Postprandial Blood Glucose And Glycaemic Index Of Immature Coconut Nuts Water (*Cocos Nucifera* L.) : Varieties Tall, Hybrid And Dwarf Of International Collection In Côte d'Ivoire

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ABSTRACT

Aims: Coconut water is a drink increasingly popular among populations and manufacturers recommend its large-scale marketing in the form of cans. Such an innovation would attract a greater number of consumers. This stady aims to determine the glycemic response and the glycemic index of coconut water in.

Study design: Can immature coconut water be consumed without risk by diabetics regardless of the variety?

Place and Duration of Study: Nangui Abrogoua University, National Centre for Agricultural Research, Abidjan, Côte d'Ivoire,. It took place from February to November, 2020

Methodology: The differents varieties tested are the West African Tall (WAT), the Malaysian Yellow Dwarf (MYD), Equatorial Guinea Green Dwarf (EGD), Port-Bouêt 121$^+$ (PB 121$^+$) and Port-Bouët 113$^+$ (PB 113$^+$). Thus, respectively, 750, 750, 850, 900 et 850 mL of water were consumed by each of the subjects making up the cohort of this stady. Hair samples after ingestion of water made it possible to determine postprandial glycemic responses. Then, using standard methods in force, the glycemic indexes of the water of these same varieties were also analyzed.

Results: The results showed that coconut water from MYD (7.3 mmol/L), EGD (6.90 mmol/L) et WAT (6.80 mmol/L) varietés give higher glycemic responses compared to PB121$^+$ (6.52 mmol/L) et PB113$^+$ (5.6 mmol/L). Regarding the glycemic index, these are rather the PB121$^+$(46.36%), NJM(44.72%) and PB113$^+$(43.71%) varieties which had values greater than EGD (41.50%) and WAT (40.04%) varieties. In view of the results obtained the water of each of the five varieties studied is classified as foods with a

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low glycemic index according to current standards.
Conclusion: Thus, According to international standards on the glycemic index, coconut water can be consumed without any problems by people of all ages. Nevertheless, moderate consumption is recommended for diabetics.

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Keywords: *Glyceamic index, immature coconut, postprandial blood glucose, Côte d'Ivoire*

1. INTRODUCTION

The coconut palm has a liquid in its cavity, called coconut water. This water is used as an intravenous serum because it meets two conditions. Firstly, the liquid is absolutely sterile in the intact nut; it remains sterile as long as aseptic precautions are taken when extracting it (**Bourdeix *et a.,* 2005)**. With regard to its composition, the work of **Naozuka *et al*** **(2011)** has shown the presence of several minerals in coconut water, with a greater proportion of potassium. It is very lipid-free but relatively rich in sugars, the main ones being fructose, glucose and sucrose (**Assa *et al.*, 2006)**. It also contains sorbitol, a hyperglycaemic carbohydrate, but in insignificant quantities (**Assa, 2007**). Coconut water can be stored in various types of packaging, such as bottles, cans or frozen under aseptic conditions. The Food and Agriculture Organisation of the United Nations recommends coconut water as an energy drink for sportspeople (**Rolle, 2007**). What's more, its high sugar content means it can be used as a raw material in the manufacture of alcoholic and vinegar products. Moreover, coconut water is more or less isotonic and its low fat and protein content has no harmful effect on the blood. It simply dilutes the blood in the same way as saline solution prepared for this purpose. Naturally, coconut water has no advantage over saline, but it can replace it in an emergency. This observation was made by both the Japanese and the British during the Burmese war, and has been proven by clinical trials in hospitals in Thailand, India and Louisiana (**Dupaigne, 1971)**.

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Perfusion with coconut water has saved the wounded, patients completely dehydrated by dysentery or cholera, and children dehydrated by persistent diarrhoea. Systematic trials with mixtures more or less rich in coconut water, carried out in 1965 at a Bombay hospital on gastroenteritis patients, did not cause any neurocirculatory disturbances for injections of volumes ranging from 400 to 1900 mL (**Bourdeix *et al.*, 2005**). Is this food, which is very rich in insoluble dietary fibre, suitable for consumption by healthy people suffering from non-communicable diseases such as diabetes? Coconut varieties, especially dwarf varieties and certain hybrids, produce water with a very sweet taste. To address this concern, it should be noted that the study on the glycaemic index of foods. This indicator has both advantages and limitations.

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The main advantage of the glycaemic index is its reliability in predicting the postprandial rise in blood sugar levels, especially in relation to the notion of slow or fast sugars. Glycaemic index tables are available for a wide range of human foods, enabling people to choose foods according to their needs or pathologies. For example, the glycaemic index can be used by diabetics to design a meal that causes few fluctuations in blood sugar levels, or by sportspeople to choose foods that are suitable for physical exercise (**Ninot, 2015**).

However, the glycaemic index has its limits. Firstly, in addition to the glycaemic index, which is expressed as the AUC, other parameters need to be taken into account. Two curves may have the same AUC but completely different profiles. For example, the glycaemic peak and the time at which it occurs are also of interest when studying the kinetics of the glycaemic response (**Sacks, 2014**). Next, the glycaemic index describes the effect of 50 g of carbohydrate contained in the food, and the term carbohydrate can include all carbohydrates (including fibre) or just available carbohydrates such as sugars and starch. Its use is therefore not practical in nutrition, as the quantities of carbohydrates may be unknown. A glycaemic index based on the quantity of food or the amount of digestible energy it contains would be more appropriate. What's more, a food is rarely eaten on its own. It was therefore considered more appropriate to consider the meal, bearing in mind that the glycaemic index of a meal is the sum of the glycaemic indexes of the foods that make it up (**Kronfeld *et al.*, 2004)**. The aim of this study was to determine the glycaemic index and postprandial responses of immature nut water from five different varieties of coconut palm (*Cocos nucifera* L.) planted in the international coconut collection in Côte d'Ivoire.

2. MATERIAL AND METHODS

2.1. Plant material

Immature nuts aged 8 and 9 months (rows 19 and 20 respectively) from mature coconut trees (planted 10 years ago) were used as the plant material for this study. Five of the most widely grown cultivars in Côte d'Ivoire were selected. These were West African Tall (WAT), The Malaysian Yellow Dwarf (MYD), Green Dwarf of Equatorial Guinea (EGD), Port-Bouêt 121^{+} (PB 121^{+}) and Port-Bouët 113^{+} (PB 113^{+}).

The West African Tall (WAT), originally from Africa, is the most widespread coconut cultivar in West Africa. It is traditionally the ecotype most commonly found in most farmers' plantations and is also used as a control for characterising tall coconut accessions. It grows rapidly in height and width, but less precociously (7 to 9 years) and produces green, brown or red nuts. WAT produces around 2.8 tonnes of copra per hectare. The oval-shaped nuts have a water content of 15-20% of the total weight of the whole nut (**Assa *et al*., 2006; APCC, 2018**).

The MYD and the EGD come from Malaysia and Brazil respectively. They grow slowly in height and their stipes are generally less robust than those of the Tall, producing yellow and green nuts respectively.

The choice of rows is justified by previous trials and by the results of several theses showing rows 19 and 20 to be the most suitable for consumption because of their sugar content (**Assa *et al*., 2007; Konan *et al*., 2013**). **Figure 1** shows photographs of nuts from the 5 cultivars studied. As for the glycaemic index evaluation chapters for coconut water, pure anhydrous glucose (Coopération Pharmaceutique Française - Place Lucien Auvert, 77020 MELUN CEDEX) served as the control for this study

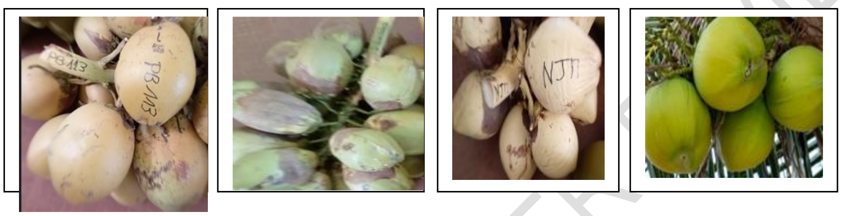

Figure 1. Photographs of nuts studed : PB113+, PB121+, MYD, EGD and WAT

2.2. Methods

2.2.1. Sampling

A cohort of twenty-five (25) volunteers aged between 18 and 43 was selected. Following a preliminary test, informations from these volunteers was collected on survey sheet. This included biological parameters (glycaemia and HDL) and measurements of morphological and anthropometric parameters (weight, height, BMI) and blood pressure. This ~~stage~~ avoids using subjects with a history of diabetes, obesity or hypertension. Pregnant and breast-feeding women were also excluded from the test. After analysing the data collected from the twenty-five volunteers, fifteen who met the inclusion criteria were selected for further testing. This group comprised 10 men and 5 women. An informed consent form was drawn up and presented to each volunteer at the start of the study. In addition, an interview was held to provide training and explanations relating to their participation in the study. The subjects were fasted for 12 hours before the start of the study sessions. Water from the sampled immature

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nuts was consumed for the same variety during the day's session. Only one variety was used per session per day.

2.2.2. Quantity of coconut water to be consumed by each subject

In accordance with the reference food (anhydrous glucose), the quantity of food to be tested should contain 50 g of available carbohydrates. Therefore, starting from the total carbohydrate levels, the available carbohydrate of each water was calculated by taking the difference in grams between the total carbohydrate and the total crude fibre level according to the following equation:

Available carbohydrates = Total carbohydrates - Fiber

The quantity of coconut water required to obtain 50 g of available carbohydrates was then determined according to the following equation:

Food portion to be ingested (g) = (100/X) x Y

X*: quantity of available carbohydrates in g/100 g of food tested (coconut water)*
Y*: quantity of available carbohydrates that the food tested is required to supply.*

Based on the fiber, total carbohydrate and available carbohydrate contents, the quantities of coconut water of the different varieties to be ingested by each subject were calculated.
On the basis of 50 g of glucose in the test food, the quantities (volumes) of coconut water consumed by the subjects were 750, 750, 850, 900 and 850 mL respectively for the EGD, MYD, PB121^{+}, PB113^{+} and WAT varieties.

2.2.3. Methodology for measuring the glycaemic index

2.2.3.1. Principle

The principle of measuring the glycaemic index (GI) of coconut water is based on an orally induced hyperglycaemia with the reference food (50 g of anhydrous glucose) and 50 g of available carbohydrates provided by the foods to be tested (water from the 5 varieties of coconut palm) and monitoring changes in postprandial glycaemia for 120 minutes (**FAO/WHO, 1998**).

2.2.3.2. Methodology

At each session, the test begins by taking the subjects' fasting blood glucose levels. This corresponds to the blood glucose level at time to and was determined 5 minutes

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Commented [UG11]: Please review this sentence. not clear after their arrival. All the subjects had previously undergone a 12 hours fast. To do this, the subjects were asked to eat their last meal at 8 p.m. at the latest the day before, so that they could start the test at 8 a.m. and they were not allowed to take part in any unusual sports on the day of the test. Only one food was tested per day, so six (6) days were needed to complete the study. Once each subject's fasting blood glucose level had been determined, each consumed the quantity of coconut water measured. The duration of consumption was 3 to 4 minutes. Postprandial blood glucose levels were determined over 2 hours. Every 15 min during the 1st hour and then every 30 min during the 2nd hour (15 min, 30 min, 45 min, 60 min, 90 min and 120 min). In practice, capillary blood (approximately 0.6 *µl*) was drawn from the subject's fingertips using a self-piercing lancet (BD Microtainer, Contact-Activated Lancet, Poland, USA) measuring 2.0 mm x 1.5 mm. The glycaemic responses (g/L) of the coconut water were determined by direct reading using a calibrated glucometer from « *On Call® Sharp, REF G115-10, MODEL OGM-121* ». The value obtained was then converted into mmol/L by a factor fc = 7/1.26.

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Finally, the method of **Brouns *et al* (2005)** was used to determine the glycaemic indexes of the different coconut waters of each variety.

Once the results had been obtained, the glycaemic response curves (mmol/L) were plotted for each subject and for each water consumed. The areas under the curves obtained were calculated by considering the part located between the curve and the horizontal line passing through the fasting blood glucose level and parallel to the time axis. The trapezoidal method was used, excluding any area below the horizontal fasting blood glucose line.

3. RESULTS

3.1. Characteristics of people who took part in the GI test

The anthropometric and biological characteristics as well as the personal and family history of the volunteer subjects were determined (**Table 1**). The results showed that all subjects met the inclusion criteria. In addition, 67% of the subjects selected to continue the test were male, aged between 22 and 40 years, compared with 33% female, aged between 24 and 35 years. The body mass index (BMI) of the entire cohort ranged from 18.20 to 23.66 kg/m^2 with an average of 21.24 kg/m^2. Individual weights ranged from 53 to 75 kg for heights of between 1.65 and 1.83 metres. Blood pressure averaged 12.5 mmHg systole and 7.6 mmHg diastole. No cases of obesity were detected among the subjects. The subjects also had a mean fasting capillary blood glucose level of 0.83 g/L..

Table 1: Anthropological and biological parameters of the study cohort

Subjects $(S)_i$	Age (years)	Sex		Weight (Kg)	Size (m)	BMI (Kg/m^2)	GAJ (g/L)	Blood pressure (mmHg)	
		M	F					Systolic	Diastolic
S_1	22	X		59	1.80	18.2	0.89	12	8
S_2	33	X		57	1.75	18.61	0.91	13	8
S_3	23	X		60	1.68	21.25	0.92	13	8
S_4	22	X		72	1.81	21.97	0.78	14	9
S_5	25	X		70	1.80	21.6	0.79	11	7
S_6	23	X		69	1.71	23.59	0.83	13	8
S_7	32		X	69	1.74	22.79	0.87	12	7
S_8	35		X	73	1.83	21.79	0.86	12	8
S_9	40	X		53	1.67	19	0.83	13	8
S_{10}	36	X		70	1.72	23.66	0.84	12	7
S_{11}	26		X	56	1.65	20.56	0.78	13	7
S_{12}	32	X		75	1.82	22.64	0.90	12	7
S_{13}	31	X		67	1.77	21.38	0.91	14	8
S_{14}	24		X	59	1.71	20.17	0.78	12	8
S_{15}	29	X		65	1.70	22.49	0.79	13	7
S_{16}	25		X	72	1,80	22.22	0.76	12	7
S_{17}	30	X		60	1.72	20.28	0.77	13	8
S_{18}	28		X	65	1.79	20.28	0.86	12	8
Total	516			1171	31.47	382.48	15.07	226	138
Average	28.66			65.05	1.74	21.24	0.83	12.5	7.6
Spreads	5.31			6.68	0.05	1.60	0.05	0.78	0.59

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3.2 Postprandial glycaemia of coconut water according to variety

3.2.1. Postprandial glycaemia induced by MYD nut water

The postprandial blood glucose levels of anhydrous glucose and water from the MYD cultivar evolved in a similar way, presenting two phases. A growth phase with a peak at 45 min for the control and at 30 min for the coconut water with different glycaemia amplitudes, followed by a progressive decrease phase leading to a glycaemia slightly higher than that of the fasting subjects at the end of the 120 min test. These results, illustrated in **Figure 2**, showed a significant difference between the postprandial kinetics of blood glucose levels induced by anhydrous glucose and coconut water. In the first phase, anhydrous glucose produced the greatest glycaemic responses after 45 minutes of consumption. In fact, at this time, anhydrous glucose (control) produced the highest peak with a value of 8.5 mmol/L. Coconut water induced a sharp rise in blood glucose from 4.6 mmol/L ± 0.32 to 7.3 mmol/L ± 0.15 for this first kinetic phase. The second phase goes from 8.5 mmol/L at t = 45 min to 5.6 mmol/L at the end of 120 min of digestion for anhydrous glucose. For MYD coconut water, the regression starts at 7.3 mmol/L and reaches 4.5 mmol/L at the end of the 120 min experiment.

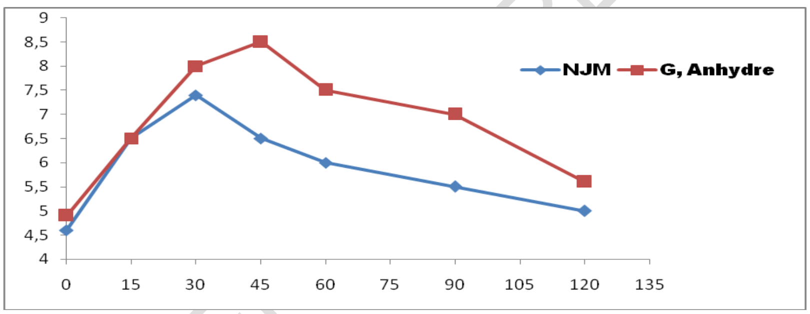

Figure 2: Glycaemic response of MYD (NJM) nut water

3.2.2. Postprandial glycaemia induced by PB113$^+$ nut water

Figure 3 illustrates the behaviour of anhydrous glucose and coconut water from the hybrid cultivar PB113$^+$ in the 15 healthy subjects who took part in the study. The two curves corresponding to blood glucose levels induced by anhydrous glucose (red) and coconut water (blue) each showed two phases. An increasing phase subdivided from 0 to 30 min (coconut water), from 0 to 45 min (control) and a decreasing phase between 45 or 30 min and 120 min. In the first phase, the increase in blood glucose levels after ingestion of the sugar glucose was greater than that after consumption of the coconut water. During this time, blood glucose levels rose from 4.5 mmol/L ± 0.5 to 8.5 mmol/L ± 0.18 and from 4.3 mmol/L to 5.6 mmol/L ± 0.73 for anhydrous glucose and coconut water respectively. After the first 45 minutes, there was a regression in postprandial kinetics to a value lower than the mean fasting blood glucose responses of the 15 participating subjects. This reduction in blood sugar levels was 2 mmol/L for anhydrous glucose and 1.5 mmol/L for coconut water from the PB113^{+} cultivar, corresponding to a 30% and 26.78% drop in blood sugar levels respectively.

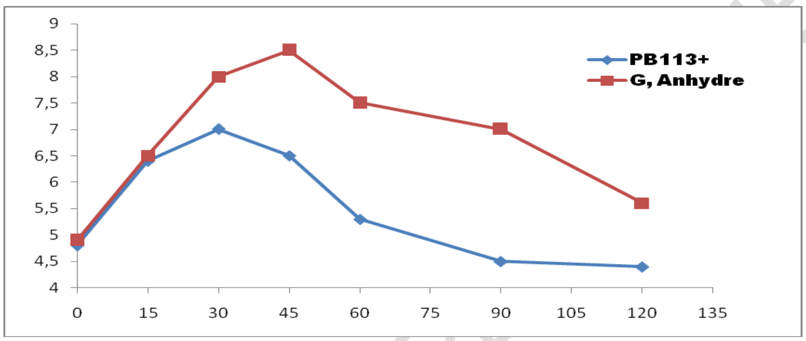

Figure 3: Glycaemic response of PB113^{+} nut water

3.2.3. Postprandial glycaemia of water from EGD nuts

The quantities of glucose in the blood following consumption of water from the EGD cultivar are shown in **Figure 4**. Glycaemic responses, expressed in mmol/L, were a function of time, ranging from 0 to 60 min at 15 min intervals, then from 60 to 120 min at 30 min intervals. The results showed a similar evolution of blood glucose kinetics in two periods, one increasing and the other decreasing. The first period saw an increase in glycaemic responses from 4.6 mmol/L ± 0.25 (fasting) to 6.9 mmol/L ± 0.03 after ingestion of water and from 4.5 (fasting) to 8.5 mmol/L ± 0.68 after ingestion of anhydrous glucose. The amplitudes of the glycaemic responses were all significantly different, with the highest peak given by anhydrous glucose (control). After 45 min, postprandial blood glucose kinetics decreased significantly to 4.4 mmol/L ± 0.48 for coconut water and 5.7 mmol/L ± 0.08 for anhydrous glucose.

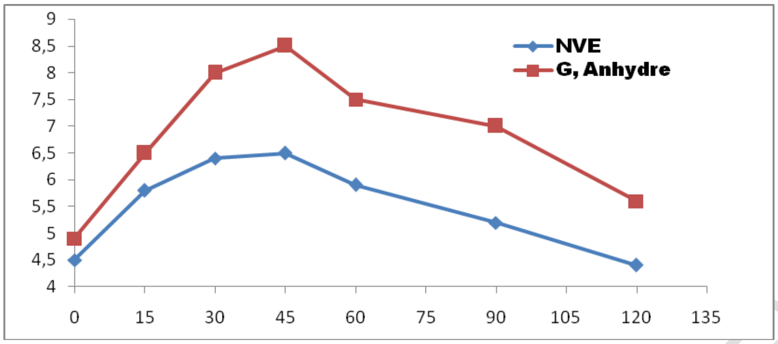

Figure 4: glycaemic responses of EGD (**NVE**) nut water

3.2.4 Postprandial glycaemia of WAT nut water

Postprandial blood glucose levels of anhydrous glucose and water from WAT cultivar nuts evolved similarly in two phases (**Figure 5)**. A growth phase with a peak at 45 min for the control and at 30 min for the coconut water, with different glycaemia amplitudes, followed by a decrease phase after 120 min. Analysis of variance showed a significant difference between the postprandial kinetics of blood glucose levels induced by anhydrous glucose on the one hand and coconut water on the other. In the growth phase, anhydrous glucose produced the greatest amplitudes, with the highest peak (8.5 mmol/L) obtained after 45 min of consumption. In the case of coconut water, the increase in blood glucose levels ranged from 4.5 mmol/L ± 0.13 to 6.8 mmol/L ± 0.7 after 30 min of consumption.

The regression phase results in a drop in blood glucose levels which appears after 45 min of coconut water ingestion. The kinetics of postprandial glycaemia fell from 8.5 mmol/L ± 1.05 to 5.6 mmol/L ± 1.05 for the reference sugar and from 6.8 mmol/L to 4.3 mmol/L for coconut water from the West African Tall cultivar.

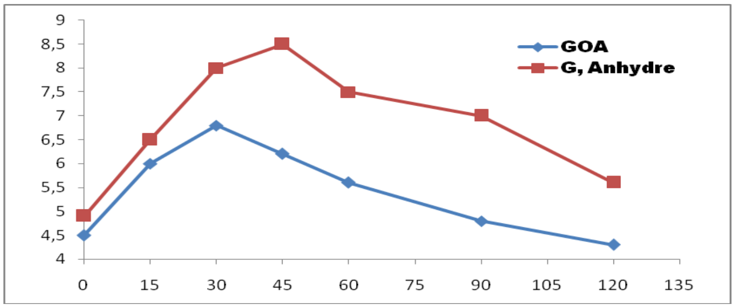

Figure 5: Glycaemic responses of WAT (**GOA**) nut water

3.2.5. Postprandial glycaemia of PB121$^+$ nut water

As with the other varieties, the glycaemic responses of subjects ingesting anhydrous glucose and coconut water from the PB121$^+$ variety are illustrated by curves that reach a peak after 45 min of consumption (control) and after 30 min of consumption before falling back (**Figure 6**). Thus, after fasting glycaemia (t_o) followed by consumption of coconut water, postprandial glycaemia increased over the period from 0 to 30 min, followed by a fall over the period from 30 to 120 min. The kinetics of coconut water (**PB121$^+$**) and anhydrous glucose are comparable with significantly different amplitudes, the highest peak being presented by anhydrous sugar. Values ranged from 4.6 to 5.8 mmol/L for the first 15 minutes of coconut water ingestion and from 5.8 to 6.52 mmol/L (peak) during the second sampling period. Following the third (45 min) and fourth (60 min) sampling times, the regression increased from 5.6 mmol/L to 5.1 mmol/L at the end of the two hours experiment.

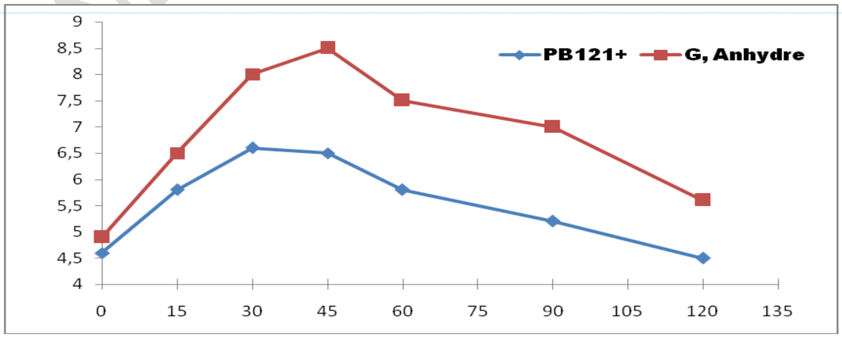

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Figure 6: Glycaemic responses of PB121$^+$ nut water

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3.3. Comparative analysis of response and glycaemic index of coconut water

The evolution of postprandial blood glucose induced by coconut water in immature nuts of the five cultivars studied is illustrated in **Figure 7**. The kinetics of postprandial blood glucose induced by coconut water and that induced by anhydrous glucose (control) showed two phases, whatever the coconut variety. The first phase of glycaemic increase began as soon as the water was ingested and stopped at 30 min (peak), followed by a second phase of fall during the period between 30 min and 120 min, with coconut water. As for the control (anhydrous glucose), the postprandial hyperglycaemic peak was reached 45 min after ingestion. The increase in blood glucose was greater in MYD, EGD and WAT coconut water than in water from PB113$^+$ and PB121$^+$ cultivars.

Analyses of variance (ANOVA) were used to divide the varieties into two groups. The first group was made up of the MYD and EGD varieties, which gave glycaemic responses of between 4.69 and 4.48 mmol/L and between 4.92 and 4.39 mmol/L respectively. For water from these two varieties, postprandial hyperglycaemia peaks were achieved at 7.30 and 6.90 mmol/L respectively after the first 30 minutes. The second group was made up of the cultivars WAT, PB121$^+$ and PB121$^+$ with peak hyperglycaemia levels of 6.8 mmol/L, 6.52 mmol/L and 5.60 mmol/L respectively after the first 30 minutes following ingestion. There was no significant difference between the water-induced glycaemic responses of each cultivar within each group.

The glycaemic index values of immature coconut water varied between 40.04 and 46.36%. There was a significant difference between the different glycaemic index values induced by the ingestion of coconut water from the varieties studied. Water from the MYD, PB113$^+$ and PB121$^+$ varieties gave statistically identical glycaemic indexes ($p = 0.071$) with values of 44.72%, 43.71% and 46.36% respectively. Similarly, water from the WAT variety (GI = 40.04%) and water from the EGD variety (GI = 41.50%) gave the same glycaemic index values ($p = 0.054$). Chi-square tests revealed independence between the type of variety and the GI value of water from that variety (**Figure 8**).

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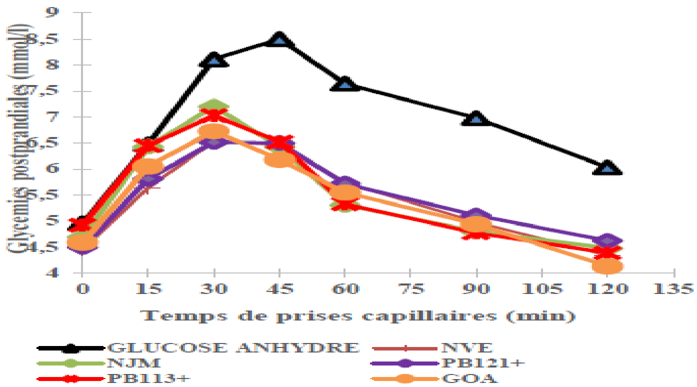

Figure 7: Postprandial hyperglycaemia curves induced by coconut water

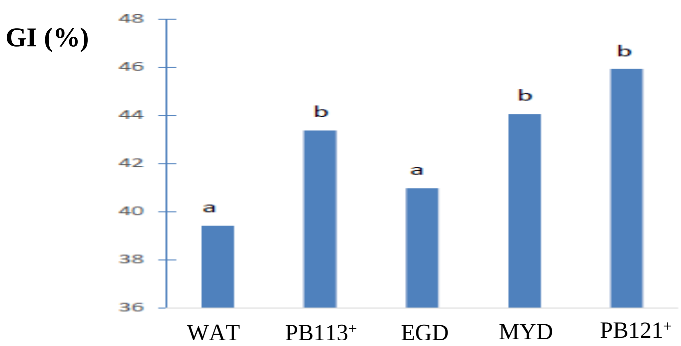

Figure 8: Band diagrams of glycaemic indexes (GI) for coconut water

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4. DISCUSSION

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The glycaemic index is used to classify foods according to the rise in blood sugar levels they produce when consumed. Results of the glycaemic responses of water from immature nuts of the coconut varieties studied were obtened. They show that consumption of coconut water led to an increase in blood glucose levels in the subjects up to 30 min after consumption. Blood glucose levels evolved differently between the two groups of varieties. Several authors, such as **Pi-Sunyer** (**2002)** and **Cheng Qian *et al* (2009)**, have shown that the postprandial glycaemia of a food depends on the intrinsic and extrinsic characteristics of the food, particularly its type. **Juntunen *et al* (2003)** and **Véga-López *et al* (2007)** have also confirmed that the glycaemic index (GI) value assigned to a food can vary greatly depending on the quality of that food. Indeed, the same food can induce variable GIs in different subjects. In our study, there was no question of compound foods, but the different origins of the nuts and the biochemical composition of the coconut water could be factors that induced the difference observed between the hyperglycaemic peaks of the MYD, EGD varieties and the WAT, PB121$^+$ and PB113$^+$ varieties. Furthermore, the GIs of the WAT and EGD varieties are statistically identical compared with the GIs of the PB113$^+$, PB121$^+$ and MYD water, which are also similar. There are a multitude of classifications of glycaemic indexes for foods, often varying from one author to another. In fact, **Gbakayoro *et al* (2012)** suggest that foods with a GI of between 35% and 50% are classed as low GI foods, while foods with a GI of between 50% and 70% are classed as medium GI foods. Foods with a GI of over 70 are referred to as high GI foods. Nevertheless, these authors have adopted this classification for people with diabetes with a view to better management. The results obtained in this study reveal that the GIs of coconut water of the varieties studied are all between 35 and 50%. Coconut water therefore has a low glycaemic index. In addition, **Gbakayoro *et al*** (**2012)** recommend that diabetics prefer foods with a low glycaemic index. What's more, coconut water contains no fat, a nutrient that diabetics should limit their consumption of while maintaining a balanced diet. Despite the statistical differences revealed by the chi-square test, the GI values for coconut water show that it belongs to the low GI family of foods. According to our results, coconut water can also be consumed by both healthy and diabetic populations without any risk of developing cardiovascular disease. This study may therefore contribute to the management of diabetes, which remains a concern and even a public health problem. The low glycaemic indexes found in the water of the varieties studied are partly due to the high fructose content in the immature coconut water of ranks 17, 19 and 21 (**Assa *et al*., 2007)**. In fact, our study focused on the water from the nuts of ranks 19 (8 months of maturity) and 20 (9 months). This idea is supported by **Atkinson *et al* (2008)** who state that fructose is a very low glycaemic index carbohydrate with a value of 15%.

After consuming the coconut water of varieties studied, all subjects experienced an increase in blood sugar levels. This rise in blood sugar is attributable to the assimilation and digestion of the ingested sugars. What's more, the coconut water ingested are very high in monosaccharides, which causes a rapid rise in blood glucose levels. Coconut water contains small quantities of sucrose (**Assa *et al*, 2007)**. **Hui (2016)** and **Jenkins *et al*** (**1981)** have demonstrated this phenomenon through their extensive research into the glycaemic index. Following the ingestion of sugars in coconut water, several digestive enzymes, including salivary alpha-amylase, pancreatic amylase, β-fructosidase, galactosidase hydrolyse sucrose and traces of starch into simple sugars. The latter are assimilated via the small intestine, resulting in a significant rise in blood glucose levels. These results are in line with those of **Wiedmeyer *et al* (2011)**, who argue that heat can make osidic bonds more vulnerable, facilitating their hydrolysis by the corresponding enzymes.

The results also show that the peaks in the glycaemic responses of varieties studied appear at 30 minutes and the anhydrous glucose (control) appear at 45 minutes after their consumption. The different amplitudes of blood sugar peaks observed between latter could be explained by the fact that blood sugar responses are linked to the quantity of hydrolysis products. The higher the quantities of hydrolysis products, the higher the glycaemic responses, illustrated by large peak amplitudes.

The fact that the amplitudes of glycaemic responses and even the glycaemic index were higher for coconut water to EGD, MYD and WAT than for PB121$^+$ and PB113$^+$ could be explained by the fact that the hyperglycaemic power in the first three coconut water is also higher than that of two latters. This distinction could also be attributable to the intrinsic and extrinsic characteristics or even the nature of variety. Evaluation of the physicochemical characteristics of the coconut water shows significant differences between macronutrient and micronutrient content. This observation confirms the assertions of **Pi-sunyer (2002), Bran-Miller *et al* (2003) and Cheng Qian *et al*** (**2009)**, who state that postprandial glycaemia depends on the intrinsic and extrinsic characteristics, and even the nature, of the food tested. This phenomenon occurred because in gelatinised form, the hydrolysis of sucrose, despite being in small quantities, is accelerated by amylases, resulting in the production of monosaccharides. Digestion of these monosaccharides resulted in a greater rise in blood glucose levels in MYD, EGD and WAT than in PB113$^+$ and PB121$^+$.

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The gradual regression in plasma glucose levels that occurred between 30 and 120 minutes after consuming the coconut water could be explained by the establishment of a system for restoring carbohydrate homeostasis. The accumulation of monosaccharides in the blood stimulates the pancreas, which secretes insulin to transport the sugars to the muscles and adipocytes. In reality, as they pass through the duodenum and jejunum into the bloodstream, the simple sugars produced by the digestion of coconut water are transported via the portal vein to the liver. In this way, 35 to 65% of glucose is stored in the liver in the form of glycogen (**Livesey *et al*., 1998),** resulting in a drop in blood glucose levels. Effectively, the β-pancreatic cells secrete insulin, which facilitates or even increases the uptake of ingested coconut water by the appropriate cells, in this case the muscles, liver and adipocytes, which use them for the body's metabolism (**Laure Rinaldi et al., 2014)**. It is this phenomenon that has led to a gradual fall in plasma glucose levels, which eventually stabilise. Blood glucose levels fall more slowly for WAT and EGD coconut water than for PB121$^+$, MYD. This stabilisation is brought about by the secretion of counter-regulatory hormones such as glucagon, epinephrine and cortisol (**Leeds, 2002)**.

All coconut water, could be classified as low glycaemic index foods (GI < 55%) according to the classification of foods according to their glycaemic index (**FAO/WHO 1998, Montignac**, **2011 , Atkison *et al*., 2021**). Also, according to the classification adopted by **Gbakayoro *et al* (2012)**, coconut water from the cultivars studied are considered low glycaemic index foods. Thus, waters of these varieties can therefore be consumed without great risk by diabetics. . As part of the diabetic diet, **Gbakayoro *et al* (2012)** state that foods with a low glycaemic index have a GI < 39, while those with a GI between 40 and 59 (40 < GI < 59) are classified as medium glycaemic index foods and should be eaten in moderation by diabetics. Foods with a high glycaemic index (GI > 60) should be avoided by diabetics.

There is a significant difference between the glycaemic indexes of the sugars produced. **Foster-Powell *et al* (2002)** argue that different varieties of the same food may have different glycaemic indexes. Better still, the monosaccharide composition and more specifically the glucose/fructose ratio of the different coconut water could also modulate variations in their glycaemic indexes.

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5. CONCLUSION

The results of our study show that there is more fructose than glucose in coconut water study. This higher fructose content allows the sugar to enter the cells directly without raising plasma glucose levels. This observation is all the more true as the glucose/fructose ratio is proportional to the glycaemic index scores of the different coconut water tested. It should be noted that PB121^{+}, MYD and PB113^{+} water have the highest GI score than water of WAT and EGD nut. The results of the present study confirm those of authors who support the same assertion linked to the monosaccharide composition and especially the glucose/fructose ratio.

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The low glycaemic indexes of the sugars in the water of immature coconut could have beneficial effects on cardiovascular risk. These effects could be justified by a clear improvement in the consumer's lipid profile. According to international standards on the glycemic index, coconut water can be consumed without any problems by people of all ages. Nevertheless, moderate consumption is recommended for diabetics

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki."

Commented [UG22]: Please add ethical approval letter from the concerned authority in appendix section.

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