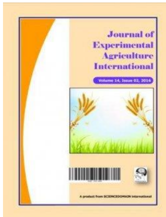

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Variation of Soluble Sugar and Minerals Contents of Kernels from Germinated Nuts of Several Coconut Cultivars (*Cocos nucifera* L.)

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Authors' contributions

This work was carried out in collaboration between four authors. Authors KBR and APM designed the study, collected samples from the field and performed the laboratory tests and produced a draft of the manuscript. Author YBYC checked the data for validity and carried out the analyses of the study. Author ANG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed to assess the soluble sugars and minerals in coconut kernels during the fruits' germination.
Place and Duration of Study: Marc Delorme Research Station for coconut, National Agronomic Research Center, Abidjan, Côte d'Ivoire, between March and May, 2010.
Methodology: The germinated nuts kernels of three coconut cultivars, namely West African Tall (WAT), Malaysian Yellow Dwarf (MYD), and improved hybrid 'PB121+' were investigated. The soluble carbohydrates profile and the mail minerals were evidenced using chromatography methods.

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Results: The overall coconut kernels studied recorded the same carbohydrate compounds, main of which are myo-inositol, sorbitol, glucose, fructose and sucrose. The result shows sucrose as the major carbohydrate in the germinated nut kernel whatever the coconut cultivar. The three coconuts also displayed the same mineral elements, especially sodium, magnesium, phosphorus, sulfur, and potassium. They are more richer in potassium and phosphorus.
Conclusion: Thanks to the great soluble sugars and minerals contents, the germinated coconut kernel could be valorized as a good food resource or used as food additive for children suffering from mineral troubles.

Keywords: Coconut kernel; sugar; mineral; cultivar; germinated nut.

1. INTRODUCTION

The coconut (*Cocos nucifera* L.) is known as the "tree of life" thanks to its numerous uses [1,2]. Till dates, the people are still using all parts of this plant for number of manufacturing products in food, crafts, cosmetics, and health concerns [3]. In Côte d'Ivoire, the coconut is cultivated over 50,000 hectares of acreage, 95% of which are located along the sandy coastal lands in the Southern region. This crop is a valuable livelihood for populations and represents the main export product for many farmers [4].

The coconut's importance largely relies on the production of fruits known as nuts [5] containing kernel or almond and fresh water for consumption. The kernels deriving from the mature nuts and the immature nuts' water are the most used coconut products. From farmers, the raw mature nuts are sold as the main profitable coconut product, but usually with lower price. Occasionally, they are processed into oil using craft tools, for other valuable usages [6].

Previous studies have examined the physicochemical parameters from coconut products for improving their valorization. Thus, regarding immature nuts, [7] showed that the raw water a delicious and nutritious drink when consumed without processing thanks to the high amount of sugar, vitamins and minerals. Such nutritive properties are widely managed in infantile nutrition. Studies performed on mature nuts by [8] accounted 33% husk, 16% shell, 33% kernel, and 18% water in the whole nut. However, the mature coconut kernel is usually processed by manufacturers into copra, oil and grated coconut for more value addition. Hence, the copra oil is used in food and other industries [3].

Yet, there are scanty researches on the germinating nuts, whereas the mature nuts often germinate and rot in the coconut farms without any way of usage. Such a concern results in a dropping of the yield of coconut kernel products leading unfortunately in significant losses for farmers. The rare studies about the germinating nuts' kernel [9] are old and partially designed because they exclusively focussed on a local Asian variety. In Côte d'Ivoire, any study is not carried out for the physicochemical characteristics of the most widely used coconut cultivars. The present study seeks to analyse some of the significant kernel valorising parameters during, namely the carbohydrates and mineral components, from the germinating coconut fruits for resulting in better uses.

2. MATERIALS AND METHODS

2.1 Study Site and Implementation

The study was performed on mature nuts of rank 26, 14 months of age, from three coconut varieties cultivated in Côte d'Ivoire, namely a dwarf coconut (Malaysian Yellow Dwarf or MYD), a tall coconut (West African Tall or WAT), and a widespread improved hybrid ($PB121^+$) resulting from the crossing between MYD taken as female parental and WAT taken as male parental. These three coconut types are widely planted in the Ivorian coconut farms. The nuts were harvested from healthy adult coconut trees having over 10 years of age. The mature raw nuts were collected at the Marc Delorme coconut Research Station of the National Agronomic Research Centre (CNRA) located at Port-Bouët, Abidjan, in Southern Côte d'Ivoire.

2.2 Sampling

Eight coconut palms per cultivar were chosen and divided into 2 sets of 4 coconuts per cultivar (Fig. 1). Each set was a replicate within each cultivar, and comprised 4 bunches of mature fruit at 14 months. From each set, 4 groups of 8 nuts each were made up. The 8 nuts of each group came from all four bunches, that is to say,

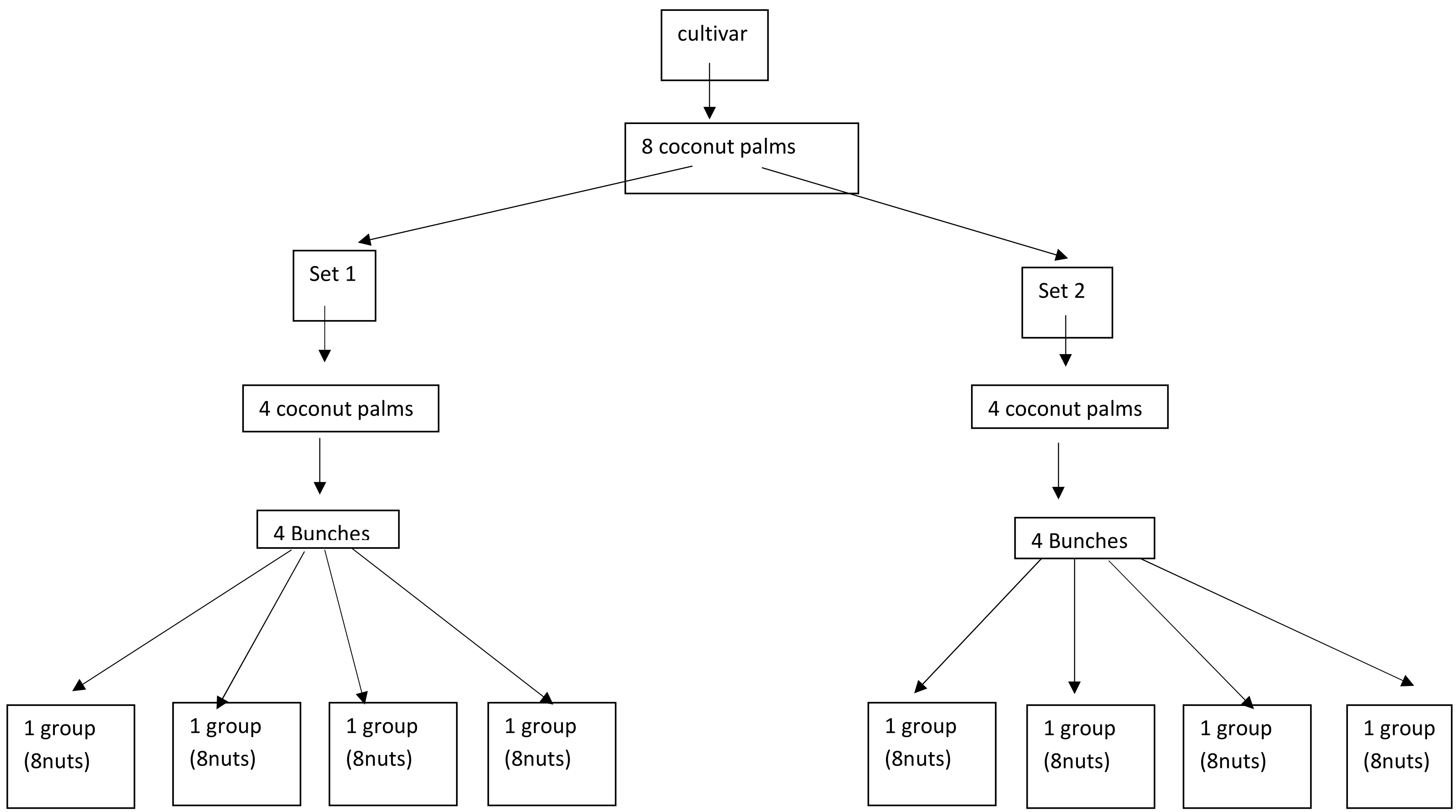

Fig. 1. Sampling method for coconuts

2 nuts from each bunch. The 8 groups per cultivar were used as coconut kernel samplings in the first nut analyses. The first analysis (T0) of nuts was carried out less than 24 hours after harvest. The nuts were then stored under a shed at the ambient temperature for one month before the second analysis was performed (T1). The remaining nuts were put in a seedbed at the nursery. One and three months after being placed in the seedbed, the third (T2) and fourth (T3) analyses were respectively carried out. For each analysis, one cultivar group was selected per set. The eight nuts from each group constituted the representative sample for the set. Thus, 8 coconut kernel samples were treated per cultivar.

2.3 Determination of the Soluble Sugars Contents

The qualitative and quantitative analyses of the studied kernel's carbohydrates composition were performed using a High Performance Liquid Chromatography (Dionex Corp., Sunnyvale, USA) equipped with a column (Carbopac MA-1) and a pulsed amperometric detector (ED40).

2.4 Determination of the Minerals Contents

2.4.1 Kernels processing for mineral analysis

Prior to minerals analysis, hundred (100) g of coconut raw kernel from each plant cultivar were first submitted to oil removal using a soxhlet device. Then, 25 g of each oil-free kernel sample were incinerated at 550°C for 12 h using electric muffle furnace for resulting in coconut kernel ashes constituted of a white residue (AOAC). The minerals assessment of the studied kernels was recovered from the resulted ashes using an Energy Dispersive Spectrometer device (EDS).

2.4.2 Operating conditions of the energy dispersive spectrometer

The EDS device used was coupled with a Scanning Electronic Microscope, operating at variable pressure (SEM-FEG Supra 40 Vp Zeiss), and equipped with an X-ray detector (CNIB, OXFORD instruments) bound to a flat shape of the EDS microanalyser (Inca cool dry, without liquid nitrogen). The operative conditions of the EDS-SEM device are:

> Zoom: 10 x to 1000000 x; Resolution: 2 nm; Variable voltage: 0.1 KeV to 30 KeV.

Thus, the chemical elements were acquired with following parameters:

> Zoom: 50 x; Probe diameter: 30 nm to 120 nm; Probe energy: 20 KeV and 25 KeV.

The chemical composition was explored in triplicate.

2.5 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using SPSS software (SPSS 12.0 for Windows, USA). Mean and standard deviations were calculated. When significant divergences are accounted at statistical probability value of (P < .05), the means were separated using the Newman Keuls post hoc test for comparison.

3. RESULTS

3.1 Carbohydrates Profile of the Germinating Nut Kernels

The soluble sugars chromatography revealed the similar components from overall coconut cultivars studied, including myo-inositol, sorbitol, glucose, fructose, and sucrose. Sucrose was the major carbohydrate component (Table 1).

3.1.1 Myo-inositol content

The myo-inositol proportions were statistically unvarying from each coconut cultivar during the seeds germination. Thus, the myo-inositol ranged between 0.85% (from initial treatment) and 1.31% (at the end latter germination) for WAT. It also recorded 1.15% and 1.40% at respective 0 month and 4 months of germination from the MYD samples. For the PB121$^+$ hybrid, the myo-inositol proportions were 0.99% (at the earlier storage); 1.04% (1 month); 1.16% (2 months), and 2.22% (4 months) during the seeds germination. In addition, any obvious change of the myo-inositol content isn't observed between the 3 studied cultivars for each germination stage of seeds (Table 1).

So, both WAT and MYD parental coconuts and their progeny (PB121$^+$ hybrid) statistically display the same kernel myo-inositol content during the seeds germination.

3.1.2 Sorbitol content

From WAT, the sorbitol proportions decreased significantly for the earlier germination stage from 13.27% (0 month) to 6.79% (1 month), and thereafter remained statistically unvarying till the full germination (4.60% at 4 months). Regarding MYD cultivar, sorbitol proportions were also statistically identical during germination. Oppositely, the sorbitol content did not significantly differentiate only the earlier germinating stages of the $PB121^+$ hybrid seeds, with 11.26% at 0 month and 7.30% at 1 month. But it decreased to 0.21% at 4 months of germination. However, the $PB121^+$ hybrid recorded sorbitol proportion statistically intermediate to both WAT and MYD parentals before the germination (0 month).

3.1.3 Glucose content

The glucose proportions in nut kernels were statistically identical (P>0.05) during germination of the overall seeds. Indeed, from 0 month to 4 months of germination, the glucose values respectively ranged between 7.65% and 5.25 for WAT, 7.65% and 6.59% for MYD, and 8.94% and 4.87% for $PB121^+$ hybrid. Before germination (0 month) the seed kernel produced by the $PB121^+$ hybrid revealed statistically similar (P>0.05) glucose content as both WAT and MYD parentals.

3.1.4 Fructose content

The seeds kernel from WAT and MYD displayed statistically unvarying fructose proportions during their germination stages. The values recovered from 0 month to 4 months germination were 13.1% to 10.02% and 12.55% to 11.17% for respective WAT and MYD cultivars.

For the $PB121^+$ hybrid, the fructose proportions were statistically constant until 2 months of germination before dropping significantly regularly to 0.41% at the 4^{th} month of germination.

However, the fructose contents were statistically identical from the overall coconut cultivars at each analysis stage.

3.1.5 Sucrose content

The seeds kernel deriving from WAT and MYD cultivars recorded close sucrose contents along the germination. WAT provided sucrose value of 65.14% to 76.02% and MYD provided sucrose value between 72.58% and 75.31% from the earlier storage (0 month) to the 4^{th} months of germination, respectively.

On the other hand, the sucrose proportions of the $PB121^+$ hybrid raised from 64.9% to 78.1% during the 1^{st} month of storage and decreasing significantly thereafter to 74.44% at the 4^{th} month of germination. At 0 month of germination, the $PB121^+$ hybrid and its male parental (WAT) were lower in sucrose content than the female parental (MYD).

3.2 Minerals Profile of the Germinating Nut Kernels

The minerals chromatography revealed the same mineral elements from the overall cultivars studied, namely sodium (Na), magnesium (Mg), phosphorus (P), sulfur (S), and potassium (K). Potassium and phosphorus accounted the greatest values in the samples (Table 2).

3.2.1 Potassium content

From the WAT and $PB121^+$ samples, the potassium content increased significantly for 1 month, reaching respective values of 39.83% and 39.59%. Thereafter, the potassium contents dropped until the 4^{th} month of germination at 33.36% and 33.76%, respectively. On the other hand, the MYD recorded K contents raised significantly for 2 months of germination with top value of 36.24%, before decreasing to 33.93% at the 4^{th} month of germination. At the earlier stages investigated (0 to 1 months), the WAT cultivar provided higher K contents than both MYD and $PB121^+$ hybrid.

3.2.2 Phosphorus content

The P contents of the nuts kernel statistically increased during the earlier storage and reached 26.69% after 1 month for WAT cultivar and 23.67% after 2 months for the $PB121^+$ hybrid. Then, they significantly decreased to 18.64% and 19.79%, respectively at the 4^{th} month of germination. From MYD cultivar, the P contents always decreased significantly during the seeds germination, from 21.15% (0 month) to 15.08 % (4^{th} month). Furthermore, the overall cultivars revealed similar phosphorus values at 0 month of storage.

Table 1. Variation of soluble sugar content of the kernel cultivars during germination

Soluble sugar (%)	Treatments	Stage of germination (month)	Cultivars		
			WAT (♂)	MYD (♀)	PB121$^+$
Myo-inositol	T0	0	0.85 ± 0.01^a	1.15 ± 0.03^a	0.99 ± 0.04^a
	T1	1	0.97 ± 0.03^a	0.97 ± 0.02^a	1.04 ± 0.04^a
	T2	2	1.09 ± 0.02^a	0.58 ± 0.02^a	1.16 ± 0.05^a
	T3	4	1.33 ± 0.02a	1.40 ± 0.03^a	2.22 ± 0.03^a
Sorbitol	T0	0	13.27 ± 0.05^a	10.42 ± 0.04^a	11.26 ± 0.29^a
	T1	1	6.79 ± 0.26^b	8.34 ± 0.06^a	7.30 ± 0.01^a
	T2	2	5.29 ± 0.09^b	6.32 ± 0.05^a	0.43 ± 0.07^{ab}
	T3	4	4.60 ± 0.17^b	5.23 ± 0.15^a	0.21 ± 0.23^b
Glucose	T0	0	7.65 ± 0.05^a	7.65 ± 0.06^a	8.94 ± 0.19^a
	T1	1	6.41 ± 0.04^a	4.48 ± 0.09^a	6.42 ± 0.03^a
	T2	2	4.37 ± 0.10^a	5.45 ± 0.25^a	5.37 ± 0.22^a
	T3	4	5.25 ± 0.15^a	6.59 ± 0.05^a	4.87 ± 0.03^a
Fructose	T0	0	13.10 ± 0.09^a	0.87 ± 0.14^a	0.84 ± 0.10^a
	T1	1	11.68 ± 0.06^a	0.82 ± 0.11^a	0.75 ± 0.07^a
	T2	2	9.65 ± 0.14^a	0.73 ± 0.35^a	0.66 ± 0.21^a
	T3	4	10.02 ± 0.20^a	0.64 ± 0.08^a	0.41 ± 0.08^b
Sucrose	T0	0	65.14 ± 0.61^a	72.58 ± 0.74^a	64.90 ± 0.99^d
	T1	1	55.15 ± 0.54^a	65.57 ± 2.27^a	78.10 ± 1.18^a
	T2	2	64.83 ± 0.28^a	64.82 ± 1.38^a	76.37 ± 0.38^b
	T3	4	76.02 ± 2.14^a	75.31 ± 0.88^a	74.44 ± 1.85^c

MYD: Malaysian Yellow Dwarf. WAT: West African Tall. PB121$^+$. Improved hybrid PB121$^+$.
Values with the same letter in the colums are not significantly different for each parameter

3.2.3 Sodium content

In PB121$^+$ hybrid samples, the sodium value decreased for the 1st month of storage from 1.03% to 0.86%, before rising significantly to 1.38% at the 4th month of germination. Regarding MYD cultivar, the initial Na proportion (2.38% at 0 month) also dropped statistically to 1.48% after 1 month of storage. Then, it remained statistically identical until the 4th month of germination. Besides, the WAT cultivar produced the highest Na content at the seeds harvest and this content did not evidence any statistical change during the germination.

3.2.4 Magnesium content

From MYD, the magnesium proportions significantly decreased from 8.36% to 6.74% for 1 month of germination, and then increased at 2 month stage before dropping significantly to 6.18% at the 4th month of germination. For the WAT, the Mg values significantly increased to 6.90% for the 1st month before dropping to 4.93% at the 4th month of germination. On the other hand, the PB121$^+$ hybrid provided unvarying Mg contents, between 6.37% and6.69, during the seeds germination. However, at 0 month of germination, the MYD displayed higher Mg value compared to both WAT and PB121$^+$ hybrid samples.

3.2.5 Sulfur content

The seeds kernel of the MYD cultivar recorded S proportions increasing significantly from 2.95% to 4.44% during 2 months of germination, before dropping significantly at 3.63% around the end of germination. Oppositely, this mineral's proportion decreased to 2.47% at the 2nd month stage for the PB121$^+$ hybrid, before increasing significantly to 3.07% at the 4th month stage. WAT cultivar provided statistically identical S content during germination. The PB121$^+$ hybrid had as much S content at 0 month as both WAT and MYD parentals.

4. DISCUSSION

The soluble carbohydrates profile of nuts kernel deriving from the HPLC investigation revealed the same components, during germination, for the overall cultivars studied. These include myo-inositol, sorbitol, fructose, glucose and sucrose. Myo-inositol is a polyol synthesized from glucose-6-phosphate (G-6-P) and having biological function in blood cholesterol reduction. It is commonly found in beans, cereals and nuts [10]. Sorbitol derives from the metabolism of leaf or peduncle polymers. It is used by the coconut tree to withstand periods of water stress. Oppositely to myo-inositol, sorbitol unfortunately increases blood carbohydrate [11].

Table 2. Variation of minerals content of the kernel cultivars during germination

Minerals (%)	Treatments	Stage of germination (month)	Cultivars		
			WAT (♂)	MYD (♀)	PB121$^+$
Na	T0	0	0.57 ± 0.09^a	2.38 ± 0.29^a	1.03±0.23^{bc}
	T1	1	0.58 ± 0.02^a	1.48 ± 0.16^b	0.86±0.13^c
	T2	2	0.79 ± 0.04^a	1.68 ± 0.08^b	1.19±0.09^{ab}
	T3	4	0.64 ± 0.32^a	1.77 ± 0.36^b	1.38±0.12^a
Mg	T0	0	5.22 ± 0.16^b	8.36 ± 0.05^a	6.69 ± 0.58^a
	T1	1	6.90 ± 0.37^a	6.74 ± 0.32^b	6.66 ± 0.10^a
	T2	2	5.38 ± 0.53^b	7.65 ± 0.10^a	7.29 ± 0.31^a
	T3	4	4.93 ± 0.02^b	6.18 ± 0.93^b	6.37 ± 0.70^a
P	T0	0	21.66 ± 0.88^b	21.15 ± 0.11^a	21.19 ± 1.32^b
	T1	1	26.69 ± 1.43^a	17.26 ± 1.06^b	24.69 ± 1.22^a
	T2	2	23.01 ± 1.41^b	18.45 ± 0.03^b	23.67 ± 0.53^a
	T3	4	18.64 ± 0.25^c	15.08 ± 1.67^c	19.79 ± 0.04^b
S	T0	0	3.52 ± 0.23^a	2.95 ± 0.22^c	3.36 ± 0.46^a
	T1	1	3.37 ± 0.23^a	3.17 ± 0.38^{bc}	3.37 ± 0.33^a
	T2	2	2.96 ± 0.50^a	4.44 ± 0.12^a	2.47 ± 0.03^b
	T3	4	3.59 ± 0.45^a	3.63 ± 0.47^b	3.07 ± 0.53^{ab}
K	T0	0	37.44 ± 0.15^{ab}	31.11 ± 0.46^b	35.29 ± 1.18^b
	T1	1	39.83 ± 2.49^a	31.88 ± 2.61^b	39.59 ± 2.48^a
	T2	2	36.59 ± 2.88^{ab}	36.24 ± 0.17^a	35.68 ± 0.72^b
	T3	4	33.36 ± 2.18^b	33.93 ± 2.05^{ab}	33.76 ± 1.69^b

MYD: Malaysian Yellow Dwarf. WAT: West African Tall. PB121$^+$. Improved hybrid PB121$^+$.
Na: Sodium, Mg: Magnesium, P: Phosphorus, S: Sulfur, K: Potassium,
Values with the same letter in the colums are not significantly different for each parameter

Other authors have shown that the sugar content into germinated seeds could be used as indicator for maintaining seed viability or aging during storage [12,13,14,15,16]. During oleaginous plants germinations, oligosaccharides are positively correlated with the seeds potential longevity [13,17,12,14,15]. Thus, oligosaccharides are involved in protecting membranes, proteins, and nucleic acids from damages occurring during drying [18]. Studies on soybean (*Glycine max*), maize (*Zea mays*), and shuttle (*Brassica campestris*) demonstrate the role of soluble oligosaccharides in protecting seeds against damage during dehydration and aging. They are involved in the survival and maintenance of seed viability during storage [19, 15].

The minerals spectrometry profile revealed the same elements for all cultivars studied during germination, greater proportions of which are with potassium and phosphorus compared to sodium, sulfur, and magnesium. Our results corroborate those of reported by [3] on coconut and those of [20] on *Irvingia gabonensis*. Indeed, at the earlier germination stages, the main minerals proportions increase in the WAT and PB121$^+$ kernels. Such an observation could be explained by the higher enzyme activity due to phytases. These results are similar with those of [21] according to which the main form of phosphate reserve into oilseeds consists in a salt complex known as phytin and comprising K, Mg, Ca, Zn and Fe. This phytin represents an important mineral reserve into the seeds. Thus, the recovery and use of the phosphate and minerals, the phytin complex needs to be hydrolyzed by phytases. Additionally, [22] showed that the coconut kernel is a good source of dietary minerals. At the full germination stage, the main minerals contents decline into the coconut kernel, as result of their use by the haustorium for the metabolism involving the young seedlings [23].

5. CONCLUSION

This study was performed to determine the main soluble sugars and minerals of nuts in germination in order to suggest ways of increasing their commercial value. The work focused on the kernels of MYD, WAT, and PB121$^+$, the three most widespread coconut cultivars in Côte d'Ivoire. Results revealed that sucrose was the major sugar component of the kernel, whereas phosphorus and potassium were the main minerals. The germinated nuts kernel of WAT and the PB121^{+} hybrid, which revealed higher phosphorus and potassium contents could be used as additive in food for the children suffering from mineral deficiencies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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