
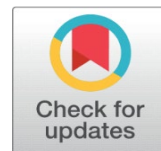


# PHYSICO-CHEMICAL CHARACTERIZATION OF COCONUT ECOTYPES IN BENIN COASTAL ZONE



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## ABSTRACT

Coconut water is highly consumed for refreshment due to its nutritional value. However, its nutritional value varies according to the ecotype and stage of maturity of ecotype. In order to identify best ecotypes with high nutritious value, a physico-chemical composition of ten (10) ecotypes was performed at earlier stage of maturity (3 months). The measured parameters were: coconut height, mass of water, total sugar content, soluble sugar content, protein, titratable acidity and pH. The obtained results showed that all parameters vary from one ecotype to another. All coconut ecotypes contain water slightly acid with a pH value less than 7. Furthermore, there is no relationship between physical and biochemical parameters. However, within characterized ecotypes, Ecotype\_2, appeared to have the best biochemical composition with a significant amount of water. This study provided important informations related to physico-chemical characteristics of coconuts ecotypes found in the coastal zone.

**Keywords:** Coconut, Water, Physicochemical Characteristics, Benin

## 1. INTRODUCTION

The coconut palm (*Cocos Nucifera* L.), the only species of the genus *Cocos*, belongs to the family *Arecaceae*. It has been described as the most widely cultivated palm in the world [Prades \(2011\)](#). Coconut palm plays an important role in the daily lives of people across tropical area where it is cultivated [Chidambaram et al. \(2013\)](#). It is a multi-purpose plant with all parts used by humans in food, handicrafts, housing, traditional medicine and many other areas [van der Vossen et al. \(2007\)](#). However, its fruit (coconut) is the most popular. Indeed, the kernel of the fruit has been considered a cash crop for many decades due to its high fat content. Thus, copra (dried kernel) was a processing product, which allowed to obtain coconut oil, an oil rich in lauric acid [Prades et al. \(2012\)](#)

However, in recent years, the demand for copra has decreased by about 75% while the demand for fresh or unripe coconut has increased exponentially (300%) [FAO \(2009\)](#).

Fresh or unripe coconut water is nowadays a common consumer product. It is a sweet, refreshing drink that comes directly from the inner part of the coconut [Steiner and Desser \(2008\)](#). Thus, there is a growing international demand for coconut water. It is a source of income for thousands of small-scale farmers in Africa and Asia. However, coconut water is not only a refreshing drink. It is also used in traditional medicine [Ediriweera \(2003\)](#) and in microbiology [Osazuwa and Ahonkhai \(1989\)](#). It can also be used to make vinegar [Sanchez \(1985\)](#) and wine [Prades et al. \(2012\)](#). These various uses of coconut water are undoubtedly linked to its biochemical composition. Indeed, several authors [Yong et al. \(2009\)](#), [Konan et al. \(2016\)](#) have shown that the biochemical composition of the water varies according to the variety and the stage of nut's maturity.

In Benin, coconut cultivation is widespread along the coast. Coconuts are consumed fresh in the form of coconut juice, fresh kernel, coconut milk and coconut cream. They are also used in the production of coconut oil [Hounhouigan et al. \(1998\)](#). However, the physical and biochemical characteristics of coconuts from different ecotypes of coconut remain to date undetermined. The present study aimed at characterizing some physical and biochemical parameters of coconut water from unripe nuts of different coconut ecotypes collected in the coastal zone of Benin. This will allow on the one hand to provide indicators that can lead to a better valorization of this product. On the other hand, it will also allow the identification of ecotypes with the best physical and biochemical characteristics that are candidates for coconut improvement program.

## 2. MATERIAL AND METHODS

### 2.1. PLANT MATERIAL

The physical and biochemical parameters were determined on samples from 10 different ecotypes of identified coconut ([Table 1](#)). Knowing that these parameters vary according to the age of maturity of the coconut, they are determined for fruits of the same stage of maturity (3 months) for all ecotypes. To do this, three (3) trees per ecotype were chosen randomly. On each tree, 3 fruits were randomly selected to form a representative sample from which the different measurements are taken.

Table 1 List of ecotypes characterized		
N°	Local or vernacular names	Codification
Ecotype_1	<i>Hibridi_yellow</i>	Var1
Ecotype_2	<i>Hibridi vòvò</i>	Var2
Ecotype_3	<i>Hibridi vèvè</i>	Var3
Ecotype_4	<i>Hibridi Ghanaton</i>	Var4
Ecotype_5	<i>Sèmè gon</i>	Var5

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<b>Ecotype_6</b>	<i>Agon yovoton</i>	Var6
<b>Ecotype_7</b>	<i>Agon miton</i>	Var7
<b>Ecotype_8</b>	<i>Hibridi</i>	Var8
<b>Ecotype_9</b>	<i>Agon koun</i>	Var9
<b>Ecotype-10</b>	<i>Agon yovoton_Kpèvi</i>	Var10

## 2.2. DETERMINATION OF PHYSICAL PARAMETERS

Several physical parameters were measured on coconuts of different ecotypes. These parameters concerned: height of the fruit, diameter of the fruit, weight of the fruit, weight of dehusked or shelled nut, weight of the fluff, the mass (volume) of water, mass of the almond and the mass of the shell. All measurements were carried on tree samples of each ecotype. The height and diameter of fruit were measured using an electronic caliper, and masses were taken using a precision balance. Specifically, the mass of water was determined according to the method described by [Assa et al. \(2007\)](#).

## 2.3. DETERMINATION OF PH AND SOLUBLE SUGAR CONTENT

The pH was measured in triplicate using a pH meter (Mettler TOLEDO), and the soluble sugar content by direct measurement always in triplicate using a refractometer according to the AOAC 2000 method.

## 2.4. DETERMINATION OF BIOCHEMICAL PARAMETERS

The protein content was determined by the method described by [Zheng et al. \(2017\)](#). The titratable acidity was determined by the method of (Tyl and Sadler, 2017) and the total sugars content by the colorimetric method reported by [Wang et al. \(2010\)](#).

## 2.5. DATA ANALYSIS

All analyses and graphics were done in the R 3.5.1 software environment [R Core Team \(2018\)](#). Results were analyzed using descriptive statistics, with results expressed as means and standard deviations. Correlations were also performed between parameters and a principal component analysis applied to the correlation matrices generated. The effect of the coconut ecotype on the biochemical and physical parameters was evaluated using linear mixed models in the nlme package [Pinheiro et al. \(2019\)](#). Ecotype was considered as fixed factor while repetition was considered as random factor, and the means were projected in the ggplot2 package [Wickham \(2009\)](#). The relationship between biochemical parameters and physical parameters were assessed using the analysis of common components in the ComDimR package. The relationship between the block (Biochemical and Physical)

and the variables has been described as well as the relationship within the variables in each block. To achieve this correlation, the fitted means were previously calculated per tree in the emmeans package [Russell \(2019\)](#).

### 3. RESULTS AND DISCUSSIONS

#### 3.1. VARIATION OF BIOCHEMICAL AND PHYSICAL PARAMETERS ACCORDING TO ECOTYPES

The biochemical and physical parameters are important criteria of choice for producers and consumers. Analysis of the data shows that the measurements of the biochemical and physical parameters vary significantly from one ecotype to another, except the pH for which values obtained do not differ significantly. The obtained results were presented on the [Table 2](#) below.

		numDF	F value	Prob
<b>Biochemical parameters</b>	Soluble sugars	9	36.40	<0.001*
	Total sugars	9	26.39	<0.001*
	Proteins	9	12.93	<0.001*
	pH	9	0.18	0.9947 <sup>ns</sup>
	Titrateable acidity	9	12.93	<0.001*
<b>Physical parameters</b>	Fruit height	9	23.62	<0.001*
	Fruit diameter	9	22.38	<0.001*
	Fruit weight	9	46.63	<0.001*
	Dehusked nut mass	9	37.85	<0.001*
	Fluff weight	9	84.02	<0.001*
	Water weight	9	6.56	<0.001*
	Albumen weight	9	7.42	<0.001*
	Shell weight	9	25.71	<0.001*

numDF: Degree of freedom

Prob: Probability

\*: Significant; ns: not Significant

For biochemical parameters ([Figure 1a](#)), the highest level of soluble sugars (5.6%) is obtained for ecotype\_9 while the lowest level (4.2%) was measured in ecotype\_8. The highest total sugar content (6%) was observed for ecotype\_2 and the lowest level (4.3%) for ecotype\_6. For protein content, the highest value was

obtained for ecotype\_1, and the lowest for ecotype\_2. The titratable acidity content varies from 0.35 to 0.62 meq/100g with the highest value ecotype\_8 and the lowest for ecotype\_2.

Regarding the physical parameters (Figure 1b), statistical analysis revealed that ecotype\_10 is the one with the large fruit size (height = 27 cm, diameter = 15.8 cm). In addition, the fruit of this ecotype also has the highest weight with the greatest mass of fluff.

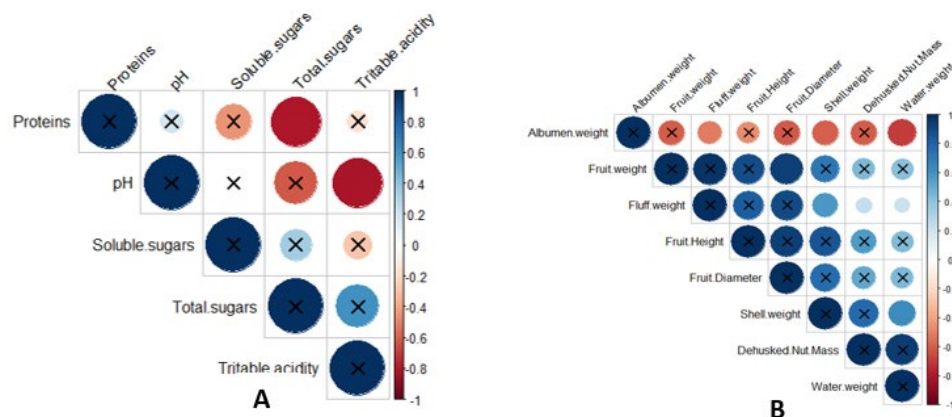


**Figure 1** Physico-chemical parameters according coconut variety

### 3.2. CORRELATION WITHIN BIOCHEMICAL AND PHYSICAL PARAMETERS

The obtained results showed that for all samples, biochemical and physical parameters could be considered as two distinct blocks without any relation. No correlation exists both parameters. However, within the biochemical parameters on the one hand and within the physical parameters on the other hand, some correlations were found. A correlation between two variables is found when “r” defined as the correlation coefficient or its absolute value is greater than or equal to 0.5. Correlation is positive when  $0.5 < r < 1$  and negative when  $-1 < r < 0$ .

Figure 2A presented below shows the correlations (r) between the various biochemical parameters studied. It appears clearly that increasing in total sugars content is positively correlated ( $r = 0.61$ ) with the content of titratable acidity, and negatively correlated with the pH ( $r = -0.6$ ), and proteins content ( $r = -0.80$ ). The pH is also negatively correlated ( $r = -0.61$ ) with titratable acidity ( $r = -0.82$ ). However, for soluble sugars, no correlation was found between the other parameters.



**Figure 2** Correlogram between biochemical (A) and physical parameters (B)

When considering physical parameters (Figure 2B), the fruit size is highly positively correlated with the fruit diameter ( $r = 0.94$ ), the fruit weight ( $r = 0.89$ ), the fluff weight ( $r = 0.82$ ) and the shell weight ( $r = 0.85$ ). However, the correlation with the dehusked (shelled) nut weight is relatively weak ( $r = 0.56$ ) when compared to the other ones. Indeed, these results show that, the larger the size of the fruit, the greater its weight, diameter, fluff weight, and shell. Moreover, the fruit weight is strongly correlated with the fruit height, the fruit diameter, the fluff weight ( $r = 0.98$ ) and the shell weight ( $r = 0.71$ ). But it is negatively correlated with albumen weight ( $r = -0.60$ ). The shelled nut weight is positively correlated with the fruit height, its diameter, and the shell weight ( $r = 0.78$ ). When the dehusked nut weight increases, the water weight increases ( $r = 0.95$ ) and the albumen weight decreases ( $r = -0.60$ ). The fluff weight is also positively correlated with the shell weight ( $r = 0.58$ ), and negatively correlated with the albumen weight ( $r = -0.57$ ). As it is shown on the correlogram (Figure 2B), an increasing in the water weight, increases the dehusked nut weight and the shell ( $r = 0.63$ ) while the albumen weight decreases ( $r = -0.69$ ). Shell weight is positively correlated with all other parameters except albumen weight.

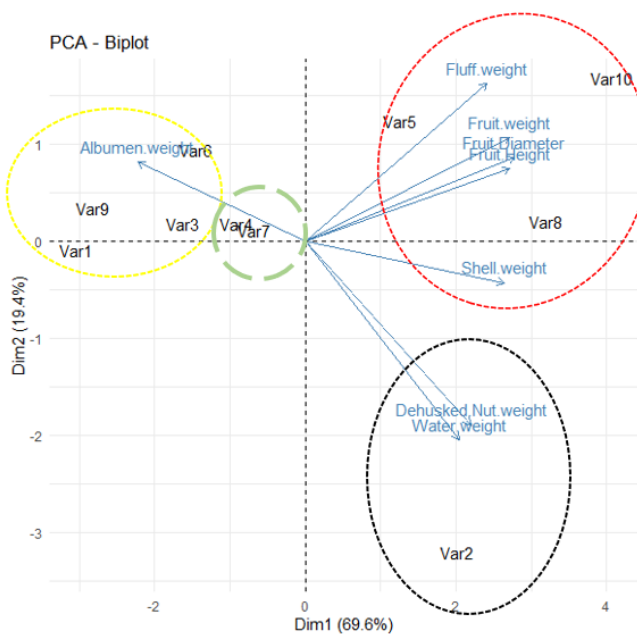
### 3.3. RELATIONSHIP BETWEEN BIOCHEMICAL PARAMETERS AND ECOTYPES

In order to establish the different links between the biochemical parameters and the ecotypes, the principal component analysis (PCA) carried out, shows that the first axis (accounting for 55.3% of total variation out of a sum of 85.5% for axes 1 and 2) separates ecotypes into two groups according to their biochemical composition (Figure 3). Then, on the one side (right) there is ecotypes with high content of total and soluble sugars, and titratable acidity; and on the other side (left) there is ecotypes with high content of protein. Furthermore, some ecotypes (Var4, Var5 and Var7) were found to have no specific biochemical parameter that made differences with others.



**Figure 3** Relationship among biochemical parameters and ecotypes

### 3.4. RELATIONSHIP BETWEEN PHYSICAL PARAMETERS AND ECOTYPES



**Figure 4** Relationship among physical parameters and ecotypes

Analogously to the biochemical parameters, a principal component analysis carried out showed that axis 1 separates ecotypes into two categories with a contribute rate of 69.6% (Figure 4). From the analyses, the ecotypes (Var5, Var8 and Var10) have the best physical parameters, in particular, the fruit height, the fruit diameter, the fruit weight, the fluff weight and the shell weight. The ecotype\_2 appears to be which contains a lot of water with a weight of shelled nut. Ecotypes 6, 9, 3 and 1 are those with a high albumen weight. Furthermore, ecotypes 4 and 7, don't have any specific criteria that could differentiate them from the whole.

### 3.5. DISCUSSION

One of the most common forms of coconut consumption is its water which is preferred at the earlier stage of the nut's maturity. This water is mainly appreciated for its biochemical composition and refreshing effect. Here, our results showed that for same stage of maturity, all biochemical parameters vary from one ecotype to another except the pH. Indeed, all coconut water extracted from ecotypes presented a pH value less than 7, which revealed that they are acids. This low acidity presents no risk for consumers. Our results are consistent with those of Benavent and Sanchozalls, (1992), who reported that the pH of coconut water is acid. According to Assa et al. (2007), high acidity of coconut water can lead to gastric disorders. Indeed, this variability in the content of biochemical compounds has been also reported in other studies. Indeed, authors underlined that the biochemical composition of coconut water varies according to the stage of maturity, and according to the ecotype Assa et al. (2007), Yong et al. (2009) Kodjo et al. (2015) Konan (2016).

For the physical parameters, the same observation was made. A significant variability of the different data is observed between ecotypes. Our results showed that the larger fruits do not necessarily have the highest water mass. Indeed, there is no correlation between the fruit size, its weight and the mass of water. However, the mass of water depends on the mass of shelled nut. When the mass of shelled nut is high, the mass of the water is also high Prades et al. (2012). Coconuts with a lot of water are not necessarily the ones that are large or fat. As for the ratio, water / albumen, our results showed that ecotypes with a large quantity of water, have less albumen or kernel, which could be explained by the stage of nut's maturity. In fact, at the immature stage, the albumen is still liquid, and a gelatinous layer can be observed in the nut. However, in advanced stage during maturation the albumen is gradually set up and conversely of the water decreases Deffan et al. (2011). Although the physical and biochemical parameters differ from one ecotype to another, there is however, no relation between both parameters. This means that physical parameters do not influence the biochemical composition of the nuts. However, there are links between the biochemical parameters that influence the composition of coconut water. Thus, pH is closely related to titratable acidity and total sugars. As the pH increases, the titratable acidity and total sugars decrease. This is perfectly understandable because acidity and pH are inversely proportional Konan et al. (2016). Indeed, acidity is characterized by the presence of strong and weak acid residues including amino acids, fatty acids and carbon dioxide dissolved in coconut water (Jayalekshmy et al., 1988). These different compounds are produced during metabolic reactions in fruits. Those reactions are often characterized by the oxidation of lipids, proteins and carbohydrates Kodjo et al. (2015). Coconut water from less acidic ecotypes would therefore contain less



residue. The ecotypes are richer in protein depending on the decrease in total sugars. These results are similar to those obtained by [Yong et al. \(2009\)](#).

Our results showed that the larger fruits do not necessarily have the highest water mass. Indeed, there is no correlation between the fruit size, its weight and the mass of water. However, the mass of water depends on the mass of shelled nut. When the mass of shelled nut is high, the mass of the water is also high [Prades et al. \(2012\)](#).

#### 4. CONCLUSION AND RECOMMENDATIONS

The results obtained during this study allowed us to assess the physico-chemical composition of coconut water consumed in the coastal zone of Benin. In view of these results, no correlation exists between biochemical and physical parameters. However, at the earlier stage of nut's maturation, which is the preferred stage of coconut water trade, ecotype\_2 appears to be the best for both water's taste and quantity of water. This ecotype could be a good candidate in coconut improvement program.

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