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Research Article

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Production and Characterization of Edible Vinegar Obtained from *Ananas comosus* Peels from Benin

OBASSA Marius Adékoulé[1], NITIEMA YEFANOVA Svitlana[2], AGBANGNAN DOSSA Cokou Pascal[1]*, KOUDORO Yaya Alain[1], OLAYE Théophile[1]

[1]Laboratory of Study and Research in Applied Chemistry, University of Abomey-Calavi, Polytechnic School of Abomey-Calavi, 01, P. O. Box 2009, Benin

[2]Laboratory of Analytical Environmental and Bio-Organic Chemistry, Department of Chemistry, University Joseph KI-ZERBO, 03 BP 7021, Ouagadougou 03, Burkina Faso

Corresponding Author: cokou2010@gmail.com

Abstract In Benin, *Ananas comosus* products are often left in wild dumpsites for flies and mosquitoes and are a source of foul odours. The main objective of this study is to valorize the co-products of the *Ananas comosus* processing industry through the formulation of edible vinegar. After the elaboration of vinegar, the organoleptic and physicochemical properties of this product were determined. The contents of phenolic compounds in the vinegar were evaluated by spectrophotometric assay. The quantification of its mineral salt content was carried out by atomic absorption spectrophotometry. Finally, the microbiological quality of the formulated product was determined according to ISO standards. From the results obtained, it appears that the pH of the formulated vinegar is 4.77±0.01; with a density of 1.02±0.02, its soluble solids content is 7.30±0.22 Brix. The dry matter and ash content are respectively 3.76±0.02% and 0.15±0.02%. *Ananas comosus* vinegar is rich in phenolic compounds and mineral salts. From the microbiological point of view, it is free of any pathogenic germ and meets the normative requirements. From sensory analysis, it is well appreciated by all tasters.

Keywords *Ananas comosus*; vinegar, physicochemical; salts, microbiological

Introduction

Ananas comosus is a tropical plant, native to South America. It is known mainly for its edible fruit [1]. It belongs to the bromeliad family and the genus Pineapple. *Ananas comosus* species is cultivated in all tropical and subtropical countries [1], [2]. *Ananas comosus* accounts for around 20% of global tropical fruit production and is the second most widely grown exotic fruit after bananas [3]. According to the FAO [4], world pineapple production has doubled in 25 years and represents more than 25.5 million tons per year. In West Africa, Benin is the second largest pineapple producer with 160,000 tons in 2011, after Nigeria [4]. *Ananas comosus* cultivation is intended to be consumed as a fresh fruit locally and in temperate countries where it is imported [3]. Indeed, the various processes for transforming pineapple into juice and dried pineapple lead to the production of large quantities of peelings that are not recycled but piled up in wild dumps. Pineapple peels have a high nutritional value due to their soluble carbohydrate content [5]. They can be used in the food industry in the formulation of food vinegar [6]. The manufacture of vinegar does not require a large investment. Production is envisaged both on an artisanal and semi-industrial scale. Pineapple vinegar is a product remarkable for the power of its aroma, its amber yellow color and its shiny appearance. Edible vinegar is used as an antioxidant, food preservative and condiment [7]. Food vinegar tends to replace lemon in traditional salads due to its easy

use. The color and aroma are the main assets of *Ananas comosus* vinegar to seduce consumers [7]. This work aims to valorize the peelings of *Ananas comosus* through its transformation into edible vinegar.

Technological diagram of pineapple vinegar production

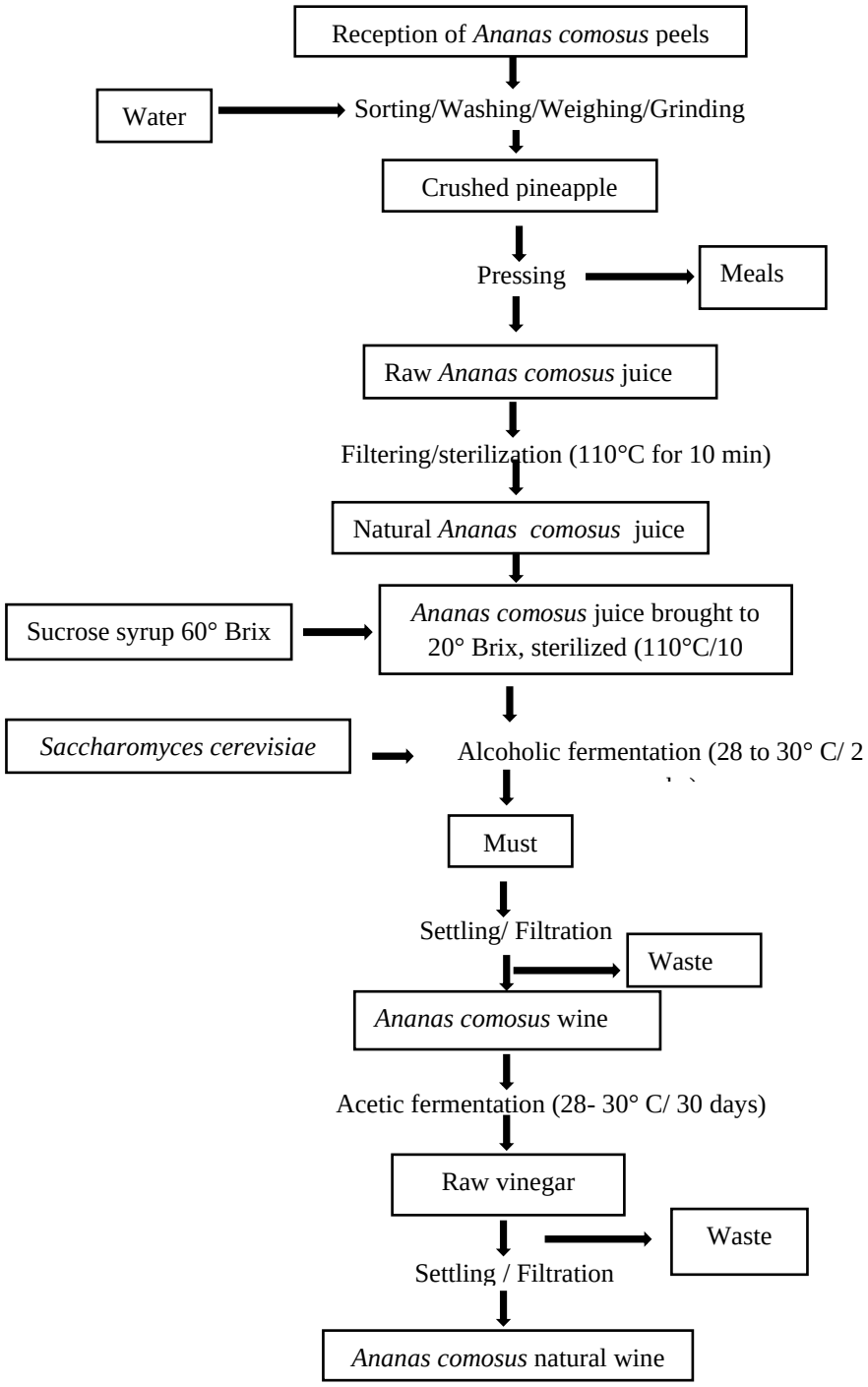

Figure 1: Technological diagram of vinegar production [7],[8].

Materials and Methods

Materials

The material consists of peelings of *Ananas comosus* and strain of *Saccharomyces cerevisiae*

Methods

Vinegar production technology

This technology was developed from the classic technology written by Estanove [7] and Mbungu *et al* [8].

Acetic fermentation

The deposit of the contents of the first fermentation (alcoholic) not being useful for the second (acetic), the wine obtained after decantation was recovered, then decanted into a second plastic jar. The wine was inoculated with commercial vinegar (unpasteurized) containing the strain of acetic acid bacteria in the proportions 3/1 v/v. The opening of the jar has been protected by means of a veil to allow the penetration of air and to avoid contamination by insects or other foreign bodies. After a month, the acetification is complete and the vinegar has been drawn off [7] [8].

Determination of phenolic compounds

Total phenol content: Total phenolic content was determined using the Folin-Ciocalteu colorimetric method with some modifications [9]. This method consisted on using a mixture of phosphotungstic and phosphomolybdic acids, which were reduced during the oxidation of phenols into a mixture of tungsten blue oxide and molybdenum. Finally, the absorbance was measured at 760 nm using a spectrophotometer and the total phenol content are expressed in micrograms of gallic acid equivalence per mL (µgGAE/mL) [9] [10], [11], [12].

Total flavonoids content: The method of aluminum trichloride ($AlCl_3$) was used to quantify total flavonoids. This technique was based on the formation of aluminum complex flavonoids. The absorbance was read at 415 nm using a spectrophotometer and total flavonoid content are expressed in micrograms quercetin equivalence per mL (µgQE/mL)[13].

Condensed tannin content: Vanillin and hydrochloric acid method was used to determine total condensed tannins content. The absorbance was measured at 500 nm using spectrophotometer and tannin content was expressed in micrograms catechin equivalence per mL (µgEC/mL) [14].

Minerals and Trace Elements Content: 5 grams of the sample were cremated following the procedure indicated above. The ash obtained was dissolved in 5 ml of hydrochloric acid (6N) and then evaporated on a hot plate at 125°C. The resulting residue was dissolved and recovered with HNO_3 (0.1N) in 100 mL flask. This solution was used to obtain the content of the minerals by Spectrophotometer Atomic Absorption. The results are expressed in relation to the dry matter [15].

Physicochemical analysis of formulated edible vinegar: The pH was determined using a portable digital pH meter. The titratable acidity, expressed as percentage of citric acid, was determined by titration with NaOH (0.1N) in the presence of phenolphthalein. The soluble dry extract (°Brix) was determined using a portable refractometer (HI 96801 of 0-80° Brix). The relative density at 20°C was determined using a pycnometer according to the method described by Massengo *et al* [16]. The dry matter was determined by drying in an oven at 105°C according to the recommended method (AOAC, 2000). The minerals were assayed by Atomic Absorption Spectrophotometry [15].

Microbiological analyzes: The microbiological quality of *Ananas comosus* liquor was assessed through the determination of mesophilic aerobic flora, coliforms and yeasts and molds. 1 mL of the sample to be analyzed was taken aseptically to which 9 mL of sterile saline peptone water was added. The mixture was vortexed for 2 minutes, serving as the stock solution. Successive tenfold dilutions were prepared for seeding Petri dishes. The total aerobic mesophilic flora was counted using PCA agar (Plate Count Agar) at 30°C for 72 h. 1 mL of each of the dilutions as well as the stock suspension was introduced into different sterile Petri dishes. Then, 20 mL of

the agar was poured into the contents of the Petri dishes. The whole was gently homogenized so as to incorporate the inoculum into the agar. After solidification, the agar is poured again to make a second layer. The count of germs was done according to the ISO 6222 1999 standard. The count of coliforms was carried out using VRBA (Violet Red Bile Agar) medium. 1 mL of each dilution was inoculated into a double layer of 10 to 15 mL of VRBA agar then incubated after solidification of the medium at 37°C for 72 h according to the ISO 21528-2: 2008 standard. Yeasts and molds were counted following incubation of 1 mL of each dilution on Malt Extract Agar (MEA, oxoid, CM 325, Hampshire, England) at 25°C for 72 hours. The count of germs in CFU/mL of samples analyzed was done according to the ISO 21527-1: 2008 standards.

Sensory analysis: Sensory tests were carried out at the end of production. From a panel of tasters, the sensory characteristics of the edible vinegar produced were evaluated according to the hedonic method [17]. The panel of tasters is made up of eighteen people of different sexes and from all social categories, chosen from among the usual consumers of this product. The descriptors or attributes to consider are: color, flavor, aroma, smell, texture, bitterness, viscosity, taste and general impression.

Results & Discussion

Physicochemical characteristics of *Ananas comosus* vinegar

Table 1 indicates the physico-chemical parameters of the formulated *Ananas comosus* vinegar. The pH, soluble solids content of pineapple vinegar are 4.77; 1.02 and 7.30°Brix respectively. Commercial spirit vinegar has a pH of 4.36 with a specific gravity of 1.00 and a soluble solids content of 0.10° Brix. The titratable acidity, dry matter and ash contents are 51.20 mg Eac/mL, 3.76% and 0.15% respectively. It was obtained with commercial alcohol vinegar, a dry matter content of 0.39%, a titratable acidity content of 20.48 mg Eac/mL and an ash content of 0.08%. The amounts of acetic acid in *Ananas comosus* vinegar and spirit vinegar are 6.20% and 3.89% respectively. The average pH value of the vinegar produced is similar to that obtained for commercial vinegar (4.36) and slightly higher than that reported by Mbungu *et al*.[8] in the DRC with mango vinegar (3.07). Moreover, density of the *Ananas comosus* vinegar produced is the same as that reported by Mbungu *et al*[8] (1.02) but on the other hand higher than that found for commercial vinegar (1.00). This variation in density would be due to the fact that commercial vinegar does not contain colloidal matter in suspension[18]. The average contents of soluble solids, titratable acidity, ash and acetic acid of the vinegar produced corroborate those reported by Mbungu *et al*[8] whose contents are respectively 5.4° Brix; 53.88 mg Eac/mL; 2.77%; 0.20% and 5.39%. Values obtained with fruit vinegars (*Ananas comosus* and mango) are above the values presented for commercial alcohol vinegar. The high concentrations obtained with fruit vinegars (pineapple and mango) could be due to the presence of organic acids, organic compounds, mineral salts or to the manufacturing process [2].

Table 1: Physicochemical characteristics of *Ananas comosus* vinegar compared with commercial vinegar

Settings	*Ananas comosus* vinegar	Commercial spirit vinegar
pH	4.77±0.01	4.36±0.02
Density	1.02±0.02	1.00±0.00
°Brix	7.30±0.22	0.10±1.34
AT (mg Eac/ mL)	51.20±2.43	20.48±2.32
Dry matter content (%)	3.76±0.02	0.39±0.01
Ash (%)	0.15±0.02	0.08±0.02
Acetic acid (%)	6.20±0.01	3.89±0.12

Content of phenolic compounds in the formulated edible vinegar

Table 2 presents the content of phenolic compounds in the elaborated vinegar. It is apparent from this table that *Ananas comosus* vinegar contains a significant amount of tannins, flavonoids and total phenols. The concentration of total phenols is 11.31 mgEAG/mL of vinegar. The contents of total flavonoids and condensed tannins are respectively 15.07µg EQ/mL and 34.43mgE Leuc/mL) in *Ananas comosus* vinegar.

The concentration of total phenols in *Ananas comosus* vinegar is much higher than those indicated by Ousaaid *et al*19] at the level of cider vinegar in Morocco, the values of which are between 0.86 and 2.02 mgEAG/mL.

This difference in value could be justified by the nature of the raw materials used. The concentration of flavonoids and condensed tannins of pineapple vinegar obtained is a beneficial advantage because these compounds have anti-inflammatory, diuretic and antioxidant activities[20]. They play an important role in the organoleptic and nutritional qualities of products [21].

Table 2: Content of phenolic compound in the edible vinegar produced

Phenolic compound	**Total phenol (µgGAE/mL)**	**Total flavonoids (µgQE/mL)**	**Condensed tannin (µgCE/mL)**
Content	11.31	15.07	34.43

Mineral salt content

Table 3 presents the mineral salt content of *Ananas comosus* vinegar. From the analysis of this table, it emerges that the formulated vinegar has a high content of mineral salts. The contents of P, K, Na and Ca are respectively 100.00 mg/L, 789.80 mg/L, 55.79 mg/L and 105.99 mg/L while those in Mg, Fe and Mn are respectively 69.79 mg/L, 2.82 mg/L and 9.48 mg/L. The mineral salt concentrations of the formulated vinegar are much higher than those indicated by Ousaaid *et al*[19] whose K, Na, Ca, Mg, Fe and Mn contents are respectively between 32.00-42.00 mg/L; 0.039-1.99mg/L; 1.57-2.62mg/L; 1.57-1.75mg/L; 0.50-0.58mg/L and 0.04-0.05 mg/L. On the other hand, the calcium (6.01 mg/L) and magnesium (2.92 mg/L) concentrations of artisanal vinegar obtained by Mbungu *et al*[8] are much lower than the levels obtained in pineapple vinegar in our work. This difference in value could be due to the raw materials used.

Table 3: Mineral salt content in the vinegar produced

Mineral salt	**Fe**	**Na**	**Ca**	**Mg**	**K**	**P**	**Mn**
(mg/Kg)	2.82	55.79	105.99	69.79	789.80	100.00	9.48

K: Potassium; Ca: Calcium ; Na: sodium; P: phosphorus; Mg: Magnesium ; Fe: Iron ; N : nitrogen

Microbiological Quality

Table 4 presents the results of the microbiological analysis of the vinegar produced. From the microbiological point of view (table 4), the vinegar produced does not contain coliforms. As for yeasts and moulds, they are below the microbiological criteria. These values are in accordance with the beverage standard which indicates that the number of yeasts and molds must not exceed 10^3CFU/mL [22]. The count of the total aerobic mesophilic flora is less than 10^3 CFU/mL. These values meet the normative requirements. Thus, the *Annas comosus* vinegar produced is of acceptable microbiological quality.

Table 4: Microbiological characteristics of *Annas comosus* edible vinegar

Microorganisms	Vinaigre	Normative values
TAMF	10^2 UFC/ mL	< 10^3 UFC/mL (FSD, 2018)
Total coliforms	Absent	< 10^2 UFC/ mL (FSD, 2018)
Yeasts	2.10^2UFC/mL	< 103 UFC/ mL (Luxembourg, 2011)
Molds	4.10^1 UFC/ Ml	< 10^3 UFC/ mL (Luxembourg, 2011)

FSD: Food Security Division; TAMF: Total Aerobic Mesophilic Flora; CFU: Colony Format Unit

Sensory analysis of *Ananas comosus* vinegar

The averages of the results obtained at the end of the sensory tests carried out on the formulated vinegar are recorded in table 5. The analysis of the results reveals that overall, the tasters really liked the pineapple vinegar with an appreciation rate of 73.88%. Tasters moderately liked the color, texture, sour taste, aftertaste and smell of the vinegar. They especially appreciate the fruity smell of the formulated product. The average appreciation rate obtained for this parameter is 67.22%. The average ratings of the other parameters are as follows: 62.22% for texture, 63.33% for color, 64.44 for acid taste and aftertaste. The ratings obtained for the aroma and the acid

smell of vinegar show that the tasters do not like the acid smell of vinegar at all (rate of appreciation of 20%) and slightly appreciate its aroma (rate of appreciation 57.77%).

Table 5: Sensory analysis

Parameters	Appreciation rate
Color	63.33
Aroma	57.77
Texture	62.22
Sour taste	64.44
Aftertaste	64.44
Fruity smell	67.22
Sour smell	20.00
General impression	73.88

Conclusion

This study made it possible to produce and characterize vinegar from the peels of *Ananas comosus* on the physicochemical, microbiological and sensory levels. The product produced has an acid pH and high levels of dry matter, titratable acidity and soluble dry matter. The evaluation of phenolic compounds shows that they are rich in total phenols, flavonoids and condensed tannins. Mineral analysis indicates that vinegar contains a significant amount of mineral salts; essential to man. From a microbiological point of view, it is free of any pathogenic germ and meets the normative requirements. From the sensory analysis, it appears that it is well appreciated by all the tasters (>73%). The transformation of *Ananas comosus* peels into vinegar solves problems related to pollution and is of undeniable economic importance.

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