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Physicochemical, Biochemical and Antioxidant Potential Characterisation of Cashew Apple (*Anacardium occidentale* L.) from the Agro-Ecological Zone of Casamance (Senegal)

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Abstract

In Africa, the number of undernourished people is increasing at an alarming rate. However, fruits play an important role in humans, especially as a source of vitamins and minerals. In Senegal, there is research on the nut, but no attention given to the cashew apple. The present study contributes to the evaluation of the physicochemical and biochemical properties of cashew apple juice from the eco-geographical area of Casamance, in southern Senegal. The plant material consists of cashew apples collected in June 2021 from 120 cashew trees. Three batches were constituted for this purpose, taking into account the colour of the apples (red, yellow, and orange). AFNOR standardised methods were used for the physicochemical and biochemical characterisation of cashew apple juice. The dry extract, dry matter, and ash content of the red, yellow, and orange varieties ranged from 14 to 14.70 ˚Brix; 12.96% to 14.17%, and 0.24 to 0.35 g/100g respectively. The multivariate analysis of variance by permutation allowed us to identify two groups of cashew apples. The first group, consisting of orange cashew apples, had the best nutritional quality and was very rich in total minerals (0.35 g/100g) and reducing sugars (18.69 mg/100g). The second group, made up of red and yellow apples, is particularly rich in protein (0.52 g/100ml) and antioxidants (43.28% in IP). Antioxidant power is positively correlated with total phenolic content (r = 0.99). Cashew co-products have a high nutritional value and a considerable economic issue.

Keywords

Anacardium occidentale L., Apple Juice, Biochemistry, Antioxidant, Senegal

1. Introduction

The cashew tree (*Anacardium occidentale* L.) is a tree of the Anacardiaceae family whose exploitation is focused on its nut.

Cashew nuts occupy a prominent place in the world market, particularly as a major source of foreign exchange for many producing countries. Global demand for cashew nuts is growing rapidly.

In Africa, the sector is at the heart of public policies in all nut-producing countries such as Ivory Coast, Guinea, Guinea Bissau, Burkina Faso, Nigeria, Tanzania, Mozambique, Benin, Kenya, Senegal, and Gambia [1]. In Senegal, the cashew nut sector plays a very important economic role in the two major cashew nut agro-ecological poles of the natural region of Casamance and Fatick in terms of income generation and job creation, particularly for rural women [2]. In Casamance, particularly in Ziguinchor and Sédhiou, cashew nuts are of excellent quality, with *KOR* (*Kernel Output Ratio*) values close to WAEMU standards (> or = 50 lbs) [1].

The average annual national production is estimated at 28,900 tonnes in 2018 [3], 97% of which is destined for export [4]. The economic dimension of cashew was introduced into environmental management from the 1980s onwards in order to better take into account the concerns of the population and take full advantage of the opportunities offered by the sector. This marked the beginning of the emergence of major forestry projects, notably the Senegalese-German Cashew Project (PASA) and the Cashew Nut Shelling Company of Senegal (SODENAS). During this same period, nut processing took off, as producers began to see other possibilities for making their crops profitable. Another link in the value chain was added, namely the processor. Initially, small-scale processing units were created. The work is laborious and the finished product is not very standardized in relation to international quality requirements.

From the 2000s onwards, the processing technique was gradually modernised with the acquisition of imported equipment allowing for a denser production of finished products.

The products of cashew nut processing are roasted almonds. Despite the intervention of several projects or programs to improve the productivity of cashew plantations, the cashew sector still suffers from numerous difficulties due to low yields, poor conservation of the almonds, and marketing difficulties. It seems important to valorise the cashew apple, a by-product of the nut's exploitation, to propel the cashew value chain and thus raise the standard of living of the poor.

Apart from cashew nuts, apples are not very highly valued, except in India and Brazil where they are used for the production of fruit juice [5] or liqueur [6]. In

Senegal, cashew apples were abandoned and rot at the expense of the nuts, especially because of their astringent taste [7] [8]. Currently, they are being used timidly for juice in Casamance, the area where they are most commonly grown in Senegal. Several studies have been carried out on the evaluation of the resource, the morphological and phenotypic characterisation of cashew trees [9], which describes the red, yellow, and orange apple varieties. Some studies have addressed production potential, extension techniques, marketing, processing [10], production [11] [12] [13] [14] [15], ecological, environmental and socio-economic impact of cashew [16], and assessment of nutrient content of raw nuts [17]. However, studies on the evaluation of cashew apple characteristics according to the top sequence of the major agro-ecological production zones of Casamance are inexistent to our knowledge. The present study focuses on the evaluation of the physicochemical and biochemical characteristics, the antioxidant power, and the energy value of the juice of cashew apple varieties. This work will promote the development of the cashew industry through the diversification of cashew apple products.

2. Material and Methods

2.1. Plant Material

Cashew apples were collected in June 2021 in Casamance, south of Senegal, from one hundred and twenty (120) cashew trees selected among the 411 characterized. From each tree and following the four cardinal points, two (2) cashew apple samples were collected in the eastern and northern orientations. The cashew apples from each region were divided according to the colour of the peel into three batches (red, yellow, and orange). These samples were then separated from their nuts. They were soaked in tap water, chilled in coolers, and transported to the Laboratory (LE3PI) of Polytechnic Superior School (ESP) in Dakar. The hypertrophied peduncle of the cashew nut was drained in the laboratory using a sieve fitted with a soft water-sucking cloth at the bottom, sliced, and ground using a blender to ensure a rapid extraction rate. The raw juice extracted from each batch was transferred to 100 ml bottles and stored in a freezer at −20˚C for the various analyses. Extracts (cashew juice) of the same colour from the different regions (Ziguinchor, Sédhiou, and Kolda) were then mixed to form the provenances (red, yellow, and orange) of Casamance (**Figure 1**).

2.2. Physicochemical and Biochemical Analyzes

Titratable acidity, pH, soluble solids content, reducing and total sugars, proteins, lipids, ash content, and energetic value were evaluated according to standard AFNOR methods [18].

Total phenolic content (TPC) was the Folin-Ciocalteu method as described elsewhere slightly modified [19]. TPC was determined as gallic acid equivalents (GAE) and values were expressed as mg GAE/g dry matter (DM) of extract. The flavonoid content, expressed as milligram catechin equivalent (mg CE) per gram of

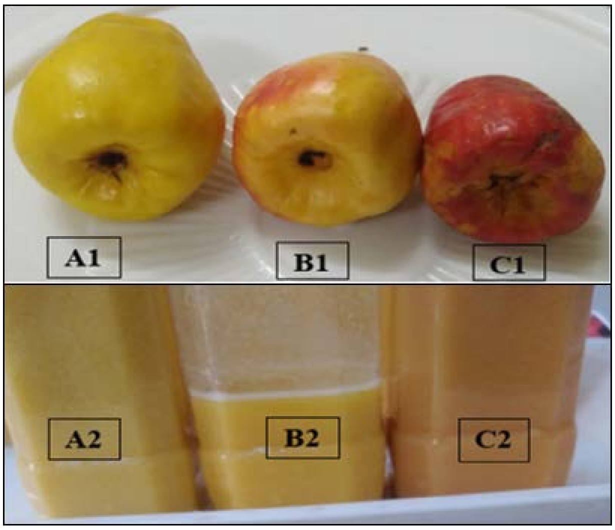

Figure 1. Yellow cashew (A1); yellow apple juice (A2); Orange cashew (B1); orange apple juice (B2); Red cashew (C1); red apple juice (C2).

dry matter, was determined using the colorimetric method described by Kim [20]. Tannins were determined by the colorimetric method of Folin Denis. The result is expressed as the milligram equivalent of gallic acid (mg GAE) per gram of dry matter [21]. The antioxidant activity was evaluated according to the percentage inhibition of honey-based extracts on the DPPH radical (2, 2-diphenyl-1-picrylhydrazyl, Sigma, chemical company, USA) by making some modifications to the method [22]. The determination of minerals was carried out by atomic absorption spectrophotometer (SAA NOVAA-350, ZEENIT 700P). The results are expressed in milligrams per gram of dry matter.

2.3. Statistical Analysis

The analytical results obtained from three independent trials were presented as mean ± standard deviation. They were subjected to multivariate analysis of variance by permutation (PERMANOVA) with one factor using the vegan package of STATISTICS R software version 4.1.1 at the 5% significance level. The non-parametric statistical method (Wilcoxon test) was used for significance testing. The ascending hierarchical classification based on physicochemical and biochemical characteristics was carried out according to the Euclidean distance dissimilarity of the Bray method [23].

3. Results and Discussion

3.1. Physicochemical, Biochemical Characterisation, and Antioxidant Activity

The physicochemical, biochemical, and antioxidant power results of raw juices from different cashew apple varieties are presented in **Table 1**. The analysis of the table shows that the juice from the red and yellow apple varieties have the same density, whether (1.03), each. These results corroborate those of Gbohaïda

Table 1. Physicochemical, biochemical characteristics and antioxidant power of the juice of three varieties of *Anacardium occidentale*.

Parameters	CAR	CAY	CAO
Density	1.03 [a]	1.03 [a]	1.03 [a]
pH value	4.62 ± 0.00 [a]	4.61 ± 0.00 [a]	4.52 ± 0.02 [b]
Dry matter (%)	14.17 ± 0.02 [a]	12.84 ± 0.02 [b]	12.96 ± 0.02 [c]
dry extract (˚Brix)	14.70 [a] ± 0.10	14.27 ± 0.25 [b]	14 ± 0.2 [c]
Ashes (%)	0.27 ± 0.02 [a]	0.24 ± 0.01 [b]	0.35 ± 0.01 [c]
Protein (g/100g)	0.49 ± 0.01 [a]	0.56 ± 0.01 [b]	0.42 ± 0.02 [c]
Lipids (g/100g)	1.31 ± 0.01 [a]	1.49 ± 0.01 [b]	1.85 ± 0.01 [c]
Reducing sugars (g/100g)	17.64 ± 0.03 [a]	20.35 ± 0.02 [b]	18.69 ± 0.02 [c]
Vitamin C (mg/100ml)	290 ± 0.02 [a]	270 ± 0.02 [b]	300 ± 0.01 [c]
Energy value (Kcal/100g)	31.33 ± 0.09 [a]	28.01 ± 0.01 [b]	29.66 ± 0.01 [c]
Polyphenols (mg EAG/g MS)	0.02 ± 0.002 [a]	0.03 ± 0.003 [b]	0.01 ± 0.002 [c]
Antioxidant activity in IP (%)	38.37 ± 1.12 [a]	48.18 ± 2.55 [b]	20.02 ± 0.06 [c]

On the same line, the means bearing the same letter are not significantly different at the 5% level. CAR = Cashew Apple Red; CAY = Cashew Apple Yellow; CAO = Cashew Apple Orange.

et al. [24], according to whom the density of the juice of red and yellow cashew apples in Benin varies from 1.03 to 1.05 and 1.03 to 1.04 respectively.

The pH of the juice of the red (4.62) and yellow (4.61) varieties is almost similar and is higher than the orange apples (4.52). The acidity of the juice of hypertrophied peduncle of the cashew nut from Casamance is between 4.52 and 4.62. Several authors [24] [25] [26] [27] have shown that the pH of cashew apple juice from Tanzania, Benin and Ivory Coast ranges from 3.9 to 4.3; 3.37 to 4.52, and 4.37 to 4.5 respectively. Cashew apples from Casamance are less acid than those from Tanzania, Benin, and Ivory Coast. The differences between countries in the acidity of cashew apple juice are thought to be related to the climates and soil types of each country.

The dry matter content of the juice of red cashew apples is higher (14.17%) than orange (12.96%) and yellow (12.84%). The refractometric dry extract composition of the red apple varieties (14.70 ˚Brix) is higher than the yellow (14.27 ˚Brix) and orange (14 ˚Brix) varieties. The ash content of the orange varieties (0.35%) is higher, followed by the yellow (0.24%) and red (0.27%) varieties.

The refractometric dry extract, dry matter, and ash content of the red, yellow, and orange apple varieties ranged from 14 to 14.70 ˚Brix; 12.96% to 14.17%, and 0.24 to 0.35 g/100g respectively and were higher in Casamance cashew apples compared to those obtained in Benin (8.2 to 10.2 ˚Brix; 7.20% to 8.43% and 0.15% to 0.23%) [26]. Several factors, including variety, agroecological zone, climate, cultivation practices, level of maturity of the fruit at harvest [28], storage conditions of the fruit [29] [30], and even the colour and shape of cashew apples affect their physicochemical composition [27].

The protein content is higher in the juice of yellow cashew apples (0.56 g/100g) than in red (0.49 g/100g) and orange (0.42 g/100g). The protein composition of Casamance cashew apple juice varies between 0.42 and 0.56 g/100g and is richer in protein than hypertrophied peduncle of the cashew nut from Ivory Coast (0.51 to 0.53 g/100g) [27] and India (0.2 g/100g) [31].

When examining lipid compounds, orange cashew apple juice (1.85 g/100g) is more abundant, followed by yellow (1.49 g/100g) and red (0.31 g/100g) respectively. The crude lipid composition of cashew apple juice, the false fruit of the cashew tree, is much lower than the real fruit, the almond (46.1 g/100g) [32].

Reducing sugars are much more present in the juice of yellow cashew apples (20.35 g/100g) than in orange (18.69 g/100g) and red (17.64 g/100g). For reducing sugars, the content is between 17.64 and 20.35 g/100g. The juice of the hypertrophied peduncle of the cashew nut from Casamance is far richer in reducing sugars than that from India (1.76 to 13.3 g/100g) [33].

Regarding vitamin C, the juice of orange cashew apples is richer (300 mg/100ml), followed by red (290 mg/100ml) and yellow (270 mg/100ml). The vitamin C content of Casamance cashew apples varies from 270 mg/100ml to 300 mg/100ml. These authors in their studies on cashew apples [34] [35] showed a vitamin C content of 219 mg/100ml. The results obtained in the present study are comparable to those of Ouattara *et al.* [36] and Damasceno *et al.*, quoted by Runjala and Kella [31], who found the vitamin C content of raw cashew juice to be 317.5 mg/100ml and 126 - 372 mg/100ml respectively.

From **Table 1**, it can be seen that the energy value varied from 28.01 to 31.33 Kcal/100g. This result is much lower than that obtained by Runjala and Kella [31] in India (51 Kcal/100g).

The total phenolic content of the juice of yellow cashew apples (0.03 mg GAE/g DM) is higher than red (0.02 mg GAE/g DM) and orange (0.01 mg GAE/g DM). However, the total phenolic composition of Casamance cashew juice is lower than that obtained in Benin by Ouattara *et al.* [36]. Michodjehoun-Mestres [37] showed that 98% of these phenols are in condensed form (tannins), compounds responsible for the astringency of the fruit.

The juice of yellow cashew apples has a higher inhibition percentage (48.18%) than red (38.37%) and orange (20.02%). The antioxidant activity of the juice of Casamance cashew apple varieties is far lower than that of different samples of processed and dried cashew apples from Benin ranging from 74.46% to 82.89% [38]. The cashew apple juice in the present study has a more pronounced antioxidant activity than the raw (41%) and roasted (37%) cashew nut [39]. However, the antioxidant power of cashew juice is almost similar to that of apple (53%) and is much lower than cashew fiber (94%) and cashew nut shell liquid (100%) (CNSL) [39].

3.2. Minerals

The raw juices obtained after the extraction of cashew apples were quantified for minerals, the results of which are given in **Table 2**. The result shows that cashew apple juice contains significant quantities of minerals, particularly potassium, phosphorus, magnesium, and calcium. These values are significantly different from one juice to another and according to the cashew apple varieties studied. Thus, the best mineral content is obtained with the orange cashew apple with values of 1492 ± 11 mg/100g in phosphorus, 207.67 ± 3.45 mg/100g in potassium, 163 ± 2.70 mg/100g in magnesium, and 47.10 ± 0.60 mg/100g in calcium. This was followed by the yellow and red apple varieties with values of 1138.67 ± 15.5 and 1060.67 ± 15.5 mg/100g phosphorus, 162.37 ± 1.25 and 144.1 ± 1.6 mg/100g potassium, 123.05 ± 1.55 and 110.20 ± 0.9 mg/100g magnesium, 42.05 ± 0.75 and 34.8 ± 1.4 mg/100g calcium respectively.

Phosphorus concentration in the juice of red, yellow, and orange varieties varies from 1060.67 ± 15.5 to 1492 ± 11 mg/100g. These results are far superior to those of the synthetic study by Lautié *et al.* [32] on cashew tree products: characteristics, valuation routes, and markets (10 to 30 mg/100g in phosphorus). However, they have low levels of trace elements. The juice of orange cashew apples is richer in sodium (25.91 ± 0.5 mg/100g) than red (23.07 ± 0.82 mg/100g) and yellow (21.31 ± 0.02 mg/100g) apples. The iron composition of the orange apple juice (10.17 ± 0.5 mg/100g) is higher than that of the yellow (6.78 ± 0.14 mg/100g) and red (4.75 ± 0.43 mg/100g) apples. The copper content is higher in the juice of orange apples (2.14 ± 0.08 mg/100g) followed by yellow (1.45 ± 0.01 mg/100g) and red (1.14 ± 0.07 mg/100g) apples. The trace element zinc is more present in orange cashew apple juice (2.2 ± 0.03 mg/100g) than in red (1.08 ± 0.04 mg/100g) and yellow (1.45 ± 0.01 mg/100g). The contents of sodium, iron, and zinc confirm the results of Assuncao and Mercadante; Michodjehoun-Mestres and Adou *et al.* [37] [40] [41].

The values obtained in the present study for calcium (34.8 ± 1.4 to 47 ± 0.6 mg/100g) and iron (4.75 to 10.17 ± 0.5 mg/100g) are far above the recommended daily allowances for these two minerals, which are 0.68 mg and 0.015 mg respectively [42].

Table 2. Minerals in juices from extract from *Anacardium occidenale* apple varieties.

Minerals (mg/100g)	CAR	CAY	CAO
P	1060.67 ± 15.5 [a]	1138.67 ± 15.5 [b]	1492 ± 11 [c]
K	144.1 ± 1.6 [a]	162.37 ± 1.25 [b]	207.67 ± 3.45 [c]
Mg	110.2 ± 0.9 [a]	123.05 ± 1.55 [b]	163 ± 2.7 [c]
Na	23.07 ± 0.82 [a]	21.31 ± 0.02 [b]	25.91 ± 0.5 [c]
Ca	34.8 ± 1.4 [a]	42.05 ± 0.75 [b]	47.10 ± 0.6 [c]
Fe	4.75 ± 0.43 [a]	6.78 ± 0.14 [b]	10.17 ± 0.5 [c]
Zn	1.08 ± 0.04 [a]	0.85 ± 0.03 [b]	2.2 ± 0.03 [c]
Cu	1.14 ± 0.07 [a]	1.45 ± 0.01 [b]	2.14 ± 0.08 [c]

On the same line, the means bearing the same letter are not significantly different at the 5% level.

3.3. Multivariate Analysis and Correlation Test

The linear correlation tests between the different parameters measured show that the correlations are significant between the physicochemical and biochemical parameters. Indeed, the multivariate analysis of variance by permutation of the different measured parameters allowed us to obtain the results represented in **Figure 2**. Thus, the dimensions (Dim1 and Dim2) obtained, which represent 100% of the information, were very sufficient to ensure a precise interpretation of the results in **Figure 2**. Dimension 1 alone accounts for 100% of the information. The correlation circle shows that all the physicochemical and biochemical parameters, the antioxidant power, and the energy value are very well represented on axis I and are either positively or negatively correlated on this axis. Thus, by comparing all the parameters evaluated on the juice of red, yellow, and orange cashew apple varieties, it is easy to note that there are two groups of cashew apples. The first group includes only orange cashew apples. The second group consists of red and yellow varieties.

Based on the permutation multivariate analysis of variance (PERMANOVA), a further and more in-depth analysis allowed the development of a dendrogram grouping all parameters (**Figure 3**). The analysis of the results on the dispersion of the variables allows the identification of the parameters that are most correlated to the two cashew apple groups. The group (red and yellow apples) is more correlated with vitamin C (Vc), protein (Pr), zinc (Zn), glucose (Glu), and cashew juice density (d). However, the orange cashew group is more correlated with iron (Fe), reducing sugar (S.r), sodium (Na), calcium (Ca), magnesium (Mg), phosphorus (P), dry matter (M_S), and water (H_2O) content. In addition, antioxidant power (IP) and potassium (K) content are also strongly correlated with orange cashews.

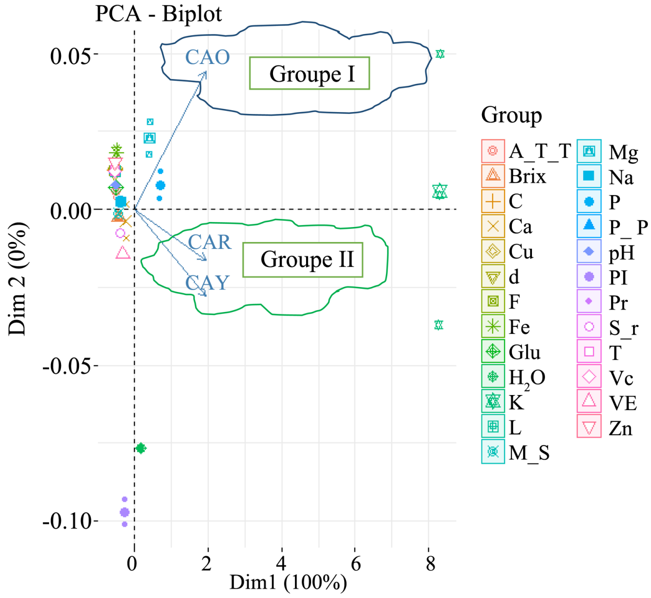

Figure 2. Correlation between physicochemical and biochemical parameters and cashew groups.

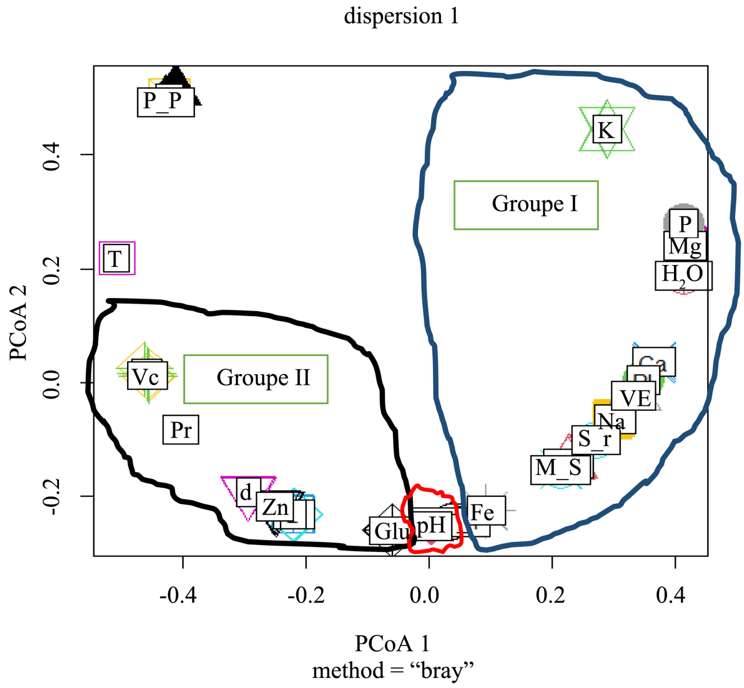

Figure 3. Distribution of physicochemical, biochemical, antioxidant and energy parameters of cashew apple juice on the factorial plane.

The two groups of cashew apples from Casamance have a similarity in acidity. Cashew apples have a significant caloric intake, so they can contribute to nutritional balance. Indeed, they are an excellent source of protein, vitamins, and minerals that can contribute to the health benefits of the population. Vitamin C has reducing properties which are the basis of its biological activity. Ascorbic acid is known as an antioxidant (highly reducing agent) and has a role as a cofactor in oxygen catalysed reactions. It is known to inhibit the synthesis of nitrosamines (carcinogenic compounds) formed in our digestive tract from nitrites and amino compounds. The antioxidant potential of cashew apple juice is of particular importance to human health.

3.4. Correlation between Physicochemical, Biochemical Variables, Antioxidant Activities and Energy Values

The analysis of **Figure 4** shows a strong correlation between physicochemical, biochemical, antioxidant power, and energy value parameters. In contrast, relatively moderate and weak correlations were observed between the above parameters. The analysis in **Figure 4** clearly shows that there is a highly significant correlation between antioxidant power (IP), total phenolic content (P_P), and vitamin C (Vc) content of cashew apple juice. Antioxidant power was positively correlated with total phenolic content (r = 0.99). However, several fruit studies cited by Soro [43] have shown that antioxidant activity is not correlated with total phenolic content and/or vitamin C. **Figure 5** also shows a very strong correlation between the raw juices of cashew apple varieties (red, yellow, and orange) from the Casamance agroecological zone.

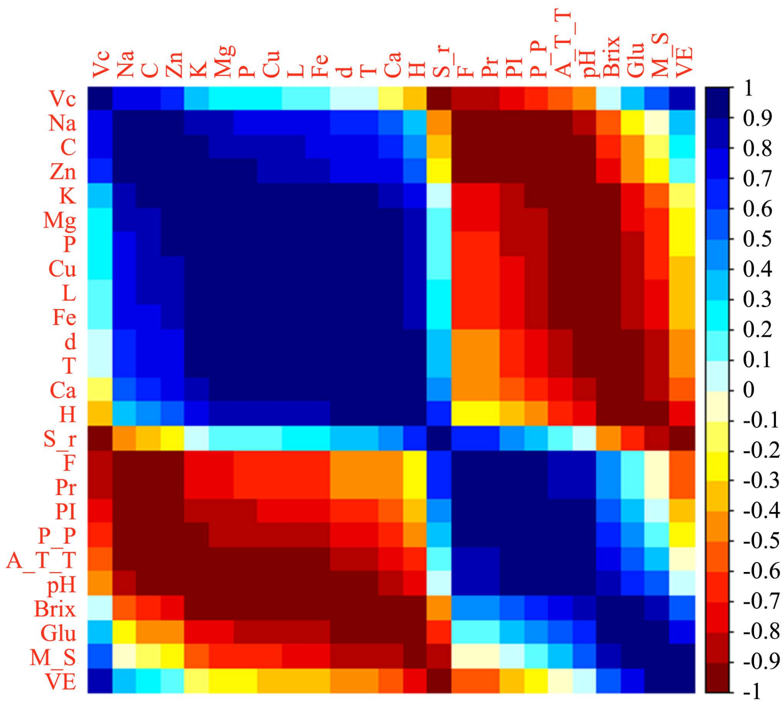

Figure 4. Correlation between physicochemical and biochemical parameters, antioxidant power and energy value of cashew apple juice.

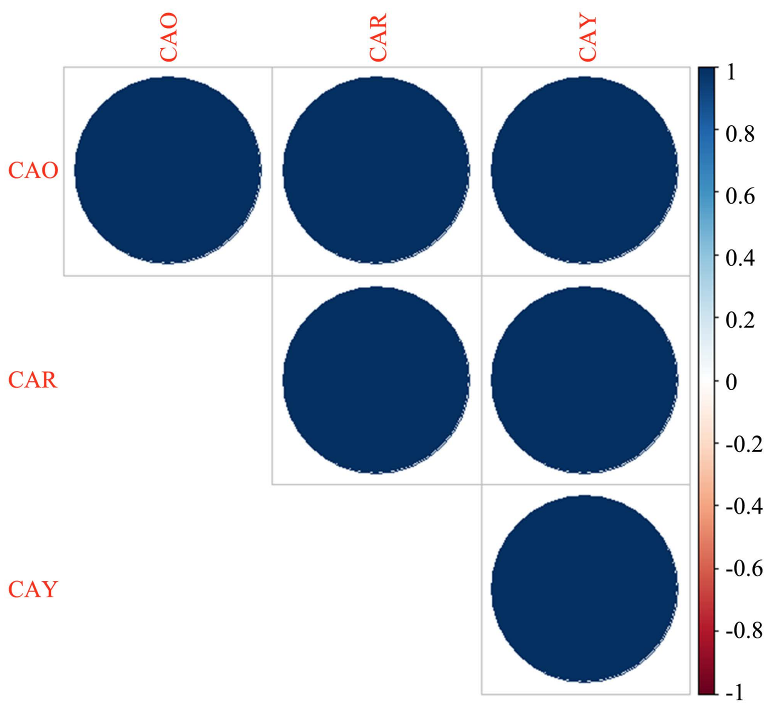

Figure 5. Correlation between cashew apple juice.

4. Conclusion

The cashew apple is a pseudo fruit with high nutritional value and technological interest. The pseudo-fruits of the varieties studied have significant quantities of macromolecules (proteins, sugars, lipids) and minerals. The orange cashew apple has the best nutritional quality and is strongly correlated with mineral elements. The orange hypertrophied peduncle of the cashew nut is a privileged resource for the production of jam, preserves in syrup, fruit juice, soft drinks, ice cream, candy, chutney, pickles, and other products. Thus, cashew pseudo fruits can be a good alternative to daily vitamin C supplementation for children and adults and can thus contribute to achieving food security in Casamance. It seems necessary to continue investigations in direction of valorization of this cashew nut co-product in order to contribute to boosting the cashew industry in Senegal. The valorisation of the hypertrophied peduncle of the cashew nut will allow the improvement of the diet of vulnerable groups and the creation of new economic activities that generate employment, and consequently, fight against unemployment in Senegal.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] African Cashew Alliance (ACA) (2014) Promouvoir les noix de cajou d'Afrique dans le monde entier. Bulletin mai 2014 No. 4, African Cashew Alliance, Accra, 15p.

[2] USAID (United States Agency for International Development) (2006) La chaine de valeurs anacarde au Sénégal, analyse et cadre stratégique d'initiatives pour la croissance de la filière. United States Agency for International Development, Washington DC, 78 p.

[3] Hien, S. (2019) Aperçu de l'évolution de la production d'anacarde et évolution du marché de noix brutes de cajou dans la sous-région et perspectives pour 2019/2020. *Forum sur le cajou sahélien*. Du 05 au 07 août 2019 à Bamako (Mali), 16 p.

[4] Programme d'Appui au Développement économique de la Casamance (PADEC) (2016) La mangue en zone sud au Sénégal: Production et commercialisation. Programme d'Appui au Développement économique de la Casamance, Sénégal, 63 p.

[5] Cavalcante, A.A.M., Rubensam, G., Picada, J.N., Silva, E.G., Moreira, J.C.F. and Henriques J.A.P. (2003) Mutagenicity, Antioxidant Potential and Antimutagenic Activity against Hydrogen Peroxide of Cashew (*Anacardium occidentale*) Apple Juice and Cajuina. *Environmental and Molecular Mutagenesis*, **41**, 360-369. https://doi.org/10.1002/em.10158

[6] Nanjundaswamy, A.M., Radhakrishniah, S. and Patwardhan, M.V. (2001) Utilization of Cashew Apples for the Development of Processed Products. Central Food

Technological Research Institute Mysore-570013, Karnataka, 152-159.

[7] Rocha, M.V.P., Oliveira, A.H.S., Souza, M.C.M. and Goncalaves, L.R.B. (2006) Natural Cashew Apple Juice as Fermentation Medium for Biosurfactant Production by *Acinetobacter calcoaceticus*. *World Journal of Microbiology and Biotechnology*, **22**, 1295-1299. https://doi.org/10.1007/s11274-006-9175-8

[8] Giro, M.E.A., Martins, J.J.L., Rocha, M.V.P., Melo, V.M.M. and Goncalves, L.R.B. (2009) Clarified Cashew Apple Juice as Alternative Raw Material for Biosurfactant Production by *Bacillus subtilis* in a Batch Bioreactor. *Biotechnology Journal*, **4**, 738-747. https://doi.org/10.1002/biot.200800296

[9] Ndiaye, L., Charahabil, M.M., Ngom, D. and Diatta, M. (2019) Caractérisation morphologique et phénotypique des pieds d'anacardiers (*Anacardium occidentale* L.) dans le département de Goudomp (Sénégal) Morphological and Phenotypic Characteriza. *European Scientific Journal*, **15**, 364-395 https://doi.org/10.19044/esj.2019.v15n36p364

[10] Khumbanyiwa, A.G., Dosso, H. and Kasalu-Coffin, E. (2000) Rapport d'évaluation. Projet de développement de la production d'anacarde. *GHA/PAAA*, Ghana, 38 p.

[11] Goudiaby, R. (2014) Réponse de quatre variétés de *Anacardium occidentale* L. aux techniques de greffage en pépinière. Mémoire d'ingénieur, ISFAR/Bambey, 50p.

[12] Sokemawu, K. (2015) Développement de la filière anacarde dans la préfecture de Tchamba au Togo: Vers une nouvelle stratégie paysanne de diversification des revenus agricoles. *Revue de Géographie de l'Université d'Ouagadougou*, **2**, 42 p.

[13] Ndiaye, S. (2017) Caractérisation des Plantations à base d'anacardier (*Anacardium occidentale* L.) dans le Balantacounda: Cas des communes de Kaour, Goudomp et Djibanar (Casamance/Sénégal). *European Scientific Journal*, **13**, 242-257. https://doi.org/10.19044/esj.2017.v13n12p242

[14] Ba, M. (2018) Détermination de la longueur optimale de la couronne de *Anacardium occidentale* L. et son influence sur les rendements de Arachis hypogaea L. dans la commune de Toubacouta. Mémoire d'ingénieur, ISFAR, Université de Thiès, Thiès, 45 p.

[15] Samb, C.O., Faye, E., Dieng, M., Sanogo, D., Samba, S.A.N. and Koita. B. (2018) Dynamique spatiotemporelle des plantations d'anacardier (*Anacardium occidentale* L.) Dans deux zones agro-écologiques du Sénégal. *Afrique SCIENCE*, **14**, 365-377.

[16] Demba, M. (2012) Importance des impacts écologiques, environnementaux et socioéconomiques de l'anacardier sur la vie des planteurs-producteurs de la région de Fatick: Cas de la commune de Toubacouta. Mémoire d'ingénieur, 12 p.

[17] Samb, C.O., Biteye, M., Faye, E., Diarra, R., Diaw N., Thiam, M. and Fall, B. (2021) Caractérisation agro morphologique, chimique et biochimique des noix brutes de trois provenances d'anacardiers (*Anacardium occidentale* L.) au sud du Sénégal. *Agronomie Africaine*, **33**, 177-189.

[18] AFNOR (Association Française de Normalisation) (1982) Recueil des normes françaises des produits dérivés des fruits et légumes. Jus de fruits. 1ére édition, Association Française de Normalisation, Paris, 327p.

[19] Georgé, S., Brat, P., Alter, P. and Amiot, M.J. (2005) Rapid Determination of Polyphenols and Vitamin C in Plant-Derived Products. *Journal of Agricultural and Food Chemistry*, **53**, 1370-1373. https://doi.org/10.1021/jf048396b

[20] Kim, D.-O., Chun, O.K., Kim, Y.J., Mon, H.-Y. and Lee, C.Y. (2003) Quantification of Polyphenolics and Their Antioxidant Capacity in Fresh Plums. *Journal of Agricultural and Food Chemistry*, **51**, 6509-6515. https://doi.org/10.1021/jf0343074

[21] Joslyn, M. (1970) Methods in Food Analysis. 2nd Edition, Academic Press, New York, 110 p.

[22] De Oliveira, R.T., Junior, J.M., Nascimento, D.V.D. and Stefani, R. (2014) Phytochemical Screening and Comparison of DPPH Radical Scavenging from Different Samples of Coffee and Yerba Mate Beverages. *International Journal of Scientific and Research Publications*, **4**, 1-7.

[23] Anderson, M.J. (2017) Permutational Multivariate Analysis of Variance (PERMANOVA). In: Balakrishnan, N., Colton, T., Everitt, B., Piegorsch, W., Ruggeri, F. and Teugels, J.L., Eds., *Wiley StatsRef: Statistics Reference Online*, John Wiley & Sons, Ltd., Hoboken, NJ, 1-15. https://doi.org/10.1002/9781118445112.stat07841

[24] Gbohaïda, V., Mossi, I., Adjou, E.S., Agbangnan, P., Boniface, B., Yehouenou, B.B. and Sohounhloué, D.C.K. (2015) Morphological and Physicochemical Characterizations of Cashew Apples from Benin for Their Use as Raw Material in Bioethanol Production. *International Journal of Pharmaceutical Sciences Review and Research*, **35**, 7-11.

[25] Odame, O., Gonu, H. and Quansah, L. (2020) Sugar Content, Ph, and Weight of Four Germplasms of Cashew Apple (*Anacardium occidentale* linn.) Fruits Grown under Two Agro-Ecological Zones in Ghana. *Ghana Journal of Science*, **61**, 73-81. https://doi.org/10.4314/gjs.v61i2.7

[26] Anonyme (2017) Caractérisation physico-chimique et morphologique de trois morphotypes de pommes d'anacarde (*Anacardium occidentale* L.) pour leur utilisation dans la production d'alcool alimentaire et de boissons spiritueuses. *Journal of Applied Biosciences*, **116**, 11546-11556.

[27] Adou, M., Tetchi, F.A., Gbané, M., Kouassi, K.N. and Amani, N.G. (2012) Physico-Chemical Characterization of Cashew Apple Juice (*Anacardium occidentale*) from Yamoussoukro, côte d'ivoire. *Innovative Romanian Food Biotecthnology*, **11**, 32-43.

[28] Drake, S.R. and Eisele, T.A. (1994) Influence of Harvest Date and Controlled Atmosphere Storage Delay on the Color and Quality of 'Delicious' Apples Stored in a Purge-Type Controlled-Atmosphere Environment. *HortTechnology*, **4**, 260-263. https://doi.org/10.21273/HORTTECH.4.3.260

[29] Drake, S.R., Elfving, D.C. and Eisele, T.A. (2002) Harvest Maturity and Storage affect Quality of 'Cripps Pink' (Pink Lady) Apples. *HortTechnology*, **12**, 388-391. https://doi.org/10.21273/HORTTECH.12.3.388

[30] Drake, S.R. and Eisele, T.A. (1999) Carbohydrate and Acid Contents of Gala Apples and Bartlett Pears from Regular and Controlled Atmosphere Storage. *Journal of Agricultural and Food Chemistry*, **47**, 3181-3184. https://doi.org/10.1021/jf981228x

[31] Runjala, S. and Kella, L. (2017) Cashew Apple (*Anacardium occidentale* L.) Therapeutic Benefits, Processing and Product Development: An Overview. *The Pharma Innovation Journal*, **6**, 260-264.

[32] Lautié, E., Dornier, M., De Souza Filho, M. and Reynes M. (2001) Les produits de l'anacardier: Caractéristiques, voies de valorization et marches. *Fruits*, **56**, 235-248.

[33] Sivagurunathan, P., Sivasankari, S. and Muthukkaruppan, S.M. (2010) Characterisation of Cashew Apple (*Anacardium occidentale* L.) fruits collected from Ariyalur District. *Journal of Biosciences Research*, **1**, 101-107.

[34] Carvalho, J.M., Maia, G.A., Figueiredo, R.W., Brito, E.S. and Rodrigues, S. (2007) Storage Stability of a Stimulant Coconut-Cashew Apple Juice Beverage. *Journal of Food Processing and Preservation*, **31**, 178-189. https://doi.org/10.1111/j.1745-4549.2007.00121.x

[35] Honorato, T.L. and Rodrigues, S. (2010) Dextransucrase Stability in Cashew Apple Juice. *Food and Bioprocess Technology*, **3**, Article No. 105. https://doi.org/10.1007/s11947-008-0053-2

[36] Ouattara, G.S., Soro, D., Chatigre, K.O. and Koffi, K. (2016) Caractérisation physico-chimique et sensorielle de diverses formulations de jus à base de pomme de cajou et d'ananas. *International Journal of Biological and Chemical Sciences*, **10**, 2447-2460. https://doi.org/10.4314/ijbcs.v10i6.4

[37] Michodjehoun-Mestres, L. (2009) Etude des composés phenoliques de la pomme cajou (*Anacardium occidentale* L.). Biochimie, chimie et technologie alimentaire. Thèse de Doctorat, Université Montpellier II, Montpellier, 97 p.

[38] Lagnika, C., Amoussa, A.M.O., Sanni, A. and Lagnika, L. (2019) Effect of Blanching and Ultrasound on Drying Time, Physicochemical and Bioactive Compounds of Dried Cashew Apple. *American Journal of Food Science and Technology*, **7**, 227-233.

[39] Trevisan, M.T.S., Pfundstein, B., Haubner, R., Wurtele, G., Spiegelhalder, B. and Bartsch, H. (2005) Characterization of Alkyl Phenols in Cashew (*Anacardium occidentale*) Products and Assay of Their Antioxidant Capacity. *Food and Chemical Toxicology*, **44**, 188-197. https://doi.org/10.1016/j.fct.2005.06.012

[40] Assuncao, R.B. and Mercadante, A.Z. (2003) Carotenoids and Ascorbic Acid Composition from Commercial Products of Cashew Apple (*Annacardium occidentale* L.). *Journal of Food Composition*, **16**, 647-657. https://doi.org/10.1016/S0889-1575(03)00098-X

[41] Adou, M., Tetchi, F.A., Gbane, M., Niaba, P.V.K. and Amani, N.G. (2011) Minerals Composition of the Cashew Apple Juice (*Anacardium occidentale* L.) of Yamoussoukro, Cote d'Ivoire. *Pakistan Journal of Nutrition*, **10**, 1109-1114. https://doi.org/10.3923/pjn.2011.1109.1114

[42] United States Department of Agriculture (2002) Nutrition Database for Standard Reference. United States Department of Agriculture, Washington DC.
Wargovich, M.J. (2000) Anticancer Properties of Fruits and Vegetables. *HortScience*, **35**, 573-575. https://doi.org/10.21273/HORTSCI.35.4.573

[43] Soro, D. (2012) 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, Institut des Régions Chaudes (IRC), Montpellier, 156 p.