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Study of Morphological Indicators of Fruits and Physicochemical Indicators of *Passiflora Juice Edulis Flavicarpa* Acclimatized in Congo-Brazzaville

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Abstract

In this study, the correlation between different morphological indicators and physicochemical variables was evaluated. The results relating to the ratios indicate that the density varies from 0.44 to 0.86 g.cm^{-3} with an average value of 0.69 ± 0.10 g.cm^{-3}. These values reflect a very variable density of the fruits studied. The pulp mass to fruit mass ratio varies from 0.21 to 0.67 with an average of 0.45. This shows that the mass of the pulp represents approximately half of the mass of the fruit. The principal component analysis (PCA) revealed that all the variables are positively correlated. The mass of the fruit, mass of the pulp, and volume of the fruit are strongly correlated while the diameter of the fruit is moderately correlated. The representation of the individuals on the F1F2 plane highlights almost the separation into 3 classes the individuals on the left, center, and right of the F2 axis. By applying the PCA correlation circle of the 4 variables, the two axes represent 97.27% or almost all of the inertia. Three classes seem to appear but not distinctly. The representation therefore highlights three classes of *Passiflora fruits edulis flavicarpa*, very close. The pulp presents physicochemical parameters in accordance with the exploited standards. Apart from the pronounced presence of vitamin C, this chemotype highlights phytocompounds such as total polyphenols and flavonoids, with acceptable levels of 106 mg GAE/100 g Ms and 59.70 mg ERU/100 g Ms, respectively. These antioxidants are capable of preventing various pathologies.

Keywords

Morphological indicator; physicochemical variables; fruit; *Passiflora edulis flavicarpa;* phytocompounds

1. Introduction

Managing a value chain in the industrial production of a food product requires mastery of the qualitative aspect of the product but also the quantitative aspect. This involves determining performance indicators, including shape and nutritional value. Morphology is equally important to have the large consumable portion. Fruits rich in micronutrients and bioactive compounds such as polyphenols are essential for health, providing antioxidants that fight chronic diseases. Indeed, according to multiple research studies, fruits contain biomolecules with significant antioxidant capacities [1, 2]. These biomolecules are the basis for the development of food additives, functional foods and nutraceuticals [3]. Passion fruit is a crop appreciated worldwide for its juiciness and nutritional benefits [4, 5]. Passion fruit is consumed when fresh. Its remarkable fragrance makes it an essential element of exotic fruits. Its limited attractiveness and excessive consumption

(due to its numerous particles) hinder its commercial development in costs. On the other hand, it is widely used in the agri-food sector where it is presented in the form of juice. Most of the time, once ripe, this fruit loses its market value while it can be used in food. Starting from the absence of the specific calibration of passion fruits and the scarcity of studies on the physicochemical quality of the juices extracted from this fruit, we were interested in determining morphological indicators of the fruits and the physicochemical variables of *Passiflora juice edulis flavicarpa* acclimatized in Congo-Brazzaville.

2. Plant Material

Passiflora fruits *edulis flavicarpa* (see Figure 1) were collected from several fruit trees from the Cataractes plateau in the Pool department in Loukoko, located in the south of the Republic of Congo. The fruits taken from different plants were grouped into four batches.

Figure 1. *Passiflora fruits edulis flavicarpa*.

3. Study Methods

3.1 Determination of some morphological indicators of fruits

The assessment of the morphology was highlighted through the morphological parameters retained in particular the mass of the fruit, the mass of the pulp, the volume, the density as well as the diameter, for a sampling of 50 fruits of yellow passionflowers. The total mass of the fruit is measured using an analytical balance of precision of 0.01 g. Subsequently, the fruit is opened longitudinally using a stainless-steel knife, and the granulated pulp is removed and then weighed in order to obtain the mass of the fresh pulp. The volume of the fruit is determined using a graduated cylinder. The fruit diameter was measured by placing the caliper around the circumference of the fruit so that it would not fall off, followed by a simple reading.

3.2 Juice extraction

Figure 2. Pulp and juice after extraction.

The juicy pulp collected manually with a metal spoon is placed in a sieve placed on a stainless-steel jar. The juice extracted by kneading with a spatula passes through the sieve serving as a filter. Once filtered, the volume of the juice is measured with a graduated cylinder and then transferred into well-sealed glass bottles and stored at a temperature of +4 °C. For the determination of polyphenols and total flavonoids, the dry extract was obtained by dehydrating a portion of the filtrate obtained during the sieving of the pulp, then kept cool pending analysis.

3.3 Determination of some physicochemical indicators of juices

Different methods were used for the determination of physicochemical indicators. The water content was carried out using the standard [6], Titratable Acidity [7], quantified by the acid-base titration using sodium hydroxide (0.1N) as titrant solution in the presence of phenolphthalein. The amount of vitamin C or ascorbic acid (reducer) present in the juice was determined by performing the oxidation-reduction titration. The titrations of free, total, and combined sulfur dioxide (SO2) were also carried out. The relative density of the juice was measured using a pycnometer and the density was deduced. The refractive index through an Abbe-type refractometer, the pH value is read directly on the scale of a pH-master, the measurement is done at a temperature of 20 ± 2 °C and according to the indications for use of the device. Sugar content by refractometry. The Free glucose and total glucose (acid hydrolysis of sucrose) were measured. Total flavonoids are evaluated by colorimetry, according to the method used by (Ngouollali et al.) with some modifications. In a 10 mL flask are successively introduced 250 µL of the hydro-ethanolic extract of pulp powder, filtered and dehydrated of *Passiflora fruits. edulis flavicarpa* and 1 mL of distilled water. Then, 75 µL of a solution of NaNO2 (5%) are added successively at the initial time (0 minutes), 75 µL of $AlCl_3$ (10%) after 5 minutes and 500 µL of NaOH (1N) at 6 minutes. Finally, 2.5 ml of distilled water are added to the mixture. A calibration curve is developed with standard solutions of catechin prepared at different concentrations. The absorbance of the mixture obtained is directly measured with a UV-visible spectrophotometer at 510 nm and the results are expressed in mg equivalent quercetin in 100 grams of dry matter (EQt/100g Ms). To quantify the polyphenols, 0.1 mL of the extract (2 mg/mL), 0.9 mL of distilled water and 0.9 mL of Folin-Ciocalteu reagent (1N) were mixed in an Eppendorff tube; then immediately after 0.2 mL of a solution of Na2CO3 (20%) is added. The mixture obtained undergoes an incubation period of approximately 40 minutes in a dark medium. The absorbance is then measured with a spectrophotometer at 725 nm against a methanol solution used as a blank. It should be noted that the calibration line was previously carried out before analysis with gallic acid taken under the same conditions as the extracts analyzed. The results obtained are expressed in mg gallic acid equivalent in 100 grams of dry matter (E GA/100g Ms).

3.4 Data processing

Means and standard deviations were used to describe the totality of the data. The arithmetic mean satisfactorily describes the data of this study. The dispersion of a data set can be perceived in different ways, including the amplitude between the minimum and maximum values. However, the standard deviation is the most used parameter. It has the advantage of considering each of the experimental values in relation to the average. For comparison purposes, the standard deviation can be expressed as a percentage, in which case it becomes the coefficient of variation (CV). The coefficient of variation indicates the degree of precision with which treatments are compared. It is an important indicator of the validity of the results. It expresses the ratio between the experimental error and the general mean.

In this work which concerns living material, it will be necessary to consider as:

- homogeneous individuals presenting, for a given variable, a CV < 20%,
- moderately variable for, 20% < CV < 60% and
- very variable for CVs > 60%.

Two multivariate methods were also used: principal component analysis (PCA) was used to reduce data complexity and identify relationships between morphological variables while ascending hierarchical clustering (AHC) grouped fruits based on their similarity.

Principal component analysis (PCA) is a method of processing data contained in a table of type: Individuals (rows) x Quantitative variables (columns). It allows us to reduce a large mass of data into a more reasonable and easily exploitable number, by constructing instead of the initial variables a small number of variables by linear combination of the first ones. These new variables are called principal components. They are supposed, under certain conditions, to summarize as well as possible the initial data. PCA allows to visualize using simple graphic representations (correlation circle) of the link between the variables and the similarity between individuals.

Ascending hierarchical classification (AHC) allows to constitute homogeneous groups of objects (classes) on the basis of their description by a set of variables, or from a matrix describing the similarity or dissimilarity of the objects. It is an interactive classification method, based on a simple principle.

4. Results and Discussion

4.1 Morphological characteristics of *Passiflora fruits edulis flavicarpa*

Morphological characteristics (minimum and maximum) of the 50 *Passiflora fruits edulis flavicarpa* harvested from different plants are presented in Table 1. The parameters used in the assessment of morphology are: fruit mass, pulp mass, fruit volume, and diameter. The mean, standard deviation, and coefficient of variation (CV) are calculated for all 50 fruits studied.

Table 1. Morphological characteristics of the 50 *Passiflora fruits edulis flavicarpa*

	Fruit mass (g)	Pulp mass (g)	Skin mass (g)	Fruit volume (cm^3)	Fruit diameter (cm)
Average	62.5	29.9	32.5	90.0	5.2
Standard deviation	23.6	18.5	8.3	28.7	0.5
RESUME (%)	37.9	61.7	25.4	31.9	10.0

Table 1 presents the values obtained for the five parameters studied. From this table, it appears that the mass of the fruit varies from 28.6 to 126.2 g with an average of 62.5 ± 23.6 g; the volume from 50.0 to 195.0 cm^3 for an average of 90.0 ± 28.7 cm^3; the mass of the pulp varies from 4.9 to 74.6 g, the average being 29.9 ± 18.5 cm; the mass of the skin from 18.9 to 51.6 g and an average of 32.5 ± 8.3 g, this shows a slight superiority of the mass of the skin compared to that of the pulp on average. For the diameter, it varies from 4.2 to 6.3 cm for an average of 5.2 ± 0.5 cm. The value of the diameter varying from 4 to 6.3 cm, coincides with the values obtained by [8] which give *Passiflora edulis flavicarpa* a diameter between 4 and 8 cm with a slight modification. Also, they are close to the values admitted by [9] and recalled by [10].

Considering the variability, the deviations between the minimum and maximum values of the different parameters are very high, indicating a large inter-fruit variability. This variability is reflected by the significant coefficients of variation, the largest being obtained for the fruit mass (37.9%) and the smallest for the fruit diameter (10%).

4.1.1 Usual ratios for the characterization of fruits

The density (Fruit mass/Fruit volume and the ratio between the mass of the fruit and that of the pulp), is also used to characterize the fruits. These ratios were determined for the fruits studied. Table 2 contains the variations, the mean, and the standard deviation of these ratios.

Table 2. Common ratios in the characterization of fruits

Settings quantitative	Average	Standard deviation	RESUME (%)
Density ($g.cm^{-3}$)	0.69	0.10	14.49
Pulp mass / Fruit mass	0.45	0.13	28.88

The results presented in Table 2 indicate a density that varies from 0.44 to 0.86 $g.cm^3$ with an average value of 0.69 ± 0.10 $g.cm^{-3}$. These values reflect a very variable density of the fruits studied. The pulp mass/fruit mass ratio varies from 0.21 to 0.67 with an average of 0.45 which shows that the mass of the pulp represents approximately half of the mass of the fruit.

4.1.2 Classification of the 50 *Passiflora fruits edulis flavicarpa*

Multivariate statistical methods such as principal component analysis (PCA), discriminant factor analysis (DFA), hierarchical ascending clustering (HAC), correspondence factor analysis (CFA), multiple correspondence factor analysis (MCFA), canonical analysis (CA) have been often used for classification.

Species and their fruits [13, 14] for the study of the 50 fruits of Passiflora edulis flavicarpa, ACP, and CAH were used.

4.1.3 Principal component analysis (PCA)

The PCA was performed on all the results on the morphological data of the fruit, namely: the mass of the fruit, the mass of the pulp, the volume of the fruit, and the diameter of the fruit. Table 3 presents the correlation coefficients that link the different variables together. It appears that all the variables are positively correlated. Among these variables, some are strongly correlated (fruit mass and pulp mass and fruit volume), and others moderately correlated (fruit diameter).

Table 3. Correlation Matrix of Variables

Variables	Var1 Fruit mass	Var2 Pulp mass	Var3 Fruit diameter	Var4 Fruit volume
Var1	**1**	0.953	0.859	0.920
Var2	0.953	**1**	0.773	0.865
Var3	0.859	0.773	**1**	0.903
Var4	0.920	0.865	0.903	**1**

Table 3 presents the eigenvalues of the different factorial axes (or principal components) that can be had with the four (4) initial variables. It is these eigenvalues that guide the choice of the principal components to be extracted.

Table 4. Eigenvalues of the first 4 principal components

	F1	F2	F3	F4
Eigenvalue	3,638	0.253	0.077	0.033
Variability (%)	**90,944**	**6,324**	1,915	0.818
% Cumulative	90,944	97,267	99,182	100,000

According to Table 4, only the eigenvalues of the first two principal components (F1 and F2) can be taken into account. The first factorial axis represents 91% of the variance while the second factorial axis contains 6%.

The PCA of four variables (Fruit mass (var1), Pulp mass (var2), Fruit diameter (var3) and Fruit volume (var4)) leads to the correlation circle shown in Figure 3.

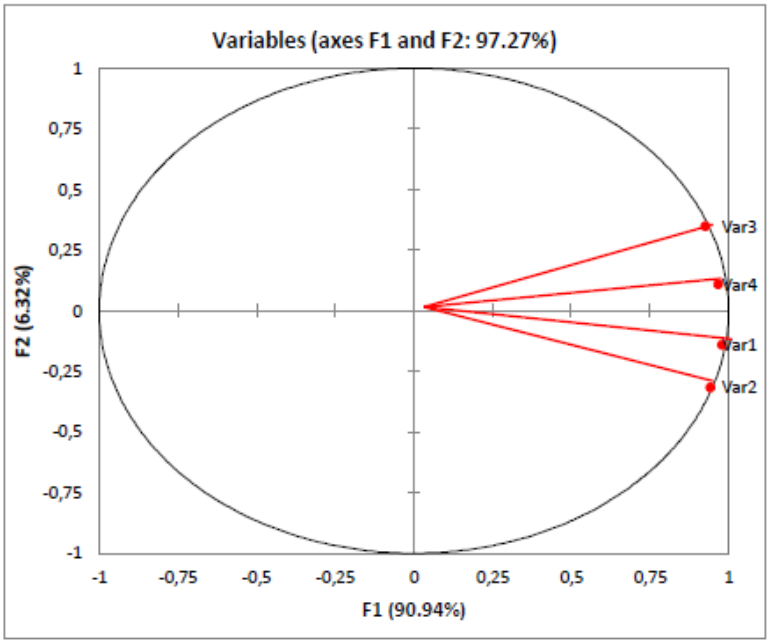

Figure 3. ACP correlation circle of the 4 variables.

It appears that the first main plane contains almost all the information on the variability (97.27%), and that all the variables are correctly represented. The F1 axis contains all the information on the physical characteristics of the fruits studied. The representation of the individuals on the F1F2 plane, highlights almost the separation into 3 classes the individuals on the left, center and right of the F2 axis.

In Figure 4, the two axes represent 97.27%, or almost all of the inertia. Three classes seem to appear but not distinctly. This figure therefore highlights three classes of *Passiflora fruits edulis flavicarpa*, but very close.

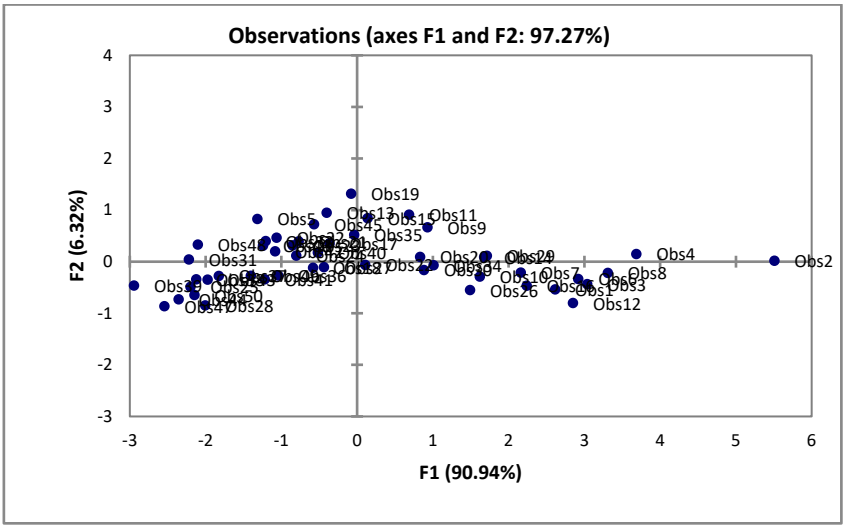

Figure 4. Representation on the F1F2 plane, in ACP of the individuals.

4.1.4 Ascending hierarchical classification (HAC)

Classification is the search for typology or segmentation, that is, a distribution of individuals into classes or categories. This is done by optimizing a criterion aimed at grouping individuals into classes, each as homogeneous as possible and, between them, as distinct as possible. The CAH iteratively groups individuals starting from the bottom (the two closest) and gradually building a tree (also called a dendrogram) finally grouping all individuals into a single class [15].

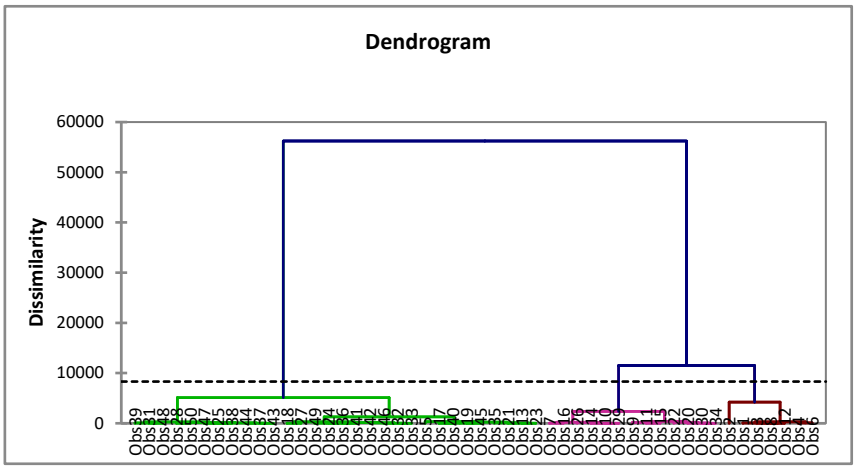

Figure 5a. CAH dendrogram of individuals constructed on 4 variables.

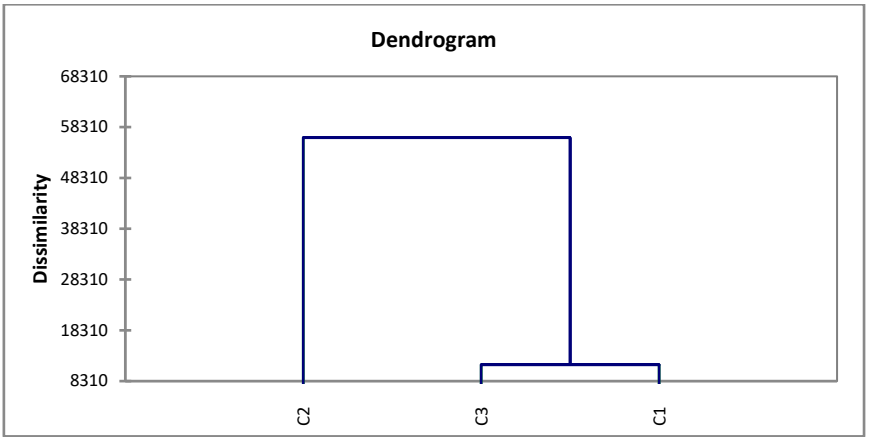

Figure 5b. CAH dendrogram of individuals constructed on 4 variables.

The dendrogram (Figures 5a and 5b) from the CAH presents three classes named Class 1, Class 2 and Class 3. Classes 1 and 3 are close in dissimilarity.

4.2 Physico-chemical indicators *P.edilis flavicarpa*

The table below presents measures of the different quantitative variables of the *P.edilis flavicarpa.*

Table 5. Measurements of quantitative physicochemical variables

Quantitative variables	Measures obtained
Water content (%)	19.25 ± 0.99
Vitamin C content (g vitamin C/liter of juice)	0.49 ± 0.01
Titratable acidity content (g of H2SO4 / liter of juice)	37.89 ± 0.28
sulfur dioxide (SO2) content (mg/l)	110.93 ± 3.29
Density (g/ml)	1.12 ± 0.01
Relative density	1.12 ± 0.01
Refractive index	1.37 ± 0.00
pH	2.76 ± 0.00
Sugar content (°Brix)	14.00 ± 0.00
Total polyphenol content (mg GAE/100mg MS	106.12 ± 0.07
Total flavonoid content (mg ERU /100g DM)	59.70 ± 0.01

Water content is an important characteristic for food processing and preservation. Like any food, fruits also contain a significant amount of water. After drying, it was obtained in this study, the amount of water equal to 19.25 g per liter of juice or 1.925 g/100 g of *passionflower edulis juice flavicarpa.* This value is close to that admitted by the standard which gives for juice and nectar a humidity rate lower than 2 g/100 g.

For one liter of juice, the mass of vitamin C is 0.48106 g, or 120.265 mg/250 ml of juice. The same analysis was carried out by Dr. Paul DUKAN who found the vitamin C content equal to 78 mg/250 ml of *passionflower edulis juice. flavicarpa.* Passion fruit is rich in vitamin C, an antioxidant that helps protect the body from damage caused by free radicals.

On the exotic plants sheet of Garden Breizh that the yellow variety is more acidic than that of the purple. The results obtained show that the acidity concentration of the passiflora edulis flavicarpa (37.89) is superior to that of passiflora edulis edulis. Which is to say that it is indeed more acidic than the purple variety.

Used as a food additive in some beverages, sulfur dioxide is naturally present in the juice of the edulis passionflower and the determined quantity is 110.93 mg or 0.11 g per liter of yellow passionflower juice. The standard [16] tolerates 10 mg per liter of sulfur dioxide as a residue of SO_2.

Density is the density relative to the volume of a liquid, it varies according to the temperature. In this study, the values of density of 1.12 g/ml at 10-16 °C, and 1.10 g/ml at 20 °C were found. On the other hand, relative to the mass of the juice, the results obtained appear identical to those of density relative to volume and it is close to the value of 1.04 admitted by the standard [17].

The refractive index of a transparent medium corresponds to its ability to deflect light. The determined quantity is 1.37124. As we have indicated above, passionflower juice is more acidic with a pH of 2.76. This pH is included in the range of values admitted by [18], i.e. 2.5 to 04.

The amount of glucose and sucrose obtained is 0.92346 g per liter of juice, or about 1/6 of the mass of a sugar cube. The sugar content per degree Brix (14.00°Brix) is in accordance with the standard which allows values between 8 and 15°Brix.

The total polyphenol content in mg GAE/100mg DM is 106.12 and that of total flavonoid in mgERU /100g DM is 59.70. Polyphenols are secondary metabolites, organic compounds present in food and essential for the body; they can have a significant impact on health and most of them are known for their antioxidant power [19, 20]. Studies carried out by [21, 22] confirm the presence in the pulp of the fruit the highest concentration of total phenol and total flavonoids of the order of 720 µgm / gmun and 2450 µgm / gm respectively [23].

5. Conclusion

This study indicates that at maturity, the fruits do not have exact dimensions. The indicators related to morphology show

that there are three classes of fruit but which are close for the genus *passionflower edulis flavicarpa.* The physicochemical properties of the pulp are in accordance with established standards. Apart from the pronounced presence of vitamin C, this chemotype highlights phytocompounds such as polyphenols and flavonoids, antioxidants capable of preventing various pathologies.

References

[1] Tsiba G, Yoka JE, M.-B., Thimotheon, A-B, Ongoka, EP. Chimcal Characterization and Anti-Radical Activity of fruits and Vegetable commonly consumed in Brazzaville. Food and Nutrition Sciences. 2020;11:773-788.

[2] Murthy HN, Dalawai D, Dewir YH, Ibrahim A. Phytochicals and biological activities of Garcinia Morella (gaertn) Desr.: A Review. 2020.

[3] Shan S, Huang X, Shah MH, Abbasi, AM. Evaluation of polyphenol content and antioxidant activity of edible wild fruits. BioMed Research International. 2019;Article ID: 1381989. https://doi.org/10.1155/2019/1381989.

[4] Ibrahim, TA, Fagbohum ED. Phytochemical and nutritive quality of dried seeds of Buchhozia coriacea. Greener Journal of Physical Sciences. 2012;2(5):185-191.

[5] Udani JK, Singh BB, Barrett, ML, Singh VJ. Rating of mangosteen juice blend on biomarkers of inflammation in obese subjects: a dose-finding pilot study. Nutr. J. 2009;8:48.

[6] Xue Q, Chen Y, Yin H, Teng H, Qin R, Liu H, Li Q, Mei Z, Yang G. Prenylated xanthones and benzophenones from the fruits of Garcinia bracteata and their potential and their potential antiproliferative and anti-inflammatory activities. Bioorg Chem. 2020 Nov;104:104339. doi : 10.1016/j.bioorg.2020.104339. Epub 2020 Oct 6. PMID: 33142411.

[7] Reddy A, Begum N, Bakshi V. Neuroprotective Effect of Garcinia Mangostana on Streptozotocin-Induced Sporadic Type Alzheimer's Disease in Mice. Int J Appl Pharm Sci Res. 2016;1(1):8-15 reviews. Molecules Vol.25, No.5690.

[8] Kako CA, Kouamé BK, Diomandé M, Boko CEA, Adjé F, Assidjo EN, Amani GN. Effects of Membrane Technologies on the Physicochemical Characteristics of Passion Fruit Extracts (Passiflora Edulis). European Scientific Journal. 2018 Nov;14(33). ISSN: 1857-7881 (Print); e-ISSN: 1857-743.

[9] Walter A, Sam C, Bataille M-C, Bompard JMG, Pascale Tcherkesoff S. Fruits of Oceania (1999, 310 p.). Illustration; ref: 14 p. ISSN 1142-2580, ISBN 2-7099-1430-1, IRD Editions, Paris.

[10] Ondo AAS. Morphological and physicochemical diversity and potentialities at the safous oil mill (Dacryodes edulis) of the ecological zone of Franceville (South-East of GABON). Marien Ngouabi University thesis. 2009;p. 242.

[11] Azeqour M, Amssa M, Baaziz M. Identification of intraclonal variability of date palm vitroplants from in vitro culture by organogenesis: morphological study. Accounts Renderings Biologies. 2002;325:947-956.

[12] Arshad M, Ashrad M, Arif N. Morphological variability of Prosopis cinemavaria (L) Druce, from Cholistan desert, Pakistan. Genetic Resources and Crop Evolution. 2006;53:1589-1596.

[13] Corbella E, Cozzolino D. Classification of the floral origin of Uruguyan honeys by chemical and physical characteristics combined with chemometrics. LWT. 2006;39:534-539.

[14] Patel SS, Mohamed Saleem TS, Ravi V, Shrestha B, Verma NK, Gauthaman K. Morphology and pharmacology of Passiflora edulis : a review. Journal of Herbal Medicine and Toxicology. 2009;3(1). DOI: 10.4103/0973-8258.59731.

[15] OECD -Passion fruit- 2021-EN- FR – V2.

[16] AFNOR (French Association for Standardization) (2000) French Association for Standardization, NF V03-707. 2000. Cereals and cereal products. Determination of water content. Reference practice method (Official Bulletin No. 2000).

[17] AOAC. Official Methods of Analysis (17th ed.). Association of Official Analytical Chemist: Washington, D.C., 2000.

[18] Codex STAN274-2005. General Standard for Fruit Juice and Nectar.

[19] Dimitrios B. Sources of nature phenolic antioxidants. Trends in food science & technology. 2006;17(9):505-512.

[20] Murthy HN, Dandin VS, Dalawai D, Park SY, Paek KY. Bioactive compounds from Garcinia fruits of high economic value for food and health. In: Merillon JM, Ramawat, KG, editors. Bioactive Molecules in Food, Reference Series in Phytochemistry. Cham, Switzerland: Springer International Publishing AG; 2019. p. 1-27.

[21] Deng, Zhou YJ, Bai MM, Li HW, Li L. Anxiolytic and sedative Passiflora activities edulis f. Flavicarpa. Journal of Ethnopharmacology. 2010;128:148-153.

[22] Dhawan, Kumar S, Sharma A. Comparative biological activity study on Passiflora incarnataand P. Edulis. Fitoterapia. 2001;72:698-702.

[23] Jucá MM, Filho FMSC, De Almeida JC, Mesquita DDS, Barriga JRDM, Dias KCF, Barbosa TM, Vasconcelos LC, Leal LKAM, Ribeiro JE, et al. Flavonoids: Biological activities and therapeutic potential. Nat. Prod. Res. 2020;34:692-705.