

Research Article



Morphological and Physicochemical Characterizations of Cashew Apples from Benin for their use as Raw Material in Bioethanol Production

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ABSTRACT

The present study aims the enhancement of agricultural resources and the reduction of post-harvest losses through the evaluation of physical and physicochemical characteristics of different morphotypes of cashew apples from Benin. In this context, cashew apples were collected in different areas of Benin and the physical characteristics (mass, height and diameter at the equator) of apples were evaluated. Then juices were extracted and their physicochemical parameters such as pH, the level of soluble solids (brix), density, acidity and carbohydrates were also evaluated. From results obtained, it appears that red morphotypes apples from North-East of Benin have the highest values for the mass, height and diameter at the equator which are respectively 94.78 ± 18.28 g, 73.69 ± 9.93 mm and 48.52 ± 2.97 mm, and are large compared to those from center and North-West of Benin. Cashew apples from center of Benin have the best extraction yields ($87.25 \pm 4.14\%$) for yellow morphotype and $80.90 \pm 3.53\%$ for the red morphotype. Juice from red morphotype apples are the highest carbohydrate content, especially those of the Center of Benin (23.66 ± 1.89 g/kg). The results show that the center of Benin is an ideal area for the promotion of cashew tree culture in the perspective to use cashew apples in the production of renewable energy such as bioethanol.

Keywords: cashew apple, morphotype, physicochemical characterization, bioethanol, Benin.

INTRODUCTION

Cashew tree (*Anacardium occidentale* L.) is a plant belonging to the family of Anacardiaceae and is considered native to the tropical regions of Brazil¹. Its culture has been easily promoted in West Africa because of its hardiness and its multiple products source. Besides fruits such as nut and apple, the plant provides a diversified range of secondary products². It is a tree that can reach ten meters and its trunk diameter can range from 1.2 to 1.5 m¹. Although rustic, it grows preferably in warm tropical areas with alternating wet and dry seasons. It adapts to various soils, but prefers light and well drained. In Benin, cashew is one of the main agricultural exports after cotton³. However, apart from the nuts, other products are not recovered. In fact, the cashew apple is considered a waste in the cashew industry; it is left to decay on the ground in fields^{4,5}. Despite its high content of carbohydrates, it contains a stringent compounds that give an unpleasant feeling to its consumption and limits its use on the global market for fruit juices⁶.

Thus, according Karuppaiya⁷ cashew apple therefore did not have a real value for commercial use. In 2011, Beninese's production of cashew are estimated at 70,000 tons⁸ and according to Camara⁹ the reports of nut / apple being about 1/4 (w / w) showed that over than 280,000 tons of cashew apples are discarded annually¹⁰. Thus, it is important to value this sugar and lignocellulose resources which are available and untapped, through its bioethanol bioconversion. Face the many drawbacks associated with the use of fossil fuels and the emission of greenhouse

gases, most countries have set up research and development programs on renewable energy sources, to counter the dependence on petroleum products which display currently record prices. Given its characteristics, the sector of ethanol is added to the long list of alternative energies, whose development is motivated by a vision converges towards the energetic autonomy.

The high cost of oils is causing, on the one hand, the increase in factors of production of agricultural products and, on the other hand, stimulation of the biofuels market.

Indeed, the high price of oil creates a favorable environment for the production of ethanol¹¹.

In Benin, the biofuel sector is still embryonic or almost nonexistent.

It would be wise, in this sector development perspective, to consider first the production of biofuel from waste agri business or starchy and lignocellulosic biomass neglected rotting every year in significant quantities.

Thus, this study will help to supply information on the morphological and physicochemical characterizations of cashew apples from Benin for their use as raw material in bioethanol production.

Emphasis is put on the calibration of cashew apples from large production areas of Benin, as well as on the physicochemical characteristics of the juices extracted from these apples, for their use in the fermentation industry for the production of renewable energy such as the bioethanol.



MATERIALS AND METHODS

Collection of cashew apple

Taking into account the geographical distribution of cashew plantations in Benin, collection areas were mainly largest and of cashew of Savalou and Bantè, located in the central part of Benin; Tchaourou, Parakou and N'Dali located in the north-eastern part; Djougou and Kouandé, located in the north-western part of Benin (Figure 1). The collection method was direct picking. The transport of apples from collected sites to laboratory was performed using portable coolers type "Eskimo" to preserve the quality of picked apples.

Physical and proximate analyses

The physical characteristics of cashew apples are determined through measurements of the dimensions (mass, length and diameter at the equator) of apples. The apple juice content is determined by direct pressing, followed by the calculation of yield using the formula [Yield (%) = (Weight of juice obtained / Weight apple treated) x100]. The Brix of different juices was performed with numeric refractometer as described by AOAC¹² method. The pH was determined with a digital pH-meter (HANNA HI 98129). Acidity of juice, expressed as citric acid content per unit of volume, was determined by titration with 0.01 mol/L of sodium hydroxide solution, using phenolphthalein as indicator¹². The density at 20°C of juices was determined using a portative densitometer. The carbohydrate was determined according to phenol sulfuric acid method^{13,14}. A standard curve was obtained using the following concentration of sucrose in (mg/ml) 2.5, 2.0, 1.25, 1.0, 0.5 g of each sample with 9 ml of distilled water was measured into test-tube. 2 ml of phenol solution (1%) and 1 ml of concentrated H₂SO₄ solution were added. This was shaken for 15 min and boiled for 30 min. It was then allowed to cool. The absorbance was then read off a spectrophotometer (spectrum lab 22) at 700 nm. The sugar concentration was then obtained by extrapolation from the standard curve.

Statistical Analyses



Figure 1: Benin's map showing the collection zones

The data generated from these studies were analyzed using Statistical Analysis Software (SAS) and SYSTAT 5.05. The statistical analyses carried out were mean and standard deviation and analysis of variance (ANOVA)^{15,16}.

RESULTS AND DISCUSSION

Aspect of different cashew apples collected

Figure 2 showed the appearance of different cashew apples encountered in collection areas. Despite all the diversity observed in cashew apple during the collection, mainly two morphotypes of cashew apple were more observed. These were Yellow and Red morphotypes (Figure 2). However, we should also mention the presence, sometimes, of Yellow-orange apples. The same observations were also reported by Soro² in the cashew apple from the Ivory Coast. These colors were only due to the thin waxy layers that constitute the apple skin. Thus, regardless of skin color, its chair still appeared yellow². Similarly, in the same planting cashew, the presence of the two different morphotypes of cashew apple were also observed. These results showed the need for a genetic classification to determine the genetic variances in the cashew apple species in Benin.

Physical characteristics of cashew apple

Tables 1 and 2 showed the physical characteristics of different samples of cashew apples collected. The analysis of these results indicated that there was a wide range ($p > 5\%$) for these characteristics, when considering the production zone. Indeed, mass, height, diameter at the equator and the juice content of cashew apples from major production areas of center of Benin were the highest and were respectively $75.84 \pm 1.83\text{g}$, $66.90 \pm 0.43\text{ mm}$, $43.42 \pm 1.51\text{mm}$ and $87.25 \pm 0.01\%$. By cons, in the Northwest zone, cashew apple samples were mostly smaller in height and diameter. However, taking into account the morphotypes, results indicated that the red morphotype have, in average, their mass, height and diameter at the equator, higher than that of yellow morphotype. Taking into account of juice content of cashew apples, the results indicated that cashew apples collected in the Center of Benin have a juice content of $87.25 \pm 0.01\%$ for yellow morphotype and $80.90 \pm 0.01\%$ for red morphotype. These levels were higher than those of other cashew apples collected in Northeast and Northwest zone. These major variations could be related, not only to the soil characteristics in collection zone, but also rainfall, because, according to Soro², the optimum growing of cashew plants depend on type of soil and rainfall. Indeed, Benin rainfall was characterized by two rainy seasons in the South and Center. However, the north was characterized by a single rainy season.

The uneven distribution of rainfall could also be an important factor in the major differences in the physical characteristics of cashew apples, when considering the geographical location of collection zone. Thus, several researches^{17,18} suggested that climatic and agro-soil

factors were important criteria which could be taken into account in the morphological classification of fruits.

Physicochemical characteristics of juice from cashew apples

Tables 3 and 4 present the physicochemical characteristics of juice from cashew apples collected.

Analysis of these results indicated that there was no significant difference ($p < 5\%$) in values of parameters such as pH, acidity and the relative density of juice, when considering the collection zone. Mean values are respectively 4.38, 2.06 and 1.03 for juice extracted from yellow morphotype; and 4.44, 2.21 and 1.03 for the extracted juice from red morphotype.

These results are similar to those reported by Soro² in the extracted juice of cashew apples harvested in Ivory Coast.

However, the results obtained on carbohydrate content and the Brix of juice extracts of cashew apples, showed that these parameters varied according to collection zone.

Indeed, juice from cashew apples collected in the Northeast and Northwest areas have a higher carbohydrate and Brix content than those from Benin Center.

The highest contents of carbohydrates in juices (16.47 ± 1.69 g/kg for yellow morphotype apples and 18.07 ± 1.18 g/kg for red morphotype apples) were obtained in samples collected in the Northeast zone. These levels of carbohydrates were higher than that of the palmyra juice¹⁹. Indeed, the cashew apple juice appeared as a raw material of choice in the production of ethanol by fermentation. In fact, according to results of this study, cashew apples was very juicy, rich in carbohydrate, and relatively acidic. It was also very rich in vitamin C and polyphenols²⁰. Finally it contained significant amounts of carotenoids^{21,22} and more than 50 aromatic compounds². Given its high carbohydrate content, it was used to make syrups, jellies, candied fruit etc. However, the transformation of the cashew apple was limited by the characteristics of the fruit. Indeed, the apple was rich in tannins², which gave it a particularly strong astringency. This astringency comes mainly from the membranes of the skin. The second factor that could limit the transformation of cashew apple juice for food purposes was its very rich in reducing sugars, particularly glucose and fructose¹. Indeed, the presence of reducing sugars which were precursors of the Maillard reaction and non-

enzymatic browning color could be a problem during processing of the fruit juice. Thus, one of the recovery methods of this resource available, inexpensive, and rotten every year in large quantities²³ was its bioconversion in bioethanol by fermentation. Indeed, today the high population's growth, combined with global economic growth and rising living standards of the population, was causing an exponential increase in energy demand. Moreover, the global transport sector was currently almost completely dependent on petroleum products. It has been proven that this sector was responsible for 60% of world oil consumption²⁴. In addition, the transport sector was the basis of more than 70% of global emissions of carbon monoxide (CO) and 19% of global carbon dioxide (CO₂) emissions²⁵. Throughout the world, there were about 806 million of cars and trucks in circulation in 2007²⁶. It is expected that this number will increase to 1.3 billion for the year 2030 and more than 2 billion vehicles for the year 2050²⁷. This growth will affect the stability of ecosystems and the global climate as well as global oil reserves. The exorbitant increase in the price of oil, the depletion of fossil fuels, growing concerned about environmental impacts, particularly greenhouse gas emissions, health and regional insecurities risks (geopolitical and geostrategic) open the way to other sources of energy²⁸. Today, the nuclear industry, for safety reasons (Chernobyl and Fukushima accidents) represents only 3% of global energy supply. For solar and wind power, the most critical was their shared intermittent and their energy storage difficulties. That is why their contribution is still low. With these remarks, biomass, which currently represents 18% of global energy supply, could be in a few decades, the main alternative to fossil fuels mining. However, despite the controversy surrounding the energy from biomass, certain characteristics make them an energy still coveted. Through photosynthesis process, from the atmospheric CO₂, biomass made available carbon molecule chains, which are an important energy stock²⁹.

In the field of transport, the best way to energy recovery from biomass was its transformation into biofuel through fermentation. Indeed, during alcoholic fermentation, sugars in the juice were converted into alcohol by a series of complex reactions.

Glycolysis was the starting point. This way, common to the fermentation and respiration allowed the conversion of glucose to pyruvic acid which was then decarboxylated to acetaldehyde and then reduced to ethanol³⁰.

Table 1: Physical characteristics of cashew apple from yellow morphotype

| Zones | Mass (g) | height (mm) | Diameter at the equator (mm) | Juice yield (%) |
|-----------------|--------------|-------------|------------------------------|-----------------|
| Center of Benin | 75.84±1.83a | 66.90±0.43a | 43.42±1.51a | 87.25±0.01a |
| North East | 65.74± 1.08b | 59.25±6.50b | 41.67±1.43a | 80.55±0.01b |
| North West | 43.26±2.33c | 60.00±0.52b | 33.55±2.42b | 77.82±0.01c |

Values are mean. The means followed by same letter in the same column are not significantly different according to ANOVA and Tukey's multiple comparison tests.



Table 2: Physical characteristics of cashew apple from Red morphotype

| Zones | Mass (g) | height (mm) | Diameter at the equator (mm) | Juice yield (%) |
|-----------------|-------------|--------------|------------------------------|-----------------|
| Center of Benin | 87.23±3.23a | 65.87±1.23a | 46.65±2.00a | 80.90±0.01a |
| North East | 94.78±1.28b | 73.69±1.93b | 48.52±2.97a | 76.98±0.01b |
| North West | 41.01±1.61c | 54.27± 3.36c | 34.79±1.53b | 74.08±0.01c |

Values are mean. The means followed by same letter in the same column are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Table 3: Physico-chemical characteristic of juice from yellow morphotype

| Zones | pH | Acidity (%) | Carbohydrate (g/kg) | Brix (Bx) | Density (20 °C) |
|-----------------|------------|-------------|---------------------|------------|-----------------|
| Center of Benin | 4.40±0.01a | 2.52±0.16a | 15.64±3.30a | 8.47±0.06a | 1.04±0.01a |
| North East | 4.48±0.02a | 1.90±0.15a | 16.47±1.69b | 9.25±0.26b | 1.03±0.01a |
| North West | 4.28±0.01a | 1.78±0.07a | 15.80±0.72b | 8.67±0.21b | 1.04±0.01a |

Values are mean. The means followed by same letter in the same column are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Table 4: Physico-chemical characteristic of juice from Red morphotype

| Zones | pH | Acidity (%) | Carbohydrate (g/kg) | Brix (Bx) | Density (20 °C) |
|-----------------|------------|-------------|---------------------|-------------|-----------------|
| Center of Benin | 4.43±0.01a | 2.44±0.07a | 23.66±1.89a | 12.63±0.06a | 1.05±0.01a |
| North East | 4.45±0.01a | 2.30±0.09a | 18.07±1.18b | 8.33±0.06b | 1.03±0.01a |
| North West | 4.46±0.01a | 1.90±0.09a | 16.57±1.49c | 8.27±0.06c | 1.03±0.01a |

Values are mean. The means followed by same letter in the same column are not significantly different according to ANOVA and Tukey's multiple comparison tests.



1. Red morphotypes

2. Yellow morphotypes

Figure 2: Some morphotypes of cashew apples growing in Benin

CONCLUSION

The present study shows that despite its low commercial value due to the presence of astringent compounds that give an unpleasant feeling to its consumption, cashew apples are rich in important compounds such as carbohydrates and vitamins.

Face with the recurrent problem of fossil energy, it represents a potential source of raw material which can

be used in the production of renewable energy, such as bioethanol.

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REFERENCES

- Lautié EM, Dornier F, De Souza M, Reynes M, Les produits de l'anacardier: caractéristiques, voies de valorisation et marchés. *Fruits*, 56, 2001, 235-248.
- Soro D. Couplage de procédés membranaires pour la clarification et la concentration du jus de pomme de cajou : performances et impacts sur la qualité des produits. Thèse de Doctorat en Sciences des Procédés-Sciences des Aliments. Institut des Régions Chaudes (France), 2012, 152p.
- Aivodji J, Anasside A, Élaboration des règles de stabilisation et de soutien des prix pour la filière anacarde. ONS, Projet d'Appui à la Sécurisation des Revenus des Exploitants Agricoles (PASREA), 2009, 73p.
- Mohanty S, Ray P, Swain M, Ray R, Fermentation of cashew (*Anacardium occidentale L.*) apple into wine. *Journal of Food Processing and Preservation* 30, 2006, 314-322.
- Santos RP, Production and characterization of the cashew (*Anacardium occidentale L.*) peduncle bagasse ashes. *Journal of Food Engineering* 79(4), 2007, 1432-1437.
- Couture R., Valorisation de la pomme de cajou au Vietnam. Rapport final du projet de recherche, 1993, 173p.
- Karuppaiya M, Sasikumar E, Viruthagiri T, Vijayagopal V, Optimization of process variables using response surface methodology (RSM) for ethanol production from cashew apple juice by *Saccharomyces cerevisiae*. *Asian Journal of Food and Agro-Industry* 3(4), 2010, 462-473.
- FAO: FAOSTAT agricultural production data 2013. Available online at <http://faostat.fao.org>.
- Camara LS, Etude sur les biocarburants en Guinée Bissau, Comité Permanent Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS), 2007, 38p.
- Gnikpo R, Essais de valorisation des déchets d'ananas et de la pomme de cajou pour la production d'alcool alimentaire. Mémoire de master en Microbiologie et Technologie Alimentaire, Faculté des Sciences et Techniques, Université d'Abomey-Calavi du Bénin, 2013, 62p.
- OCDE, Organisation de Coopération et de Développement Économiques. Incidences de la croissance de la production de biocarburants sur les marchés agricoles. AGR/CA/APM (2005) 24/FINAL. Programme de travail du Comité de l'agriculture pour 2005/2006. 60p.
- AOAC, Official Methods of Analysis, Association of Official Analytical Chemist Inc: Virginia, 1990, USA.
- Agbo NG, Ronald ES, Characteristics of juice from Palmyrah Palm (*Borassus*), fruit. *Plant Foods Hum. Nutr.*, 42(1), 1999, 55-70.
- Ezoua P, Kouamé D, Agbo NG, Caractéristique du jus de la pulpe fraîche du fruit de rônier (*Borassus aethiopum Mart.*). *Cahier d'agriculture*, 8, 1999, 126-128.
- Alder HL, Roessler EB, Introduction to probability and statistics (6th edition). Freeman W.H., San Francisco, 1977, 426 p.
- Ogbeibu AE, Biostatistics, a Practical Approach to Research and Data Handling. Mindex Publishing Company Ltd. Benin City, Nigeria, 2005, p.264.
- Ugese FD, Baiyeri PK, Mbah BN, Agroecological variation in the fruits and nuts of shea butter tree (*Vitellariaparadoxa C. F. Gaertn.*) in Nigeria. *Agroforest. Syst.* 79, 2010, 201–211.
- Kouglbléno N, Ahouansou RH, Aïssi M V, Houssou PA, Padonou W, Fandohan P, Mensah GA, Soumanou MM, Caractérisation physique du fruit et valeur nutritionnelle de la pulpe de karité (*Vitellariaparadoxa*) collecté dans différents parcs au Bénin. *Bulletin de la Recherche Agronomique du Bénin (BRAB) Numéro spécial Agriculture & Forêt.* 2012, 43-49.
- Adjou ES, Amamion H, Tchobo FP, Aïssi VM, Soumanou MM, Extraction assistée par enzyme du jus de la pulpe fraîche du rônier (*Borassus aethiopum Mart.*) acclimaté au Bénin : caractérisation physico-chimique et microbiologique. *Int. J. Biol. Chem. Sci.* 7(3), 2013, 1135-1146.
- Michodjehoun-Mestres L, Souquet J-M, Fulcrand H, Bouchut C, Reynes M and Brillouet JM, Monomeric phenols of cashew apple (*Anacardium occidentale L.*). *Food Chemistry*, 112(4), 2009, 851-857.
- Assunção RB, Mercadante AZ, Carotenoids and ascorbic acid composition from commercial products of cashew apple (*Anacardium occidentale L.*). *Journal of Food Composition Analytical*, 16, 2003, 647–657.
- Abreu F, Perez AM, Dornier M, Reynes M, Potentialités de la microfiltration tangentielle sur membranes minérales pour la clarification du jus de pomme de cajou. *Fruits*, 60, 2005, 33-40.
- AbohAB, Dougnon JT, Atchade TGS, TandjiekponAM. Effet d'aliments à base de pomme cajou sur les performances pondérale et la carcasse des canetons en croissance au Bénin. *Int J BiolChemSci*, 5(6), 2011, 2407-2414.
- I.A.E (International Energy Agency). Key world energy statistics 2008: Head of Communication and Information Office. Printed in France by SOREGRAPH, 2011, rue dela Fédération, 75739: Paris Cedex 15, France: OECD/IEA, 2008, 82p.
- Goldemberg J, Environmental and ecological dimensions of biofuels. In: Proceedings of the conference on the ecological dimensions of biofuels: Washington, 2008, 65p.
- Plunkett J. W.: Plunkett's automobile industry Almanac 2008: automobile, truck and specialty vehicle industry market research, statistics, trends & leading companies. Plunkett Research Ltd: Houston, Texas, 2009, 49p.
- W.B.C.S.D. (World Business Council for Sustainable Development) Mobility 2030: meeting the challenges to sustainability. The sustainable mobility project, 2009, 87p.
- Meher LC, Sagar DV, Naik SN, Technical aspects of biodiesel production by transesterification-a review. *Renew Sustain Energy Rev.* 10, 2006, 248-68.
- Benoist A, Eléments d'adaptation de la méthodologie d'analyse de cycle de vie aux carburants végétaux : cas de la première génération. Paris, France, 2009, 226p.
- Kassim-Housseny C, Vinification continue avec levures immobilisées: Analyse du système et conception du réacteur industriel. Thèse de Doctorat, Institut National Polytechnique de Toulouse. 2012, 232p.

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