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### RESEARCH ARTICLE

#### FUNCTIONAL PROPERTIES OF TABLE SUGARS DERIVED FROM THE SAP OF THE INFLORESCENCES OF 03 COCONUT (COCOS NUCIFERA.L) CULTIVARS IN CÔTE D'IVOIRE

**Okoma D. Muriel J.<sup>1</sup>, Konan K. Jean Louis<sup>1</sup> and Assa Rebecca R<sup>2</sup>**

1. Marc Delorme Research Station for coconut, National Centre of Agronomic Research (CNRA), Abidjan, Côte d'Ivoire.
2. Laboratory of Biochemistry and Food Sciences, UFR Biosciences, University Felix Houphouët Boigny, Abidjan, Côte d'Ivoire.

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#### *Abstract*

This study is part of a context of diversification of the uses of the Ivorian coconut tree. The objective was to determine the functional characteristics of crystalline sugars derived from the sap of inflorescences of three coconut cultivars. Red and white sugars from cane were taken as controls. Variations in final temperatures coupled with distinct cooking times were carried out in order to evaluate the effect of the time/temperature couple on the studied parameters. Thus, three different treatments were applied. The functional characterization of the sugars studied shows that coconut sugars are an important source of total polyphenols with levels ranging from 34.64 to 143.12 mg/100g. No polyphenolic compounds were assayed in white cane sugar. Coconut sugars from treatment 1 are less energetic than those from the other two treatments. On the other hand, brown and white sugars from sugar cane are more energetic than those from coconut trees. In view of all the above, coconut sugars, especially those from treatment 1, are natural sweeteners with a low energy value. In addition, they are rich in polyphenols and flavonoids, unlike refined cane sugar and its red counterpart which contains very few nutrients. Thus, coconut sugars produced in Côte d'Ivoire can be considered as a phytonutrient substitute, capable of replacing sugarcane sugars.

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#### **Introduction:-**

In Côte d'Ivoire, coconut is cultivated on 50,000 ha, 90% of which are spread along the coast where it is the main cash crop for 20,000 families (CNRA, 2015). This coconut grove provides an average annual yield of 500 million nuts. The nuts are mainly sold by the producers as whole nuts, deburred or dried copra. The country produces an average of 625,000 tons of copra per year (CNRA, 2015), which represents 0.18% of the Gross Domestic Product (GDP). Côte d'Ivoire is Africa's leading exporter of coconut products (Konan andal, 2014). Most of the work done in technology in Côte d'Ivoire focuses on nuts. Indeed, copra is the most important form of coconut value addition in Côte d'Ivoire. It is mainly used to produce oil. However, the fall in the market value of coconut oil, due to competition from other oilseeds, has led to a massive abandonment of the nucicultural sector.

**Corresponding Author:- Okoma D. Muriel. J**

Address:- Marc Delorme Research Station for coconut, National Centre of Agronomic Research (CNRA), Abidjan, Côte d'Ivoire.

Among the many ways of adding value to the coconut tree, in Asia, the sap from the inflorescence occupies an important place and is of growing interest. With 13 to 17% carbohydrates, it is almost as rich as sugar cane juice (Konan and al., 2014; Xiaet al., 2011) and is almost acid-base neutral, containing water-soluble vitamins (Hebbarand al., 2015).

In Côte d'Ivoire, with the exception of the recent work carried out on the biochemical properties of the sap of coconut inflorescences, its valorization into table sugar has not yet been done. However, in view of the drop in copra prices, the diversification of coconut uses is essential.

Much work has been done in Asia on the biochemical properties of coconut sugar.

However, the protocols on the method of producing crystal sugar from sap are ambiguous and very imprecise, making them non-reproducible.

In addition, no study has been done on sugars derived from the sap of the different varieties of coconut palm popularized in Côte d'Ivoire. However, at the genetic, agronomic and morphological levels, diversities are observed in these coconut cultivars.

In addition, the alarming evolution of metabolic diseases has raised public health policy concerns. Thus, the search for alternatives aimed at developing natural sweeteners to replace industrial sugars is encouraged.

Consequently, the general objective of this study is to determine the functional characteristics of crystalline sugars derived from the sap of inflorescences of three coconut cultivars (*Cocos nucifera*. L) as a function of the time/temperature couple in Côte d'Ivoire.

## **Materials and Methods:-**

### **Hardware**

### **Biological material**

The biological material consisted of sap from the inflorescences of row 8 (Figure 17) of three coconut cultivars. These came from plots 043, 034 and 064 of the CNRA Station Marc-Delorme which are located respectively 1.8, 2 and 1.5 km from the laboratory. These cultivars are:

1. -Great West Africa (GOA), originating from West Africa, which has an earliness of 7 years with a yield of 0.7 t to 1.5 t copra/ha/year. It was planted in 1998 on plot 043.
2. -The PB121<sup>+</sup> hybrid resulting from the cross between the Malaysian Yellow Dwarf (MJD) and the improved GOA was created by WHRI-assisted pollination in 1964 (De Nuce and Rognon, 1986). Its improved version was created in 1992. It has the best average yield per hectare in the world (4 t copra/year). It is the most widespread coconut palm in the world (Konan, 2005). On plot 064, the trial that houses it was planted in 1996.
3. -The PB113<sup>+</sup> hybrid, resulting from a cross between the Red Dwarf of Cameroon (NRC) and the improved Grand Rennel (GRL). It produces 4 t copra/year. It was also created in 1992 and has been planted on plot 034 since 1996.

This choice is motivated by the fact that the GOA cultivar is traditionally the most widespread local variety in Côte d'Ivoire and is used as a control in all experiments on large coconut trees. PB121+ and PB113+ are the hybrids that the CNRA has popularized worldwide for their high productivity and tolerance to certain biotic and abiotic stresses.

Samples of commercially available white sugar (Tém B) and brown sugar (Tém R) from sugar cane were used as controls.

### **Equipment for harvesting and processing the sap of coconut inflorescences:**

To harvest the sap, a ladder was used to reach the spathe, it was tied with a wire and a knife was used to cut it. Cans were used to collect the sap. An electric hot plate (TRIOMPH) equipped with a temperature and time regulator was used to vaporize the sap. The heating of the sap also required a frying pan and stainless spatulas.

## Methods:-

### Coconut sugar production methods

Sap from the inflorescences of the three coconut cultivars was collected and processed using the **Okoma and al. (2019)** method. The freshly collected sap was first sprayed for 30 minutes at an increasing temperature of 60-140 °C. The sap was then processed by the Okoma method [7]. One liter of sap was boiled for two, three, five, eight and twelve minutes at 60, 80, 100 and 120 and 140°C respectively.

At the end of this step, a syrup is obtained, then kneaded with a wooden spatula to aerate the medium and cooled at room temperature (25°C) for 10 minutes. This resulted in a viscous mass which was sprayed a second time at 60°C for 30 minutes followed by mixing with a spatula for 20 minutes.

However, variations in the final temperatures coupled with different firing times were carried out in order to evaluate the effect of the time/temperature couple on the studied parameters.

Thus, three different time/temperature pairs or treatments were applied.

Indeed, one liter of sap is transformed into crystalline sugar during 45, 40 and 35 minutes at temperatures varying from 60-120; 60-140 and 60-160°C respectively for treatments T1, T2 and T3.

### Constitution of sugar batches

The T1, T2 and T3 treatments applied generated three (3) batches of sugars per variety. The study covered three campaigns during the year 2017, January, June and December. Nine batches of coconut crystalline sugar were produced per campaign and two batches of sugars (brown and white) of cane were sampled. In total, 27 batches of coconut crystal sugar were produced and six batches of cane sugars were analyzed. The physico-chemical parameters were repeated three times and each lot was analyzed.

### Functional characterization

#### Total protein

The protein contents were obtained by the Kjeldahl method(**AOAC 1990**), using the total nitrogen content of the sample. The method consists of several steps, including mineralization, distillation and titrisol NaOH (0.1N) assay.

Two grams of sugar sample were dried in an oven at 70° C for 10 hours to determine the dry matter content (% DM). The test sample (PE) thus corrected (PNe) was then used for the nitrogen determination.

The following formulas were used to determine the protein content.

$$M N (\text{mg}) = 14 \text{ mg N} \times 0, 1 \times V \text{ HCl}$$

$$\% \text{ nitrogen} = \frac{M N}{10 \times PNe}$$

Total protein as a percentage of dry sample mass (dry matter) is determined by this equation:

$$\text{Total protein (\%)} = 6.25 \times \text{Total nitrogen (\%)}$$

**PNe:** Net Sample Weight

**V HCL:** Volume of chloridric acid

**0,1:** Acid normality

**M N:** Mass of nitrogen

**6.25:** Nitrogen-to-protein conversion factor (**FAO, 1998**)

#### Energy value

The energy value (VE) of sugars was determined according to the **Akpabio and al. (2012)** method [10], using the following formula:

$$\text{VE (Kcal/100 g)} = 9 \text{ TMG} + 4 \text{ TST} + 4 \text{ TPr} + 3 \text{ TAT} (2)$$

**VE:**Energy value in Kcal/100 g, **TMG:** Fat content, **TST:** Total sugars content, **TPr:** Protein content, **TAT:** Titratable acidity content.

### Total polyphenol content

The determination of total polyphenols in the sugar samples was carried out according to the **Singleton and Rossi, (1965)** method using the ciocalteus folin reagent. The processing of the samples was done in two phases.

In the <sup>first</sup> phase, all the polyphenolic or non-polyphenolic compounds, capable in alkaline medium of reducing the reagent of folin ciocalteu were measured. For this purpose, 10 g of crystalline sugar was dissolved in 90 mL of distilled water ( $s_1$ ). Then, 100  $\mu$ L of  $s_1$  was introduced into test tubes and 500  $\mu$ L of folin reagent ciocalteus diluted 1/10 with distilled water was added. After two minutes, 400  $\mu$ L of 20% (w/v) sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) was added to start the redox reaction. The mixture was then placed in a 40°C water bath for five minutes and kept in the dark for 30 minutes at room temperature. This allowed the development of a blue coloration characteristic of the presence of polyphenols.

In the second phase, a specific polyphenol compound, polyvinylpyrrolidone (PVPP), was used to bind the polyphenols (**Boizot and Charpentier, 2006**).

Two mL of dilute sugar solution ( $s_1$ ) was taken from centrifuge wells to which 0.1 g PVPP was added. The mixture was homogenized and then centrifuged at 5000 rpm for 10 min. The supernatant was collected and 100  $\mu$ L was removed to undergo the same treatment described in Phase 1.

The OD reading was taken at 760 nm with the spectrophotometer. The control contained distilled water in place of the sample. The difference between the ODs obtained with PVPP and without PVPP was used to determine the true ODs of the total polyphenols in the samples. A calibration curve obtained from different concentrations of a standard phenolic compound, gallic acid (or 3,4,5 -trihydroxybenzoic acid) with an initial concentration of 0.5 mg/mL, was used to determine the total polyphenol contents of the crystal sugar samples.

### Dosage of flavonoids

The determination of flavonoids was performed according to the method described by **Meda and al. (2005)**. A 1:10 diluted crystalline sugar extract solution was prepared from 10 g sugar and 90 mL distilled water. Subsequently, 0.5 mL of the resulting solution was introduced into a test tube.

To the contents of the tube were added successively 0.5 mL distilled water, 0.5 mL 10% (w/v) aluminum chloride, 0.5 mL 1 M potassium acetate and 2 mL distilled water. The tube is left standing for 30 min in the dark and the OD is read at 415 nm against a blank. A standard range established from a quercitrine stock solution (0.1 mg/mL) under the same conditions as the assay was used to determine the amount of flavonoids in the sample.

### Statistical Analysis

The statistical analysis of the data consisted of univariate analyses. In this case, the descriptive analysis of the functional parameters of coconut sugar. This concerned the determination of the minimum, maximum, coefficient of variation of the quantitative parameters and the frequency of modalities of the different qualitative parameters.

Next, the comparative analysis of the three cultivars was performed using the single criterion analysis of variance (ANOVA 1). Indeed, this ANOVA test is preceded by the MANOVA (Multiple Analysis of Variance) in order to check if the variables taken together make it possible to highlight the existence of a significant difference between the cultivars on the basis of the analyzed parameters. The ANOVA 1 test was followed by the post-ANOVA test of the smallest significant difference (ppds).

## Results:-

### Protein content

**Table 1** shows that the protein contents of the coconut sugars studied vary from  $0.2 \pm 0.04$  (PB121+, T1) to  $0.67 \pm 0.16$  g/100g (GOA, T3) regardless of the treatment applied. They are statistically superior to those of brown cane sugar ( $0.13 \pm 0.04$  and  $0.14 \pm 0.08$  g/100g). No protein was determined in white cane sugar.

Nevertheless, within each cultivar, the treatment induces an ascending classification of the protein content of sugars

and subdivides them into three significantly different groups. The sugars of cultivars PB121+, PB113+ and GOA, derived from the T1 treatment, contain the lowest protein contents ( $0.20\pm 0.04$ ;  $0.24\pm 0.03$  and  $0.28\pm 0.04$  g/100g, respectively). The T3 treatment provides significantly higher protein levels ( $0.45\pm 0.10$ ;  $0.59\pm 0.10$  and  $0.67\pm 0.16$  g/100g) (**Table 1**).

#### Energy value

The energy value (VE) of the coconut sugar produced from processing 1 ranges from  $329.4\pm 4.28$  (PB113+) to  $336.17\pm 3.47$  Kcal/100 g (GOA) (**Table 1**). However, it increases to a statistically higher value of  $346.48\pm 4.36$  Kcal/100 g (GOA) for treatment 2, but the highest energy values are recorded for sugars from treatment 3, with  $348.7\pm 5.64$  (PB121+),  $342.65\pm 4.71$  (PB113+) and  $359.41\pm 5.62$  Kcal/100 g (GOA). For this treatment, the sugar of the PB113+ hybrid is less energetic. In addition, the EVs provided by the brown ( $386.78\pm 4.02$  Kcal/100 g) and white ( $402.13\pm 5.17$  Kcal/100 g) sugars of sugar cane are statistically higher than those of coconut sugar.

#### Polyphenol contents

Total polyphenol (TP) levels in coconut sugars vary significantly from  $34.64\pm 1.95$  (GOA, T3) to  $143.12\pm 5.17$  mg/100g (PB113+, T1) and are statistically higher than those of brown sugar ( $20.37\pm 2.12$  mg/100g) (**Table 1**). Regardless of the treatment applied, white and brown sugars from sugar cane contain significantly less TPT than coconut sugars. Regardless of the cultivar, PB121+ ( $100.74\pm 4.35$  mg/100g), PB113+ ( $143.12\pm 5.17$  mg/100g) and GOA ( $62.22\pm 3.22$  mg/100g), sugars from treatment 1 contain significantly more total polyphenols than those from the other two treatments.

However, sugars of the cultivars PB121+ ( $91.76\pm 6.05$  mg/100g), PB113+ ( $122.88\pm 4.92$  mg/100g) and GOA ( $36.35\pm 2.46$  mg/100g) from treatment 2 contain statistically more polyphenols than those from treatment 3 ( $44.07\pm 2.84$ ;  $69.01\pm 3.08$  and  $34.64\pm 1.95$  mg/100g), respectively in the same ecotypes.

#### Flavonoid contents

The flavonoid contents of the studied coconut sugars reported in **Table 1** range from  $2.87\pm 0.98$  (PB121+, T3) to  $7.25\pm 1.95$  mg/100g (PB113+, T1). Significant differences exist between the sugars of the studied coconut cultivars and those of the sugarcane controls (Pinter < 0.001).

Regardless of the treatment applied; 1, 2 or 3, the PB113+ hybrid ( $7.25\pm 1.95$ ;  $4.44\pm 0.83$  and  $3.54\pm 0.75$  mg/100g) provides sugars that are statistically richer in flavonoids than the sugars of the other two cultivars.

However, treatments 2 and 3, do not induce a significant difference between PB121+ ( $3.92\pm 0.13$  and  $2.87\pm 0.98$ ) and GOA ( $3.22\pm 0.44$  and  $2.44\pm 0.42$ ). The treatments grouped the flavonoid contents of the sugars studied into three groups.

The first group consists of the sugars produced by treatment 1. Thus, PB113+ ( $7.25\pm 1.95$  mg/100g), PB121+ ( $6.31\pm 1.02$  mg/100g) and GOA ( $4.60$  mg/100g) contain respective levels of flavonoids at treatment T1 ( $7.25$ ;  $6.31$  and  $4.60\pm 0.88$  mg/100g), which are higher than the sugars of the second group, from treatment 2, ( $4.44\pm 0.83$ ;  $3.92\pm 0.13$  and GOA  $3.22\pm 0.44$  mg/100g; respectively for the same cultivars). The lowest levels are recorded with the sugars from treatment 3.

**Table I:-** Functional characteristics of the crystalline sugars studied.

Features	Treatments	Cultivars			Wit B	Wit R	F	P inter
		PB121+	PB113+	GOA				
	T1	0.20±0.04 Cb	0.24±0.03 Ca	0.28±0.04 Ca	0	0.14±0.02 Ac	67,81 7	< 0,00 I
<b>TPR (g/100g)</b>	T2	0.38±0.05 Bb	0.41±0.07 Bb	0.57±0.02 Ba	0	0.13±0.04 Ac	48,29	< 0,00 I
	T3	0.45±0.10 Ab	0.59±0.10 Aa	0.67±0.16 Aa	0	0.14±0.08 Ac	80,57	< 0,00 I
<b>EV (Kcal/100g)</b>	T1	332.47±4.54 Cc	329.4±4.28 Cc	336.17±3.47 Cc	401.89±5.24 Aa	386.36±4.12 Ab	110,2 64	< 0,00 I
	T2	341.01±5.36 Bc	339.98±6.64 Bc	346.48±4.36 Bc	402.13±5.17 Aa	385.78±4.02 Ab	116,8 2	< 0,00 I
	T3	348.7±5.64 Ac	342.65±4.71 Ad	359.41±5.62 Ac	401.86±6.25 Aa	386.24±4.82 Ab	134,7 13	< 0,00 I
<b>TPT (mg/100g)</b>	T1	100.74±4.35 Ab	143.12±5.17 Aa	62.22±3.22 Ac	6.53±0.90 Ae	20.37±2.12 Ad	111,8 9	< 0,00 I
	T2	91.76±6.05 Bb	122.88±4.92 Ba	36.35±2.46 Bc	6.55±0.50 Ae	20.25±2.44 Ad	136,7 5	< 0,00 I
	T3	44.07±2.84 Cb	69.01±3.08 Ca	34.64±1.95 Cc	6.52±0.85 Ae	20.14±2.10 Ad	101,2 6	< 0,00 I
<b>TFLA (mg/100g)</b>	T1	6.31±1.02 bA	7.25±1.95 aA	4.60±0.88 cA	1.11±1.19 eA	2.27±0.22 dA	103,6 4	< 0,00 I
	T2	3.92±0.13 bB	4.44±0.83 aB	3.22±0.44 bB	1.15±1.17 dA	2.31±0.15 cA	77,23	< 0,00 I
	T3	2.87±0.98 bC	3.54±0.75 aC	2.44±0.42 bC	1.13±1.18 cA	2.30±0.50 bA	50,81	< 0,00 I

For each character, the values with the same capital letter in each column are statistically identical. For each row, the values with the same lowercase letter, in each row, are statistically identical. **F**, value of the statistical test; **P inter**, value of the probability of the statistical test between cultivars; **TPR**: protein content; **TGT**: total carbohydrate content; **VE**: energy value; **TPT**: total polyphenol content; **TFLA**: flavonoid content; **Tém B** : Sugar control Sugar cane white; Control **R**: Sugar control Sugar cane red; **PB121+**: PB121 improved hybrid; **PB113+**: PB113 improved hybrid; **GOA**: Great West African cultivar; **T1**: treatment 1; **T2**: treatment 2; **T3**: treatment 3

### Discussion:-

However, the proteins in the sap sugar of coconut inflorescences are present in small quantities and are higher than those of brown cane sugar, whereas the white control does not contain any. In coconut, the protein content increases

with the cooking temperature of the sap. Indeed, the heat allows the release of proteins into the medium. This explains their relatively high number in the sugars of treatments 2 and 3. Thus, heat facilitates their dosage in coconut sugars according to **Howe et al. (2005)**. These results also confirm the work of **Antoine et al. (2010)** who also made the same observation. Our results are in line with those of **Choong et al. (2016)** who found that he measured 0.28 mg/100 g of protein in palm crystal sugar, whereas refined cane sugar did not contain any. The refining process of cane sugar would have a depressant effect on all nutrients including protein. In general, the protein acts as a substrate in the Maillard reactions that occur in the production of coconut sugar. Thus, high levels could influence the quality of coconut sugar (**Naknean and Meenune, 2016**).

Sugars or carbohydrates, of general formula  $(CHO)_n$ , are generally the macromolecules that are primarily biosynthesized by plants. They constitute the major energy reserve that supports the metabolism of plants.

In addition, several metabolic cycles, including the glyoxylate cycle, convert proteins and lipids into carbohydrates.

Thus, the energy value (EV) of coconut crystal sugar is mainly dependent on its carbohydrate content. It has been shown that white cane sugar is more energetic than coconut sugars. However, for a given cultivar, the energy value increases with temperature. Indeed, heat treatments, especially cooking, increase the protein, lipid and ash content of food (**Antoine et al., 2010**). These molecules have been used in the calculation of the energy value of sugars and even participate, as far as proteins and lipids are concerned, in neoglucogenesis.

Over the past decade, there has been considerable interest in bioactive compounds in foods. The various researches on the phytochemical profiles of foods have focused on the role of their consumption in the prevention of diseases related to oxidative stress.

Among these compounds of nutritional interest, polyphenols have been widely highlighted for their health benefits (**Acosta-Estrada et al., 2014**).

The results of this study reveal that sugars from coconut cultivars are much richer in polyphenols than brown cane sugar, which contains very little polyphenols while its white counterpart does not.

The different cane sugar refining operations for the removal of impurities and decolorization of raw sugar would affect the amount of polyphenols in the cane sugars. On the other hand, there is a temperature depressing effect on the polyphenol content of coconut sugars with a decrease of about 50% from the first to the third treatment.

Most thermal processes lead to a degradation of phenolic compounds.

Indeed, according to **Igualet et al. (2013)**, heat treatments applied during jam production cause a significant decrease in polyphenols. **Klopotek et al. (2005)** showed that, during the transformation of strawberries into juice, pasteurization at 85°C for 5 minutes resulted in a 30% loss of polyphenols.

Other authors, however, revealed a positive effect of heat on polyphenol content. This is the case of **Colin-Henrion, (2008)** who indicates that during the cooking of apples in compote, an average increase of 50% in the polyphenol content is observed. **Leong and Oey (2012)** examined the effects of short-term heat treatment (110°C for 8 seconds) on enzymes and phenolic compounds in apricot nectar. The results show that heat treatment leads to complete inactivation of the enzymes (polyphenol oxidase and peroxidase), as well as a significant increase in the content of phenolic compounds (**Acosta-Estrada et al., 2014**). According to these authors, the increase in polyphenol content is due to a release of phenolic compounds that were initially associated with the cell walls. While the heat induced during the different treatments led to a degradation of these walls.

Unlike refined cane sugar, our results are different from those reported by **Choong et al. (2016)**. Indeed, these authors studied the physico-chemical properties of crystalline sugar of the *Arenga pinnata* palm in comparison with cane sugar. Their results corroborate the inexistence of polyphenols in white cane sugar. On the other hand, the levels of polyphenols obtained in coconut sap sugar are much higher than those of *Arenga pinnata* palm sugar. The sap of coconut tree inflorescences would be richer in polyphenols than that of palm. Moreover, the work of **Lathro (2019)**, on the same plant material as ours, has revealed lower polyphenol contents.

These differences could be due to the fact that the sap from coconut inflorescences contains more polyphenols than the water in the nuts. Due to its greater involvement in the plant's life, coconut sap contains more polyphenolic elements than coconut water (Konan et al., 2013).

Among all phenolic compounds, flavonoids are the most abundant.

The flavonoid contents of coconut sugars, like total polyphenols, are all higher than those of brown cane sugar. The PB113+ hybrid is also predominant. The presence of polyphenols is more marked in the sugars from the first treatment.

This is thought to be due to the degradation of certain polyphenolic molecules under the effect of heat and the action of polyphenol oxidase enzymes (Konan et al., 2013), which are activated when the firing temperature is between 60 °C and 100 °C.

Polyphenolic compounds such as flavonoids are important antioxidants that protect biological macromolecules from degradation (Xia et al., 2011).

In addition, various epidemiological studies have shown the existence of an inverse correlation between the consumption of polyphenol-rich foods and the risk of developing cardiovascular disease.

However, the available data on the effects of polyphenols on human cancers are more disparate. Their action on human cancer cell lines is frequently protective and induces a reduction in the number of tumors and their growth (Scalbert et al., 2005).

Moreover, they could reduce the risk of a number of pathologies, in particular those related to aging and oxidative lesions responsible for cancer, cardiovascular disease or neurodegeneration (Acosta-Estrada et al., 2014). Data on the effects of polyphenols in the prevention of diabetes in humans are less numerous than in animals. Indeed, the acute or chronic administration of polyphenols in animal models has shown effects on glycemia. They act through various mechanisms, including inhibition of intestinal glucose absorption (Dembinska-Kiec et al., 2008). They also play an important role in the assimilation of glucose in peripheral tissues, through the inhibition of gluconeogenesis, adrenergic stimulation of glucose absorption or insulin release from pancreatic  $\beta$  cells (Scalbert et al., 2005).

Thus, coconut sugar can be considered a functional food because of the considerable amount of total polyphenols it contains with antioxidant properties (Leccese et al., 2011).

### **Conclusion:-**

Our results reveal that within each cultivar, the different treatments applied induce an increase in energy value. On the other hand, the total polyphenol and flavonoid contents decrease when the temperature increases. The functional characterization of crystalline sugars from the sap of three coconut cultivars according to the time/temperature couple shows that these sugars are an important source of total polyphenols with contents varying from 34.64 to 143.12 mg/100g.

It is treatment 1 that provides a significant amount of polyphenols.

No polyphenolic compounds have been dosed into the white cane sugar. Regardless of the treatment applied; 1, 2 or 3, the PB113+ hybrid ( $7.25 \pm 1.95$ ;  $4.44 \pm 0.83$  and  $3.54 \pm 0.75$  mg/100g) provides sugars that are statistically richer in flavonoids than the sugars of the other two cultivars.

Coconut sugars from treatment 1 are less energetic (332.47 to 336.17 Kcal/100g) than those from the other two treatments. On the other hand, brown (386 Kcal/100g) and white (401 Kcal/100g) sugars from sugar cane are more energetic than those from coconut.

In view of all the above, coconut sugars, especially those from treatment 1, are natural sweeteners with a low energy value. In addition, they are rich in polyphenols and flavonoids, unlike refined cane sugar and its red counterpart which contains very few nutrients.



Thus, coconut sugars produced in Côte d'Ivoire can be considered as a phytonutrient substitute, capable of replacing sugarcane sugars.

### Contribution of the authors

This work was carried out in collaboration among all authors. Authors ODMJ, ARR and KKJL designed and wrote the study protocol. Author ODMJ conducted the documentary research, conducted the laboratory analyses, the statistical analysis and the first draft and revised the manuscript. Authors KKJL and ARR took part in the interpretation of the results and provided a major contribution in the elaboration of the final document.

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### Competing interests:

Authors have declared that no competing interests exist.

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