Original Research Article

Physico-chemical characterization of granulated sugar from coconut (Cocos Nucifera L.) inflorescence sap Cultivars and sugar cane in Côte d'Ivoire

---

SUMMARY

Aims: To evaluate and compare some physico-chemical characteristics of powdered sugar from the inflorescences of three of the most widespread coconut cultivars in Côte d'Ivoire compared to sugar from cane sugar to diversifying coconut exploitation in Côte d'Ivoire.
Experimental design was used**:** The sap was extracted from inflorescences of row 8 of PB113+, PB121+ hybrid and GOA cultivar. Three different treatments that varied time and temperature were set. The physico-chemical characterization concerned the sugar samples from each pair. Samples of white and brown sugar from sugar cane, sold commercially in Côte d'Ivoire, were used as controls.
Place and duration of studies: Marc Delorme Station for Coconut Research at the National Centre for Agricultural Research, Côte d'Ivoire between January 2017 and March 2018.
Methodology: The sap from the freshly collected coconut tree inflorescences was directly transformed into granulated sugar by thermal spraying (Okoma et al, 2019), without preservatives. Three treatments varying the time/temperature pair were tested. Thus, the processing consisted of:
T1: boil 1 liter of sap for 45 minutes at a temperature varying from 60-120°C
T2: boil 1 liter of sap for 40 minutes at a temperature varying from 60-140°C
T3: boil 1 liter of sap for 35 minutes at a temperature varying from 60-160°C
The physico-chemical characterization concerned the coconut sugar samples from each treatment and covered the dry matter content (DMS), moisture (HUM),
ashes content (ASH), hydrogen potential (pH), titratable acidity content (TAT), total and reducing sugar contents, fat content and crude fibers. We considered the white and brown sugar from sugar cane sold in the sample as control samples.
Results: All the physico-chemical characteristics of the crystalline coconut and sugar cane sugars analyzed generated significant differences (p<0**.5)** between them and the controls. Regardless of the treatment, the controls white and brown cane sugar provide statistically identical DMS, greater than 99.45 g/100g respectively. These levels are higher than those provided by the sugar of coconut cultivars. In addition, white (0.27 to 0.29) and brown (0.42 to 0.50) cane sugar contains less water than all coconut cultivars (0.76 to 1.70). Regardless of the treatments applied, crystalline coconut sugar contains ashes contents (ASH) that range from 1.45 to 2.85 and are statistically higher than the proportions found in brown sugar cane sugar (0.11 to 0.28). White sugar cane sugar does not contain ashes. The pH of white sugar and brown sugar (6.09 and 6.44) is significantly higher than that of coconut sugar (4.82 and 6.19). The titratable acid content of coconut sugar ranged from 1.25 to 2.19 compared to 0.94 to 1.99 in cane sugar. Total sugar contents (TST) represent 81.15 to 87.54% of the dry matter in coconut cultivars. This is lower than the TSTs for white sugar (99.01 to 99.04%) and brown sugar (95.6 to 95.73%) sugar cane. Crystal sugar in coconut cultivars contains

statistically fewer reducing sugars (6.75 to 7.89%) than white sugar cane sugar (8.11 to 8.12%). Its red counterpart, with 6.14%, contains smaller amounts of reducing sugars.
Conclusion: Sugars are the main constituents of the dry matter of the coconut and cane sugar crystals studied. However, the different heat treatments applied to the sap of coconut inflorescences significantly affected all the physico-chemical parameters of each sugar. The physico-chemical characteristics have statistically differentiated coconut sugar from sugar cane sugar. However, for a better valorization of crystalline coconut sugar in Côte d'Ivoire, additional studies to determine its carbohydrate, mineral, vitamin and energy content should be considered.

Keywords: coconut sap sugar, sugar cane sugar, physico-chemical parameters, valorization, Côte d'Ivoire

1. INTRODUCTION

Among the many ways in which coconut trees are valued, the sap from inflorescences occupies an important place and is of growing interest. This sap has a neutral pH (6.97 to 7.32) and is mainly composed of carbohydrates (16.08 g/100 ml sap), mainly sucrose (9.40 to 12.24 g/100 ml sap) **[1]**. It is a raw material for the development of other by-products, whose added value helps to address the low profitability of copra **[2,3]**. It is used to make syrup or coconut sugar by thermal dehydration **[4]**. In addition, it ferments spontaneously, leading first to a drink containing 5% to 8% alcohol **[5]**, then to an acid product containing 4% to 7% acetic acid **[6]**. It is thus used for the production of alcohol by distillation, and for vinegar making **[7]**. Unfortunately, the recovery of coconut palms in Côte d'Ivoire is still mainly limited to their fruits, copra and the oil resulting from their processing. With the exception of recent work carried out on the biochemical properties of the sap of coconut tree inflorescences, its valorization is non-existent. Thus, the production of table sugar from the sap of coconut tree inflorescences has been considered in Cote d'Ivoire since 2015. This study aimed to highlight the factors that transform the sap of coconut inflorescences into crystalline sugar. The results showed that the parameters involved in crystallization are on the one hand the quality of the sap, and on the other hand time, temperature and crystallization mode **[8]**. However, the physico-chemical characterization of coconut table sugar, inherent in its recovery, has never been carried out in Côte d'Ivoire. Also, very few studies compare different coconut varieties in terms of the constituents of table sugar, derived from their saps. In addition, from a nutritional point of view, no comparative study of the properties of brown and white sugar cane, widely consumed in Côte d'Ivoire, has been undertaken. Also, from an agronomic, morphological and genetic point of view, coconut ecotypes present many diversities. In addition, according to **[9]** the quality of coconut granulated sugar depends on production parameters. This study evaluates and compares some physico-chemical characteristics of powdered sugar from the inflorescences of three of the most widespread coconut cultivars in Côte d'Ivoire. These are the traditional variety, Great West Africa (GOA) and the improved hybrids PB121+ and PB113+. Coconut sugar samples were obtained using the method of **[8]**. Three different pairs (time/temperature) were set and the physico-chemical characterization was done for the sugar samples from each pair. Samples of white and brown sugar from sugar cane, sold commercially in Côte d'Ivoire, were used as controls. Indeed, the production of table sugar from the sap of coconut tree inflorescences represents a technological innovation. This could increase the interest of the coconut tree for producers and consumers of this speculation and constitute an important way to revive the nuclear sector in Côte d'Ivoire.

2. EQUIPMENT AND METHODS

2.1 EQUIPMENT

2.1.1 Experimental site

Our study was carried out at the Marc Delorme Research Station of the Centre National de Recherche Agronomique (CNRA), based in Port-Bouët (Abidjan) in southern Côte d'Ivoire. It houses the international collection of coconut palms for Africa and the Indian Ocean, which is classified as an international heritage site. The station covers an area of 998 ha.

2.1.2 Biological material

The biological material consisted of three categories of powdered sugar, derived from the sap of the inflorescences of three cultivars. These are the West African Grand Cultivar (GOA) and the improved hybrids PB121+, resulting from the Malaysian Yellow Dwarf Cross (NJM x GOA+) and PB113+, resulting from the Cameroon Red Dwarf Cross and the improved Great Rennell (NRC x GRL+). In addition, the brown sugar and white sugar cane sugar, bought in supermarkets, were used as controls.

2.1.3 Materials for processing coconut inflorescence sap into crystalline sugar

The equipment for the production of crystalline coconut sugar is shown in Table 1.

Table 1 : Coconut sap extraction equipment

Materials	Use
An electric heating plate (TRIOMPH) with adjustable temperature and time	Spray the sap according to the desired time-temperature combination
Stainless steel stove	Heating the sap
Wooden and stainless-steel spatulas	Homogenize the sap
Electronic scale	Weigh the sap and granulated sugar
Refractometer	Check the °Brix of products in training
pH meter	Measure the pH of the products in formation

2.2 METHODS

2.2.1 Sampling

The sap was harvested from the inflorescences of row 9 of the cultivars GOA, PB121+ and PB113+, at 07h, 12h and 17h. Only the 12h and 17h harvests were used for processing into table sugar. The 07h one is consecutive to 14h of flow, which favors the development of microorganisms and therefore fermentation, making it impossible for the sugar to crystallize. Ten trees with no signs of disease or pest attacks were selected by cultivar for sap extraction. For each variety, the sap from the ten trees is mixed and divided into three 1-litre batches. A technology combining a pair (Time/Temperature) is applied in batches, i.e. three crystalline sugar production technologies in total that have been applied. Indeed, the different technologies consisted of boiling one liter of sap for 45, 40 and 35 minutes at a temperature varying from 60-120; 60-140; 60-160 respectively. The production campaigns for crystalline coconut sugar were repeated three (03) times in January, June and December. A total of 27 samples of coconut powdered sugar (3 lots X 3 cultivars X 3 campaigns) were produced and analyzed.

2.2.2 Transformation of coconut inflorescence sap into crystalline sugar

The sap from the freshly collected coconut tree inflorescences was directly transformed into granulated sugar by thermal spraying **[8]** without preservatives. Three treatments varying the time/temperature pair were tested. One liter of sap from each cultivar was boiled for 45, 40 and 35 minutes at temperatures ranging from 60-120; 60-140; 60-160 respectively. Thus, the processing consisted of:
T1: boil the sap for 45 minutes at a temperature ranging from 60-120°C

T2: boil the sap for 40 minutes at a temperature varying from 60-140°C
T3: boil the sap for 35 minutes at a temperature ranging from 60-160°C

For each pair (time/temperature) tested, the physico-chemical parameters of the sugar samples obtained were determined by cultivars. All analyses were performed in three replicates.

2.2.3. Evaluation of physico-chemical parameters to coconut sugar

2.2.3.1. Physical characteristics of coconut crystal sugar

The dry matter content (DMS) and moisture content (HUM) were determined by drying coconut crystalline sugar and sugar cane samples in an oven (Memmert, Berlin, Germany) at 104° C for 24 hours **[10].** They are expressed as a percentage of wet sample mass.
The ash content (ASH) was determined using the **[10]** method. It consisted of the elimination by incineration at 550°C, for 12 hours, in a VOLCA V 50 muffle furnace, of all the organic compounds contained in the crystal sugar samples. Ashes are expressed as a percentage by mass of dry sample.

2.2.3.2. Chemical characteristics of coconut crystal sugar

The hydrogen potential (pH) of the crystalline sugar samples was evaluated using a portable pH meter from HANNA. Ten (10g) samples were weighed and homogenized in 100 mL of distilled water with stirring. The mixture was filtered on filter paper (Whatman) and the filtrate was collected in an erlen. The pH meter electrode was directly immersed in the filtrate for pH reading.
The total titratable acidity (TAT) was expressed as mass of acid equivalents per mass of crystalline sugar sample. It was determined by titrimetric assay with decinormal soda (NaOH 0.1N), according to the **[10]** standard**.**
The total sugar content is determined according to the method described **by [11]** using phenol and sulphuric acid.
Reducing sugars were evaluated by the 3,5- dinitrosallicyclic acid method **[12]**.
The total lipids were extracted with Soxhlet according to **[13]**.
The crude fiber content was obtained by the method of **[14]**. Two (2) g of sugar sample were weighed into a flask and fifty (50) mL of 0.25N sulphuric acid was added. The whole content was brought to a boil for 30 minutes under reflux condenser. Then 50 ml of 0.31 N soda was added to the contents and brought to a boil for 30 min in reflux condenser. The extract obtained was filtered on Whatman paper. The residue was washed several times in hot water until the alkalis were completely removed, before being dried in an oven at 105°C for 8 hours. The dried residue is cooled in the desiccator and then weighed, before being incinerated in the oven at 550°C for 3 hours and cooled again in the desiccator. The calculation of the raw fibers is done in percentage of dry sample mass.

2.2.3.4. Data processing

The SPSS 16.0 software was used for statistical analysis of the data. Thus, a one-factor analysis of variance (ANOVA) was performed at the 5% probability of significance level. For each treatment, the factor assessed was the coconut cultivar. The significantly different averages were classified by the Newmann Keuls test. The relationships between the variables were assessed by analyzing Pearson's correlation indices.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Physical characteristics of crystalline coconut sugar obtained by treatments 1,2 and 3

Coconut sugar was obtained by boiling the sap for 45 minutes at a temperature ranging from 60-120°C for treatment 1. Treatment 2 consisted of boiling the sap for 40 minutes at a temperature ranging from 60-140°C. Concerning treatment 3, coconut sap was brought to a boil for 35 minutes at a temperature varying from 60-160°C.

For each of the three time/temperature pairs that were tested, the coconut sugar obtained had a crystalline structure and a specific coloring for each treatment (Photo1)
All the physical characteristics of the crystalline sugars analyzed generated significant differences (p<0**.5)** between the coconut cultivars studied and the controls.

3.1.1.1.1.1 Dry matter content

The dry matter content (DMS) of coconut crystalline sugar increases statistically (< 0.001) with the pair (time/temperature) tested through T1, T2 and T3 treatments (Table 2). It also differentiates between the three cultivars studied (< 0.001). However, regardless of treatment, the controls for white and brown cane sugar provide statistically identical DMS of (99.66; 99.50 and 99.80 g/100g) and (99.49; 99.45 and 99.52 g/100g) respectively. These levels are higher than those provided by the sugar of coconut cultivars. The DMS of the PB113+ hybrid increase statistically by 98.26; 99.18 to 99.60 g/100g for T1, T2 and T3 treatments respectively. However, for the same treatments, these averages are higher than those obtained with PB121+ (97.53;98.20 and 98.73 g/100g) and GOA (97.73; 98.03 and 99.32).

3.1.1.2. Moisture content

The moisture content (HUM) of coconut crystalline sugar decreases statistically per cultivar, considering the three treatments (Table 2). Crystalline sugar from the hybrid PB113+, records moisture contents that vary from 1.54; 1.06 to 0.76% in treatments 1.2 and 3. These rates are statically lower than those provided by sugar from the other two coconut ecotypes. Indeed, the sugars that were supplied by the hybrid PB121+ (1.70 ms 1.14 and 0.82) and the cultivar GOA (1.64; 1.12 and 0.80) have statistically identical contents. However, for this characteristic, white and brown cane sugar contains less water than all coconut cultivars

3.1.1.3. Ash content

Regardless of the treatments applied, crystalline coconut sugar contains ash contents (TCE) that vary from 1.45 to 2.85 taking into account all cultivars studied. Statistically, TCE demonstrated differences between cane sugars and those obtained from the sap of the coconut cultivars studied. Indeed, white cane sugar does not contain ash and brown sugar contains proportions between 0.11 and 0.28 which are statistically lower than those of coconut sugar. Treatments 1, 2 and 3 result in a decrease in TCE per cultivar according to the statistical classification of their average (Table 2). Thus, the crystalline sugar of the PB121+ hybrid contains 2.82; 2.58 and 1.45% ash in treatments 1, 2 and 3 respectively. For the same treatments, the sugar of the PB113+ hybrid contains 2.85; 2.55 and 2.33% ash. The cultivar GOA gives sugar with ash proportions ranging from 2.8; 2.53 to 2.25%. With the exception of treatment 3, the granulated sugar of the three cultivars studied contains ash contents that are statistically equal.

Table 2: Physical characteristics of coconut and cane crystal sugar

Characters	Treatments	Cultivars						
		Tém B	**Tém R**	**PB121+**	**PB113+**	**GOA**	***F***	***P inter***
	1	99.66±0.17^{Aa}	99.49±0.16^{Aa}	97.53±1.5^{Bc}	98.26±1.3^{Bb}	97.73±1.1^{Bc}	*367,383*	*< 0,001*
DMS	2	99.50±0.27^{Aa}	99.45±0.26^{Aa}	98.20±1.3^{Ac}	99.18±0.98^{Ab}	98.03±1.75^{Ac}	*347,08*	*< 0,001*
	3	99.80±0.12^{Aa}	99.52±0.14^{Aa}	98.73±1.3^{Ab}	99.60±0.11^{Aa}	99.32±0.45^{Aa}	*402,987*	*< 0,001*
F		*4,5*	*4,61*	*40,02*	*30,53*	*29,45*		
P intra		*0,07*	*0,10*	*< 0,001*	*< 0,001*	*< 0,001*		
HUM	1	0.27±0.11^{Ae}	0.50±0.22^{Ad}	1.70±1.3^{Ab}	1.54±0.78^{Ac}	1.64±0.54^{Aa}	*279,75*	*< 0,001*
	2	0.28±0.15^{Ae}	0.44±0.22^{Bd}	1.14±0.54^{Bb}	1.06±0.16^{Bc}	1.12±0.84^{Ba}	*302,183*	*< 0,001*
	3	0.29±0.12^{Ae}	0.42±0.20^{Bd}	0.82±0.45^{Cb}	0.76±0.14^{Cc}	0.80±1.02^{Ca}	*298,854*	*< 0,001*
F		*2,55*	*21,45*	*46,83*	*69,87*	*43,21*		
P intra		*0,06*	*< 0,001*	*< 0,001*	*< 0,001*	*< 0,001*		
ASH	1	0	0.28±0.12^{Ab}	2.82±0.30^{Aa}	2.85±0.21^{Aa}	2.8±0.9^{Aa}	*42,722*	*< 0,001*
	2	0	0.11±0.9^{Bb}	2.58. ±0.40^{Ba}	2.55±0.87^{Ba}	2.53±0.25^{Ba}	***32,615***	***< 0,001***
	3	0	0.25±0.9^{Ac}	1.45±0.40^{Cb}	2.33±0.87^{Ca}	2.25±0.25^{Ca}	*45,128*	*< 0,001*
F			*32,54*	*28,79*	*14,68*	*30,54*		
P intra			*< 0,001*	*< 0,001*	*< 0,001*	*< 0,001*		

For each character, the values with the same capital letter in each column are statistically identical. On each line, the values with the same lowercase letter are statistically identical.

F, statistical test value; **P inter**, statistical test probability value between cultivars; **P intra**, statistical test probability value within cultivars; **DMS**, dry matter content; **HUM**, moisture content ; **TCE**, ash content; **Tém B**, Tém **B**, Tém **R**, Tém **R**, Tém R, Tém R , **PB121+**, PB121 improved hybrid; **PB121+,** PB113 improved hybrid; **GOA**, West African cultivar.

3.1.2. Chemical characteristics of crystalline coconut sugar obtained by treatments 1,2 and 3

3.1.2.1. Hydrogen potential

Considering the three treatments, the hydrogen potential (pH) of crystalline sugar in coconut cultivars varies between 4.82 and 6.19 (Table 3). The pH of white sugar and brown sugar is significantly higher than that of coconut sugar per treatment and ranges from 6.09 to 6.44 (Table 3). For each cultivar, the treatment induces a classification of the pH of coconut sugars into three groups. The first group consists of treatment 1 per cultivar. These sugars, compared to the other two treatments, have a statistically higher pH of 5.64 (PB121+), 6.19 (PB113+) and 5.7 (GOA).
The second group is formed by sugars from the treatment of, which have a pH of 5.13 (PB121+), 5.21 (PB113+) and 5.02 (GOA). The 3rd group is characterized by sugars produced by treatment 3 and which have the lowest pH values ranging from 4.94 (PB121+), 5.02 (PB113+) to 4.82 (GOA).

3.1.2.2. Total titratable acidity

The total titratable acidity of coconut sugar in all cultivars studied varies from 1.25 to 2.19 taking into account all treatments. In addition, within each cultivar, the different treatments produce sugars with statistically different acidity levels ($P<0.001$). The hybrid PB121+, provides crystalline sugars whose acidity increases from 1.25 for treatment 1 to 1.83 and 2.06 for treatments 2 and 3. This increasing trend in acidity with treatment is also observed with sugars from the other two coconut cultivars. The sugars of the PB113+ hybrid have an acidity of 1.28;1.74 and 2.03; those of the cultivar GOA 1.47; 2.08 and 2.19 respectively for treatments 1.2 and 3 (Table 3).

3.1.2.3 Sugar content

Total sugars

Whatever the cultivar, sugars are mainly represented in crystalline sugar samples. The total sugar content (TST) represents 81.15 to 87.54% of the dry matter in coconut cultivars. Analysis of the variance of the averages shows that white sugar and brown sugar from sugar cane contain higher total sugar contents than coconut sugar (Table 3). Thus, the TST of white and brown sugar from sugar cane varies from 95.60 to 99.01%. However, in sugar cane, brown sugar contains fewer total sugars (95.6 to 95.73%) than white sugar (99.01 to 99.04%). The classification of the averages within each cultivar shows that TST divides the sugars produced into three distinct groups (Table 3).

Reducing sugars

Considering all coconut cultivars, the levels of reducing sugars (TSR) vary from 6.75 to 7.89%. The crystalline sugar of cultivars contains statistically fewer reducing sugars than white sugar cane sugar, which has SRTs ranging from 8.11 to 8.12. Its red counterpart, with 6.14%, contains smaller amounts of reducing sugars (Table 3).

3.1.2.4 Fiber content

No fiber was found in white and brown cane sugars. However, traces of fiber were found in the coconut crystalline sugar samples (Table 3).

3.1.2.5 Fat content

The crystalline sugar crystals of sugar cane and coconut do not contain fat (Table 3).

Table 3: Chemical characteristics of coconut and cane crystalline sugar

		Cultivars						
Characters	**Treatments**	**Tém B**	**Tém R**	**PB121+**	**PB113+**	**GOA**	***F***	***P inter***
pH	1	5,44±1,2^{Aa}	6,12±1,13^{Ab}	5,64±1,34^{Ac}	6,19±1,23^{Ab}	5,7±0,98^{Ac}	*67,817*	*< 0,001*
	2	5,39±0,18^{Aa}	6,09±0,22^{Ab}	5,13±0,15^{Bd}	5,21±0,17^{Bc}	5,02±0,20^{Be}	*248,29*	*< 0,001*
	3	5,41±0,15^{Aa}	6,10±0,17^{Ab}	4,94±0,10^{Cd}	5,02±0,10^{Cc}	4,82±0,16^{Ce}	*180,57*	*< 0,001*
F		*4,5*	*4,61*	*40,02*	*30,53*	*29,45*		
P intra		*0,07*	*0,10*	*< 0,001*	*< 0,001*	*< 0,001*		
TAT	1	1,95±0,12^{Aa}	0,96±0,18^{Ad}	1,25±0,18^{Cc}	1,28±0,17^{Cc}	1,47±0,10^{Cb}	*95,145*	*< 0,001*
	2	1,99±0,15^{Ab}	0,94±0,10^{Ad}	1,83±0,12^{Bc}	1,74±0,12^{Bc}	2,08±0,05^{Ba}	*154,29*	*< 0,001*
	3	1,94±0,15^{Ac}	0,96±0,09^{Ad}	2,06±0,15^{Ab}	2,03±0,18^{Ab}	2,19±0,06^{Aa}	*185,96*	*< 0,001*
F		*2,55*	*21,45*	*46,83*	*69,87*	*43,21*		
P intra		*0,06*	*< 0,001*	*< 0,001*	*< 0,001*	*< 0,001*		
TST	1	99,01±0,24^{Aa}	95,73±0,22^{Ab}	81,98±0,25^{Cc}	81,15±0,2^{Cc}	82,66±0,24^{Cc}	*110,264*	*< 0,001*
	2	99,04±1,02^{Aa}	95,60±1,02^{Ab}	83,50±1,02^{Bc}	83,28±1,02^{Bc}	84,49±0,25^{Bc}	*116,82*	*< 0,001*
	3	99,01±0,25^{Aa}	95,70±0,25^{Ab}	85,18±0,24^{Ac}	85,55±0,25^{Ac}	87,54±0,2^{Ac}	*134,713*	*< 0,001*
F		*6 ,32*	*2,54*	*28,79*	*14,68*	*30,54*		
P intra		*0,001*	*0,12*	*< 0,001*	*< 0,001*	*< 0,001*		
TSR	1	8,12±1,16^{Aa}	6,14±1,12^{Ac}	6,83±1,24^{Bb}	6,75±1,16^{Bb}	6,80±1,13^{Bb}	*148,197*	*< 0,001*
	2	8,11±1,13^{Aa}	6,15±1,14^{Ac}	7,78±1,15^{Ab}	7,51±1,12^{Ab}	7,48±1,06^{Ab}	*136,75*	*< 0,001*
	3	8,12±1,15^{Aa}	6,14±1,10^{Ac}	7,89±0,84^{Ab}	7,46±1,08^{Ab}	7,58±0,95^{Ab}	*101,26*	*< 0,001*
F		*2,55*	*2,45*	*46,83*	*69,87*	*43,21*		
P intra		*0,06*	*0,10*	*< 0,001*	*< 0,001*	*< 0,001*		
TFI		0	0	-	-	-		
FAT				Non contenu				

For each character, the values with the same capital letter in each column are statistically identical. On each line, the values with the same lowercase letter are statistically identical.
F, statistical test value; **P inter**, statistical test probability value between cultivars; **P intra**, statistical test probability value within cultivars; **pH**, hydrogen potential; **TAT**, total titratable acidity ; **TST**, total sugar content, **TSR**, reducing sugar content; TFI, crude fiber content; FAT,fat content; **Tém B**, Tém **B**, Tém **R**, Tém **R**, Tém R, Tém R   , **PB121+**, PB121 improved hybrid; **PB121+,** PB113 improved hybrid; **GOA**, West African cultivar.

3.2 DISCUSSION

The color of a food is the first quality factor that the consumer appreciates and has a remarkable influence on its acceptance **[15]**. Crystal sugar was obtained by thermal dehydration of the sap of coconut inflorescences. In this study, three pairs (time/temperature) were tested. Thus, for final temperatures of 120, 140 and 160°C, white, brown and red coconut sugar colors were obtained respectively. The non-enzymatic Maillard reactions would be at the origin of this color change. Several factors are responsible for the differences in the color of coconut sugar. Indeed, the agro-ecological situation, climatic conditions, varieties and the processing process used are said to be at the origin of the coloring of coconut sugar **[16]**. A study in the Philippines showed that coconut sap sugar from coconut varieties planted in the mountains is normally light brown in color and the same coconut varieties, when planted near the sea, produce a dark brown sugar **[17]**. Also, non-enzymatic browning would also be implicated in the color change of coconut sugar. Indeed, this phenomenon of intense browning observed in sugars, would result from the reaction between phenolic compounds and metal ions such as iron (Fe). In addition, oxidation and polymerization of phenols once in contact with oxygen may also cause these different stages of browning **[18]**.

The dry matter content of crystalline sugar produced from the sap of the inflorescences of the cultivars GOA, PB121+ and PB113+ is higher than that measured by **[19]** in crystalline sugar produced from the water of the nuts of these same cultivars. This could be related to the fact that total soluble solids and dry matter contents are higher in sap than in coconut water **[20, 21]**. The difference shows that from the inflorescences, not all the constituents of the sap would be stored in the coconut water. Significant proportions would be used for structural formation and development of nut components. Indeed, sap comes from the hydromineral absorption of coconut trees from the soil (raw sap) and the phenomena of photosynthesis and transpiration (elaborated sap) of the plant **[22]**. It therefore contains nutrients, which are transported and distributed by conductive tissues (xylem and phloem) to different parts of the coconut tree, including nuts **[1]**. In addition, the dry matter contents of coconut sugar that were measured in this study increase with the combination of time and temperature regardless of the cultivar. This phenomenon could be explained by the fact that it is the dissolved and non-volatile macromolecules that form the dry matter of coconut sugar. The dissolution of these constituents would increase with temperature. However, the MST of white and brown sugar from sugar cane, considered as a control sugar in this study, is higher than that of coconut sugar. This could be related to the refining process that sugar cane juice has undergone, unlike coconut sugar, which is obtained by handcrafted processes.

We find that cane sugar samples have a high MSD than coconut sugar and also contain less water. In addition, coconut sugar samples with high MST also contained less water. Thus, the thermal dehydration of coconut sap at high temperatures increases the dry matter content of coconut crystalline sugar and reduces its water content. The decrease in moisture content observed in the study can be rationalized by the thermal dehydration of coconut syrup at high final temperatures.

The ashes contained in coconut crystal sugar decrease with the temperature and cooking time of the sap. However, our results indicate that white cane sugar does not contain ash. Ash levels found in brown cane sugar are comparable to those found by other authors **[23, 24]** and are lower than coconut sugar. Indeed, the refining process of sugar cane sugar includes a step of washing and clarifying the raw sugar crystals. Thus, [**24**] showed that washing removed up to 86% of the ash, indicating that there would be more ash in the surface layer than in the crystal. As the ashes are mainly composed of minerals, white sugar cane sugar would not contain any and its brown sugar would contain less than cane sugar. This result could be linked to the mineral richness of the raw material and the different treatments applied to it. Coconut sap contains more ashes than sugar cane juice **[1, 25]**. The coconut tree could absorb larger quantities of minerals from the soil than sugar cane. These minerals are transported by sap and accumulated in the plant's organs, especially end organs such as leaves and nuts. This is why sap provides less ash than coconuts **[26]**. The mineral accumulation in the terminal plant parts is all the more true as the leaves constitute a support generally used to evaluate the intensity of the coconut tree's mineral nutrition**.**

pH measurements showed that coconut sugar was significantly more acidic than white and brown sugar cane sugar. However, regardless of the treatment applied to the sap of the three coconut cultivars studied, the pH of the sugar from the PB113+ hybrid is statistically higher than that of the PB121+ hybrid and the GOA cultivar. This characteristic, which refers to oxonium ion acidity (HO"), shows that the sap produced by PB113+ coconut hybrids contains less oxonium ions than that of the other cultivars studied. These ions could result from the internal metabolism of the plant which leads to the development of sap. Our coconut sugar samples obtained by a traditional dehydration process, without the addition of preservatives such as lime ($Ca(OH)2$) and maltodextrin, appear to be more acidic than maple sugar, date palm sugar or even coconut sap sugar produced in Indonesia which has a pH of 7.74 **[27, 28, 29,30]**. Indeed, the pH of their sap was higher than that of our solutions, which did not contain preservatives before their transformation into sugar.

It is likely that there is a link between the pH of the solution of the sugars obtained and the initial pH of the sap or juice of their parents. Although few studies have reported the relationship between the initial pH of sap/juice and the pH of the corresponding sweetener or sugar, this hypothesis is supported by the results of some previous studies, particularly when concentrating sugars in syrup or sugar **[31,28,29,32]**.

In addition, for each cultivar, the treatment applied to coconut sap reduces the pH and increases the titratable acidity of the crystalline coconut sugar obtained when the cooking temperature of the sap increases. Indeed, during the heating process, the latent heat is likely to accelerate the action of enzymes acidifying the medium, so the pH of the sugar decreases and thus increases its acidity. This decrease in pH is due to the increase in acidity in the environment, which is explained by the increase in saturated fatty acids present in coconut crystalline sugar. Indeed, the work of **[33]** showed that unlike mono and polyunsaturated fatty acids, saturated fatty acids increase with cooking at between 70 and 90°C. In addition, the analysis of variance shows that crystalline sugar from the sap of the GOA cultivar is statistically more acidic than sugar from the PB121+ and PB113+ hybrids, regardless of the treatment. This difference may be due to the fact that coconut tree inflorescence sap contains different doses of acidic compounds such as ascorbic acid, amino acids, fatty acids and carbon dioxide **[34, 35].**

The total sugar content (TST) of white and brown sugar cane sugar is higher than the total sugar content of coconut crystal sugar samples. However, statistical analysis indicates that this parameter does not induce any statistical difference between cultivars. The total sugar contents measured in our work are comparable to those found in crystalline sugars from coconut trees grown in Thailand **[36]**. Sugars, or carbohydrates, of the general formula (CHO)n, are generally macromolecules that are primarily biosynthesized by plants. They constitute the main energy reserve that supports plant metabolism. In addition, several metabolic cycles, including the glyoxylate cycle, convert proteins and fats into carbohydrates.

In addition, within a given cultivar, the total and reducing sugar contents increase with heat treatment. Indeed, **[37]** Martin et al. 2014 reported that during the coconut sugar manufacturing process, temperature increase could accelerate the hydrolysis of sucrose into reducing sugars. Reducing sugars come from the hydrolysis of the glycosidic bond of polysaccharides such as sucrose in the case of plants of the palmaceae family. However, high levels of reducing sugars were measured in the crystalline coconut sugar samples that were obtained at high final temperatures. According to **[38]**, reducing sugars are substrates that cause sap to brown through Maillard reactions during the production of coconut syrup and sugar

Unlike the crystalline sugar in coconut water, which contains small amounts of lipids and fibers **[19]**, the sap sugar of the cultivars studied does not contain them. This difference could be related to the richness of coconut water in these elements and the manufacturing process of these different crystalline sugars.

4. CONCLUSION

This study was carried out in order to evaluate and compare some physico-chemical characteristics of powdered sugar from the inflorescences of three of the most widespread coconut cultivars in Côte d'Ivoire. These are the traditional variety, Great West Africa (GOA) and the improved hybrids PB121+ and PB113+. For the production of coconut sugar samples, three different pairs (time/temperature) were set and the physico-chemical characterization focused on the sugar samples from each pair by cultivar. Samples of white and brown sugar from sugar cane, sold commercially in Côte d'Ivoire, were used as controls. The physico-chemical characterization of coconut sugar shows that, at high coconut sap cooking temperatures, the color of coconut sugar crystals becomes darker, acidity increases, resulting in a decrease in pH. In addition, white cane sugar does not contain ash and its brown counterpart contains very little ash and their dry matter is mainly composed of sugars. However, no fat and crude fiber were found in crystalline coconut and sugar cane sugars. However, for a better valuation of coconut table sugar in Côte d'Ivoire, additional studies to determine its carbohydrate, mineral, vitamin and energy content should be considered.**COMPETING INTERESTS**

"The authors stated that there are no competing interests."

CONSENT (IF APPLICABLE)

Not applicable

ETHICAL APPROVAL (IF APPLICABLE)

Not applicable

REFERENCES AND REFERENCES

1. KONAN N'Guessan Ysidor, KONAN Konan Jean-Louis, KONAN Brou Roger, ASSA Rebecca Rachel, OKOMA Djeya Muriel Joëlle, ISSALI Auguste Emmanuel & al. Changes in physicochemical parameters during storage of the inflorescence sap derived from four coconut (Cocos nucifera L.) varieties in Côte d'Ivoire. Journal of Experimental Agriculture International. 20015;5(4):352-365.
2. Cortazar R.M., Rogelio F.F. et Fuentes D.A.I.M. C/N, ratio increases in the phloem sap during floral transition of the long-day plants Sinapsis alba and Arabidopsis fhaliana. Plant cellule physiology. 2010;43:684-688.
3. Hebbar, K.B., Arivalagan, M., Manikantan, M.R., Mathew, A.C., Thamban, C., Thomas, G.V. and Chowdappa, P. Coconut inflorescence sap and its value addition as sugar – collection techniques, yield, properties and market perspective. Current Science. 2015;109(8):1–7.
4. P.P. Shameena Beegum, M.R. Manikantan, R. Pandiselvam, M. Arivalagan and K.B. Comparative evaluation of natural vinegar produced from mature coconut water and coconut inflorescence sap. International Journal of Innovative Horticulture. 2018;7(2):123-127.
5. Surendran, I.P. Pancayath institutions and developmental schemes in Lakshadweep. International Journal of Economic and Business Review. 2015;3:121-126.
6. Van der Vossen H.A.M. & Chipungahelo G.S.E. Cocos nucifera L. In vegetable oils/Oléagineux. Van der Vossen H.A.M. and Mkamilo G.S. Editions, Wageningen, Netherlands, Prota. 2007;14:67-72.
7. Okoma.D. Muriel, Konan.K. Jean-Louis, R. Assa.Rebecca and Konan. N. Ysidor. Development of a Method to Produce Granulated Sugar from the Inflorescences Sap of Coconut (Cocos nuciferaL.) in Ivory Coast: Case of Hybrid PB113+. Journal of Experimental Agriculture International. 2019;39(2):1-9.
8. Naknean, P.; Meenune, M.; Roudaut, G., "Characterization of palm sap harvested in Songkhla province, Southern Thailand. International Food Research Journal. 2010;17:977-986.
9. AOAC standard, 1990. AOAC. Association of Official Analytical Chemist, Arlington. Official methods of analysis.
10. Dubois M., Gilles K., Hamilton J., Rebers P. et Smith F. Colorimetric method for the determination of sugars and related substances. Analytical Chemistry. 1956;280:350-356.

11. Bernfeld P. Amylase β and α (Assay method), in methods in enzymology I, Colowick an Kaplan. Edition Academic press. 1995; New York, pp. 149-154.
12. AFNOR. Huiles essentielles : recueil de normes françaises/AFNOR. 2ème Edition. 1986;474 p.
13. Wolff. J.P. Manuel d'analyse des corps gras. Azoulay Edition Paris. 1968 ; 517 p.
14. Naknean, P., Meenune, M. and Roudaut, G. Changes in properties of palm sugar syrup produced by an open pan and a vacuum evaporator during storage, International Food Research Journal. 2013;20(5):2323-2334.
15. Bambang Nurhadi, Nandi Sukri, Wahyu Kristian Sugandi, Annisa Puteri Widanti, Resi Restiani, Ziske Noflianrini, Bayu Rezaharsamto & Marleen Herudiyanto. Comparison of crystallized coconut sugar produced by traditional method and amorphous coconut sugar formed by two drying methods: vacuum drying and spray drying. International Journal of Food Properties. 2018;21(1):2339-2354.
16. Websit of Coconut Sugar Philippines. "Coconut Sugar Health Info." 2009. http://www.coconutsugarphilippines.com/ coconutsugarhealthinfo.php.
17. Romain J., Thomas C., Pierre S. et Gérard B. Science des aliments : Biochimie-Microbiologie-Procédés-Produits, volume 2 : Technologie des produits alimentaires. Ed, TEC & DOC, Lavoisier. 2006;p 180.
18. Lathro Akpro Anselme, Konan Konan Jean-Louis, Grodji Gbogouri Albarin, Brou Konan Roger, Yao Saraka Didier. Physicochemical coconut water assessment and of the microbiological quality of its sugar extracted of five coconuts ecotypes at the Marc Delorme station, Côte d'Ivoire. International Journal of Applied Biology and Pharmaceutical Technology. 2018;1(9):24-31.
19. Kamolwan Jangchud, Pimolpan Puchakawimol and Anuvat Jangchud.2007. Quality changes of burnt aromatic coconut during 28-day storage in different packages. Food Science and Technology. 2007;40(7):1232-1239.
20. Yong, J.W.H.; Ge, L.; Ng, Y.F.; Tan, S.N. The Chemical Composition and Biological Properties of Coconut (*Cocos nucifera* L.) Water. *Molecules.* **2009**;14:5144-5164.

21. Loustau D, Domec J-C and Bosc A. Interpreting the variation in xylem sap flux density within the trunk of maritime pine (Pinus pinaster Ait.): application of a model for calculating water flows at tree and stand levels. Ann. Sci. For. 1998;55:29–46.
22. Mathlouthi. Amorphous sugar. 1995;P 75-100.

23. Marianne McKee, Ronnie Triche and Charley Richard. Sugar Processing Research. Institute, Inc New Orleans. 2011; La 70124.
24. M.A. Clarke. Cane Syrups, Golden Syrups, and Molasses. Encyclopedia of Food Sciences and Nutrition (Second Edition). 2003
25. Konan N.Y., Konan J.L., Assa R.R., Niamké S., Allou K. et Biego H. Caractérisation physicochimique de l'eau des noix matures de nouveaux hybrides améliorés de cocotiers (Cocos nucifera L.) grands. International Journal of Biological and Chemical Sciences 2013;7 (6):2385-2395.
26. Somawiharja, Y., Wonohadidjojo, D.M, Kartikawati, M., Suniati, F.R.T. and Purnomo, H. 2018. Indigenous technology of tapping, collecting and processing of coconut (Cocos Nucifera) sap and its quality in Blitar Regency, East Java, Indonesia. Food Research. 2018;2(4):398-403
27. Ben Thabet, Souhail Besbes, Hamadi Attia, Claude Deroanne, Frédéric Francis, Nour-Eddine Drira & Christophe Blecker. Physicochemical Characteristics of Date Sap "Lagmi" from Deglet Nour Palm (Phoenix Dactylifera L.). International Journal of Food Properties. 2009;12:3, 659-670.
28. Clement, A., L. Lagace and B. Panneton. Assessment of maple syrup physico-chemistry and typicity by means of fluorescence spectroscopy. J. Food Eng. 2010;97:17-23.
29. Heiligmann, R.B., P. Smallidge, G.W. Graham, and B. ChaboT. Managing maple trees for sap production in North American maple producer's manual, 2nd Ed. 2006; P.31–80.
30. Apriyantono, A, Aristyani, A., Nurhayati, Lidya, Y., Budiyanto, S. and Soekarto, S. T. Rate of browning reaction during preparation of coconut and palm sugar, International Congress Series, 1245. 2002;P 275- 278.
31. Ho, C.W., Wan Aida, W.M., Maskat, M.Y. and Osman, H. Effect of thermal processing of palm sap on physic-chemical composition of traditional palm sugar. Pakistan Journal of Biological Sciences. 2008;11 (7):989–995.

32. Chen A., Roberts C., Barnard R. Effect of a short-tem diet and exercise intervention on metabolic syndrome in overweignt children. Metabolism Clinical and Experimental. 2006;55,871-878.
33. Renata V., Vera L.S., Fagundes-Neto U. Biochemical profile of coconut water from coconut palms planted in an inland region. Jornal de Pediatria (Rio J). 2006;82(4):308-312.
34. Naozuka J., Da Veiga M.A.M.S., Richter E.M., Paixão T.R.L.C., Angnes L. & Oliveira P.V. Use of metals and anion species with chemometrics tools for classification of unprocessed and processed coconut waters. Food Analytical Methods. 2011;4:49-56.
35. Sikaret Kongkaew, Manat Chaijan, and Siriporn Riebroy. Some Characteristics and Antioxidant Activity of Commercial Sugars Produced in Thailand. Kmitl Science and Technology Journal. 2014;14(1):1-9
36. Martin, W., B. Cairns, and G. Bal. Adjoint methods for adjusting three-dimensional atmosphere and surface properties to fit multi-angle/multi-pixel polarimetric measurements. Journal of Quantitative Spectroscopy & Radiative Transfer. 2014;144:68-85.
37. Naknean P, Meenune M and Roudaut. Characterization of palm sap harvested in Songkhla province, Southern Thailand. International Food Research Journal. 2010;17:977-986.