and pineapple wine. The juice extraction yield was 59.55% and represents more than half of the fruit weight. This value was similar to the maximum juice content (64.65%) reported for pineapples in India by Dhar *et al*. (2008). The pH (3.80 ± 0.01) of juice was close to the value of 3.7 as measured by Chanprasartsuk *et al*. (2012) on the pineapple juice from Queen variety. These acidic pH values were between 3 and 4 correspond to those of grape juice (Akin, 2008). Titratable acidity was 0.67 ± 0.01% for the juice and this was in agreement with values (0.69% and0.67%) obtained respectively by Dhar *et al*. (2008) and by Chanprasartsuk *et al.* (2012) for the Queen variety. This acidic character of pineapple juice can be explained by the presence of organic acids, especially citric acid that was characteristic of tropical fruits. Brix value in pineapple juice was 15.00 ± 0.1 ° Brix and is higher than that of the Cayenne variety (12 ° Brix) of Benin obtained by Gbéhounou and Gbassi, (2004). This value was similar to that reported (15.3%) by Hemalatha *et al*. (2013) for the pineapple juice in India and lower than that of juice extracted from the Queen variety (18.0 ± 0.1 ° Brix) (Chanprasartsuk *et al*., 2012). Same observation was made for the density. Chaptalization of juice increases its density, Brix and theoretical alcohol content passing respectively from 1066.00 ± 1 to 1100.00 ± 1, from 15.00± 0.1 to 25.00± 0.1 and from 9.30± 0.1 to 13.80 ±0.10.

No significant changes in these parameters were observed during maturation. On other hand, pH decreased while titratable acidity increase after fermentation and during maturation. However, the sensory reveals no taste or smell anomaly attributable to lactic or acetic sting linked to the activity of spoilage microorganisms responsible of wine acidity increasing (Ribéreau-Gayon et al. 2012). This could be explained by the addition of ascorbic acid in order to stabilize it. The theoretical alcohol content of chaptalised juice was 13.8 ± 0.1% vol.alc. The alcohol content was similar to those of wines (between 13 and 14%) (Meillon, 2009).

**Evolution of quality parameters during fermentation**

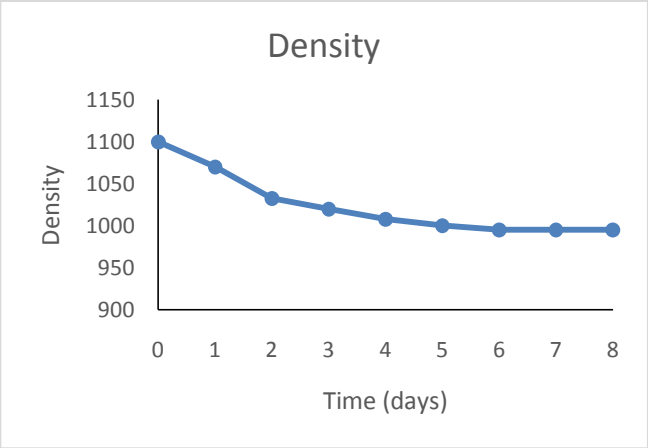


Figure 3. Evolution of the density during fermentation

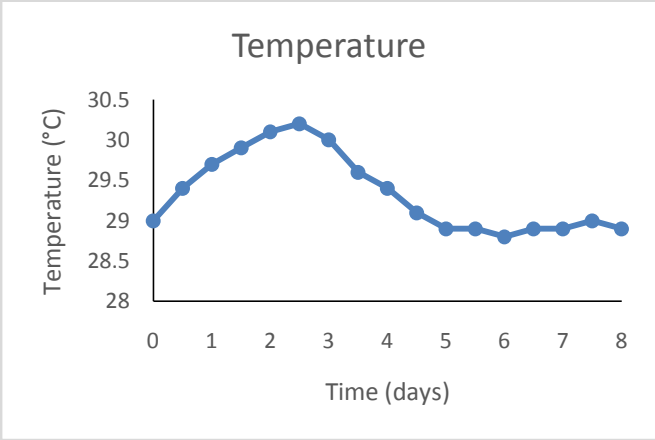


Figure 4. Evolution of the temperature during fermentation.

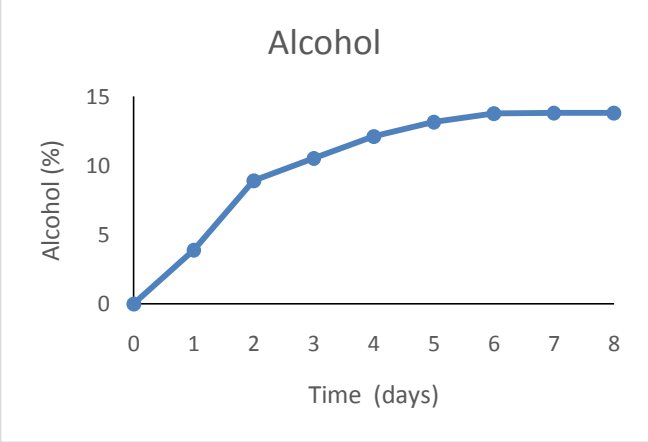


Figure 5. Evolution of the alcohol content during fermentation

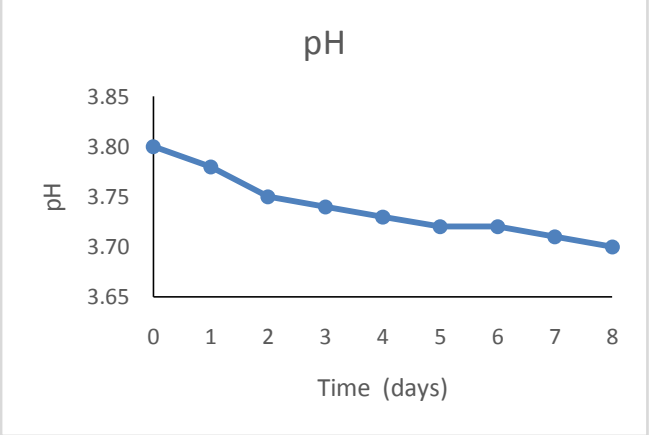


Figure 6. Evolution of pH during fermentation

Analysis of figures 3-6 revealed that density and pH decrease during fermentation from 995 to 1100 and 3.80 to 3.70 respectively, while alcohol level increases from 0 to 13.8%. The fermentation temperature varies between 2.9 ° C and 32.2 ° C. Decrease in density was exponential during the first 02 days of fermentation from 1032 ± 1, and then progressively from the 3rd day until its stabilization after 6 days of fermentation at 995 ± 1. This decrease in density could be justified by the metabolism of commercial yeast *Saccharomyces cerevisiae* var cerevisiae inoculated in pineapple wort for fermentation. Indeed, during alcoholic fermentation, yeasts degrade sugars, producing alcohol and CO2 which was released through the bubbler. Thus, the pineapple juice sugar, more dense than water, was gradually replaced by alcohol, less dense than this later, giving a final lower density. The end of the fermentation was confirmed in the 6th day by $CO_2$ production through the bubbler which becomes hardly noticeable with a stabilization of the density value at 995 ± 1. This density profile during the fermentation was similar to those obtained by several authors such as Nanthaporn and Niorn (2013), Roodagi *et al*. (2012) and Chanprasartsuk *et al* (2012) during pineapple juice fermentation. The final density was in accordance with those obtained by idise (2012) (998-995) and Chilaka et al. (2010) (940-960) at the end of fermentation. The 6-day fermentation period was quite low compared to that of 10 days reported by Chanprasartsuk et al (2012) and that of 12 days reported by Chilaka et al. (2010). The fermentation temperature was 28.8 ± 0.1 ° C at the beginning. It increases during the first hours to 30.2 ° C. In fact, yeast metabolism is exothermic and induced during fermentation energy production. The yeast high activity seeded due to their high number and favorable environmental conditions could explain temperature increasing in the first two days. From the second day of fermentation, a temperature drop was observed with stabilization the 5th day at 28.9 ° C and remains more or less stable with slight variations (± 0.1 ° C) until the end of fermentation. This lowering of the temperature could be explained by a slight slowdown in the yeast activity due to the production of alcohol in the medium as well as the reduction of nutrients. Temperature values taken while long fermentation (29.5 ± 0.7 ° C) were slightly elevated compared to those of 25 ° C repported by Chanprasartsuk et al. (2012) in a temperature condition or in ambient temperature (25 ± 2 ° C) by Okunowo *et al*. (2005) for the production of orange wine and 26.1 ± 3.0 ° C used by Ibegbulem *et al*. (2014). This temperature was however in accordance with 28 to 32 ° C repported by Chilaka et al. (2010). These temperatures respectively promote rapid ethanol production as well as secondary metabolites include glycerol which gives to the wine favorable attributes. Indeed, according to Torija et al (2003), the fermentation temperature increase causes an increase in alcohol yield while lower temperatures favor secondary metabolites formation such as esters, glycerol etc. However, Morakul, (2011) reported that excessive temperatures (>30 ° C) can be detrimental to wine quality and lead to stuck fermentation. This was confirmed by Musyimi *et al*. (2013) who noted that at 35 ° C, juice sugar has not been fully utilized by yeasts during mango wine production. Density changes evoke a rapid alcohol synthesis in pineapple wine the first two days of fermentation. The alcohol content at the end of fermentation (13.8% vol.alc). corresponds to the alcohol content of the wines, generally between 11 and 14 % ( Meillon , 2009). This value was similar to those (12.7% and 13.5%) respectively obtained by Ibegbulem et al. (2014) and Idise (2012) for pineapple wine and (12 and 14 %) obtained by Kocher and Pooja (2011) for guava wine. According to Akin (2008), the metabolism of yeast during alcoholic fermentation induces a continuous change of the environment and the consumption of carbon and nitrogen substrates is following by acid metabolites production. This would explain the decrease of the pH during the first days of fermentation and confirms the absence of inhibition of *Saccharomyces cerevisiae* var cerevisiae inoculated into the wort for the production of pineapple wine. The evolution of pH during fermentation of white grapes by the same author has showed a first phase characterized by a decrease (about 0.2 pH units) of the pH, followed by a second phase characterized by an increase of pH until the end of fermentation. The kinetics of the pH in the wort of white grapes in the fermentation is comparable to that obtained in our study. The final pH value obtained was similar with results reported by Chanprasartsuk *et al*., (2012) who obtained final pH value of 3.9. This value was however high compared those of (3.4 to 3.5) obtained by Idise (2012) at the end of pineapple juice fermentation but was concordant with the pH of the wines after fermentation which is generally 2.0 to 4.0 (Perrin, 2008).

## Microbiological characteristics pineapple wine

Microbiological analyzes of pineapple wine (Table 2) revealed 1CUF / mL total flora on average. Yeasts were enumerated in the same proportions. We noted that mold, total and thermotolerant coliform and Staphylococcus aureus were absent. This allowed to conclude that prodeced wine was suitable for human consumption. Indeed, high ethanol concentrations in the wine (13.8% vol.alc) associated with the preservatives (SO2, ascorbic acid) could protect wine against pathogenic and spoilage microorganisms. These results were in accordance with standards (less than 2 CFU / ml of wine) and showing a good bottling ( Massini, 2010).

Table 2. Microbiological characteristics of pineapple wine

| Parameters | Number of colonies counted CFU /mL) | |
|---|---|---|
| | Pineapple wine (bottling ) | pineapple wine (03months after bottling ) |
| Total mesophilic flora | 01 | 01 |
| Yeasts | 01 | 01 |
| Molds | <1 | <1 |
| Total coliforms | <1 | <1 |
| Fecal coliforms | <1 | <1 |
| *Staphylococcus aureus* | <1 | <1 |

## Sensory characteristics of pineapple wine

Evaluation of sensory characteristics of wine revealed absence of undesirable sour taste and pungent . According to the tasters , the wine produced was crystal clear ( 60%) or gloss (40%) , yellow gold ( 46.67 %) or white ( 26.67% ), had means aromatic intensity (53.33 %) dominated by pineapple flavor ( 66.67 %). It was pleasant to drink (80%), had acid thin taste ( 66.67 %) , average length in mouth ( 66.67 %) and generous alcohol taste ( 73.34 %).

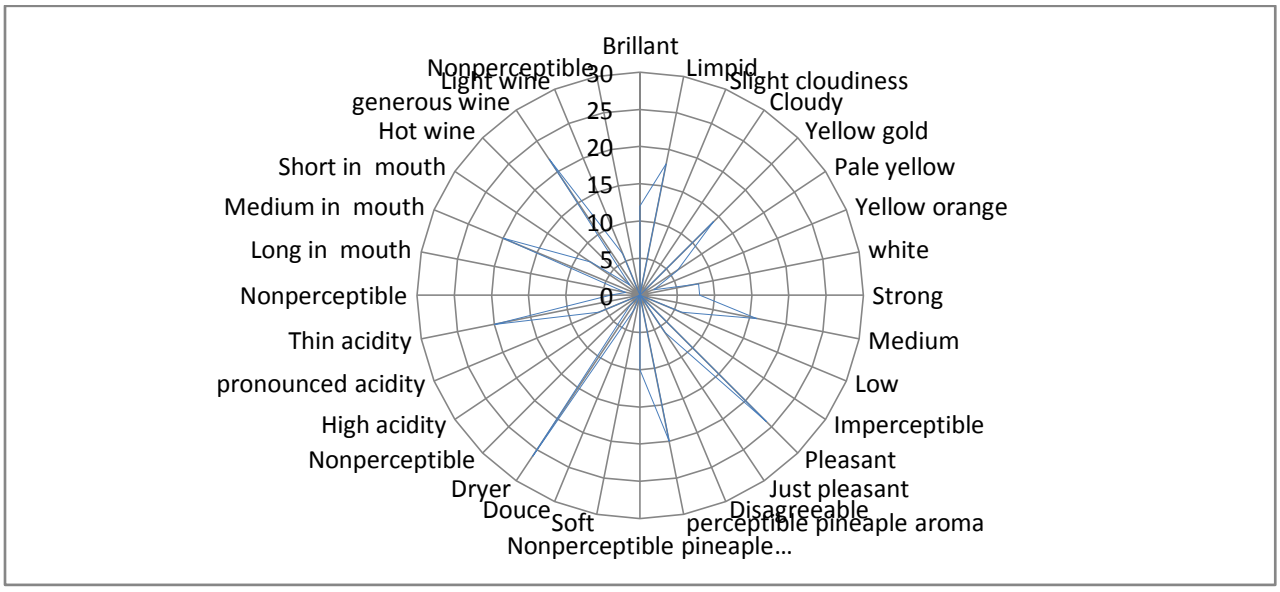


Figure 7. Sensory characteristics of samples

## Conclusion

This study highlighted potential of the " abicaxi " pineapple variety from Benin in wine production. Crude pineapple wine was obtained a by controlled fermentation of pasteurized pineapple juice with commercial yeast *Saccharomyces cerevisiae*. We noted high fermentation activity of the yeast which to complete the fermentation after 06 days. The post -fermentation treatments including collage, sulfuring and filtering pineapple wine allowed its brilliance, clarity and microbiological stability.

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