

Variation of soluble sugar and minerals contents of kernels from Germinated Nuts of Several Coconut Cultivars (*Cocos nucifera* L.)

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.

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 (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

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. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

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 trees per cultivar were selected and divided into 2 sets of 4 coconut trees each, representing 2 experimental repetitions within the cultivar. The bunch of mature nuts, of 14 months of age, was harvested from each coconut plant and seven nuts were selected. At overall, 56 nuts were collected (7 nuts * 4 coconut plants * 2 sets) and stored for one month. Afterwards, the nuts were put in the seedbed of a coconut nursery at ambient temperature, and then treated for physicochemical traits during various stages of the germination trend.

Prior to the germination stages, the nuts were initially treated (treatment T0) for recording the raw nuts characteristics below 24 hours after harvesting, and then treated again (T1) after one month of storage. The remaining nuts put at the nursery were analysed during their germination, specifically for one month (treatment T2) and three months (treatment T3) later (2 months and 4 months after harvesting, respectively). For each treatment, the coconuts were batched per cultivar and the nuts were considered as representative sample per batch.

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 I).

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).

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

123

124 ***Sorbitol content***

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

134

135 ***Glucose content***

136 The glucose proportions in nut kernels were statistically identical ($P>0.05$) during
137 germination of the overall seeds. Indeed, from 0 month to 4 months of germination,
138 the glucose values respectively ranged between 7.65% and 5.25 for WAT, 7.65%
139 and 6.59% for MYD, and 8.94% and 4.87% for PB121⁺ hybrid. Before germination
140 (0 month) the seed kernel produced by the PB121⁺ hybrid revealed statistically
141 similar ($P>0.05$) glucose content as both WAT and MYD parentals.

142

143 ***Fructose content***

144 The seeds kernel from WAT and MYD displayed statistically unvarying fructose
145 proportions during their germination stages. The values recovered from 0 month to 4
146 months germination were 13.1% to 10.02% and 12.55% to 11.17% for respective
147 WAT and MYD cultivars.
148 For the PB121⁺ hybrid, the fructose proportions were statistically constant until 2
149 months of germination before dropping significantly regularly to 0.41% at the 4th
150 month of germination.

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

153

154 ***Sucrose content***

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

159 On the other hand, the sucrose proportions of the PB121⁺ hybrid raised from 64.9%
160 to 78.1% during the 1st month of storage and decreasing significantly thereafter to
161 74.44% at the 4th month of germination. At 0 month of germination, the PB121⁺
162 hybrid and its male parental (WAT) were lower in sucrose content than the female
163 parental (MYD).

164

165 **Table 1** : Variation of soluble sugar content of the kernel cultivars during
166 germination

167

Soluble sugar (%)	Stage of germination (month)	Cultivars		
		WAT (♂)	MYD (♀)	PB121 ⁺
Myo-inositol	0	0.05 ± 0.01a	0.08 ± 0.03a	0.06 ± 0.04a
	1	0.07 ± 0.03a	0.07 ± 0.02a	0.09 ± 0.04a
	2	0.09 ± 0.02a	0.08 ± 0.02a	0.08 ± 0.05a
	4	0.08 ± 0.02a	0.08 ± 0.03a	0.08 ± 0.03a
Sorbitol	0	0.78 ± 0.05a	0.42 ± 0.04a	0.68 ± 0.29a
	1	0.46 ± 0.26b	0.34 ± 0.06a	0.63 ± 0.01a
	2	0.29 ± 0.09b	0.32 ± 0.05a	0.43 ± 0.07ab
	4	0.28 ± 0.17b	0.23 ± 0.15a	0.21 ± 0.23b
Glucose	0	0.45 ± 0.05a	0.53 ± 0.06a	0.54 ± 0.19a
	1	0.41 ± 0.04a	0.48 ± 0.09a	0.42 ± 0.03a
	2	0.37 ± 0.10a	0.45 ± 0.25a	0.37 ± 0.22a
	4	0.32 ± 0.15a	0.43 ± 0.05a	0.22 ± 0.03a
Fructose	0	0.77 ± 0.09a	0.87 ± 0.14a	0.84 ± 0.10a
	1	0.68 ± 0.06a	0.82 ± 0.11a	0.75 ± 0.07a
	2	0.65 ± 0.14a	0.73 ± 0.35a	0.66 ± 0.21a
	4	0.61 ± 0.20a	0.64 ± 0.08a	0.41 ± 0.08b
Sucrose	0	3.83 ± 0.61a	5.03 ± 0.74a	3.92 ± 0.99bc
	1	5.15 ± 0.54a	5.57 ± 2.27a	6.74 ± 1.18a
	2	4.83 ± 0.28a	4.82 ± 1.38a	5.37 ± 0.38ab
	4	4.80 ± 2.14a	4.35 ± 0.88a	2.68 ± 1.85b

168

169 **MYD** : Malaysian Yellow Dwarf. **WAT** : West African Tall. **PB121⁺**. Improved hybrid PB121⁺.
 170 Values with the same letter in the columns are not significantly different for each parameter.
 171

172 **3.2. Minerals profile of the germinating nut kernels**

173 The minerals chromatography revealed the same mineral elements from the overall
 174 cultivars studied, namely sodium (Na), magnesium (Mg), phosphorus (P), sulfur (S),
 175 and potassium (K). Potassium and phosphorus accounted the greatest values in the
 176 samples (Table 2).
 177

178 **Potassium content**

179 From the WAT and PB121⁺ samples, the potassium content increased significantly
 180 for 1 month, reaching respective values of 39.83% and 39.59%. Thereafter, the
 181 potassium contents dropped until the 4th month of germination at 33.36% and
 182 33.76%, respectively. On the other hand, the MYD recorded K contents raised
 183 significantly for 2 months of germination with top value of 36.24%, before
 184 decreasing to 33.93% at the 4th month of germination. At the earlier stages
 185 investigated (0 to 1 months), the WAT cultivar provided higher K contents than both
 186 MYD and PB121⁺ hybrid.
 187

188 **Phosphorus content**

189 The P contents of the nuts kernel statistically increased during the earlier storage
 190 and reached 26.69 % after 1 month for WAT cultivar and 23.67 % after 2 months for
 191 the PB121⁺ hybrid. Then, they significantly decreased to 18.64 % and 19.79 %,
 192 respectively at the 4th month of germination. From MYD cultivar, the P contents
 193 always decreased significantly during the seeds germination, from 21.15% (0
 194 month) to 15.08 % (4th month). Furthermore, the overall cultivars revealed similar
 195 phosphorus values at 0 month of storage.
 196

197 **Sodium content**

198 In PB121⁺ hybrid samples, the sodium value decreased for the 1st month of storage
 199 from 1.03 % to 0.86 %, before rising significantly to 1.38% at the 4th month of
 200 germination. Regarding MYD cultivar, the initial Na proportion (2.38% at 0 month)
 201 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.

205

206 ***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% and 6.69, during the seeds germination. However, at 0 month of germination, the MYD displayed higher Mg value compared to both WAT and PB121⁺ hybrid samples.

215

216 ***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.

224

225

226 **Table 2** : Variation of Minerals content of the kernel cultivars during germination

227

Minerals (%)	Stage of germination (month)	WAT (♂)	Cultivars MYD (♀)	PB121 ⁺
Na	0	0.57 ± 0.09a	2.38 ± 0.29a	1.03±0.23bc
	1	0.58 ± 0.02a	1.48 ± 0.16b	0.86±0.13c
	2	0.79 ± 0.04a	1.68 ± 0.08b	1.19±0.09ab
	4	0.64 ± 0.32a	1.77 ± 0.36b	1.38±0.12a
Mg	0	5.22 ± 0.16b	8.36 ± 0.05a	6.69 ± 0.58a
	1	6.90 ± 0.37a	6.74 ± 0.32b	6.66 ± 0.10a
	2	5.38 ± 0.53b	7.65 ± 0.10a	7.29 ± 0.31a
	4	4.93 ± 0.02b	6.18 ± 0.93b	6.37 ± 0.70a

P	0	21.66 ± 0.88b	21.15 ± 0.11a	21.19 ± 1.32b
	1	26.69 ± 1.43a	17.26 ± 1.06b	24.69 ± 1.22a
	2	23.01 ± 1.41b	18.45 ± 0.03b	23.67 ± 0.53a
	4	18.64 ± 0.25c	15.08 ± 1.67c	19.79 ± 0.04b
S	0	3.52 ± 0.23a	2.95 ± 0.22c	3.36 ± 0.46a
	1	3.37 ± 0.23a	3.17 ± 0.38bc	3.37 ± 0.33a
	2	2.96 ± 0.50a	4.44 ± 0.12a	2.47 ± 0.03b
	4	3.59 ± 0.45a	3.63 ± 0.47b	3.07 ± 0.53ab
K	0	37.44 ± 0.15ab	31.11 ± 0.46b	35.29 ± 1.18b
	1	39.83 ± 2.49a	31.88 ± 2.61b	39.59 ± 2.48a
	2	36.59 ± 2.88ab	36.24 ± 0.17a	35.68 ± 0.72b
	4	33.36 ± 2.18b	33.93 ± 2.05ab	33.76 ± 1.69b

228

229 **MYD** : Malaysian Yellow Dwarf. **WAT** : West African Tall. **PB121**⁺. Improved hybrid PB121⁺.

230 **Na** : Sodium, **Mg** : Magnesium, **P** : phosphorus, **S** : sulfur, **K** : Potassium,

231 Values with the same letter in the columns are not significantly different for each parameter.

232

233 **4 DISCUSSION**

234

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

244 Other authors have shown that the sugar content into germinated seeds could be
 245 used as indicator for maintaining seed viability or aging during storage [12,
 246 13,14,15, 16]. During oleaginous plants germinations, oligosaccharides are
 247 positively correlated with the seeds potential longevity [13,17,12,14,15].. Thus,
 248 oligosaccharides are involved in protecting membranes, proteins, and nucleic acids
 249 from damages occurring during drying [18]. Studies on soybean (*Glycine max*),
 250 maize (*Zea mays*), and shuttle (*Brassica campestris*) demonstrate the role of
 251 soluble oligosaccharides in protecting seeds against damage during dehydration
 252 and aging. They are involved in the survival and maintenance of seed viability
 253 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.

REFERENCES

- [1]. Bourdeix R. La sélection du cocotier (*cocos nucifera* L.). Etude théorique et pratique. Optimisation des stratégies d'amélioration génétique. Thèse de l'Université de Paris sud, centre d'Orsay (France). 1989 ; 194 p.
- [2]. Zushum M, Weimei Q. Caractéristiques et évaluation des variétés de cocotier de l'île Hainan (Chine) plantation, recherche, développement. 1997 ; 4:202-203. French.
- [3]. Van der Vossen H and Fagbayide J. *Helianthus annuus* L. In: Van der Vossen, H.A.M. & Mkamilo, G.S. (Editeurs). PROTA 14 : Oléagineux. Ressources végétales de l'Afrique tropicale. 2007; :101-108.
- [4]. Konan J, Allou K, N'goran A, Diarrassouba L, Ballo K. Bien cultiver le cocotier en Côte d'Ivoire. Fiche technique sur le cocotier. Direction des Programmes de Recherches et de l'Appui au Développement. 2006; 4 p.
- [5]. De Taffin G. Le cocotier. Le Technicien d'Agriculture Tropicale. Paris, France. 1993 ; 100 p.
- [6]. Assa R, Konan J, Nemlin J, Prades A, Agbo N, Sie R, 2006. Diagnostic de la cocoteraie paysanne du littoral ivoirien. Sciences et Nature, 2: 113-120.
- [7]. Bachrach L, Gardner J. Garegiver knowledge, attitudes, and practices regarding childhood diarrhea and dehydration in kingston, Jamaica. Revue Panam Salud Publica. 2002 ; 12 : 37-44
- [8]. Konan K. Etude de la tolérance à la sécheresse chez le cocotier (*Cocos nucifera* L.) : évaluation de quelques paramètres biologiques et physiologiques. Thèse de Doctorat de l'Université de Cocody (Côte d'Ivoire). 1997 ; 110p.

- 319
320 [9]. Balasubramaniam K, Jayalath T, Wijesundera C, Hoover A, De Silva M.
321 Biochemical changes during germination of coconut. *Annals of Botany*. 1973; 37:
322 439-445.
- 323
324 [10]. Clements K, Rex G, Betty D. Myo-inositol content of common foods
325 development of a high myo-inositol diet. *American Journal of Chemical Nutrition*.
326 1980; 33: 1954-1967. DOI: 10.1093/ajcn/33.9.1954
- 327
328 [11]. Tsuneyuki O, Sadako N. Digestion, absorption, fermentation and metabolism of
329 functional sugar substitutes and their available energy. *Pure and applied*
330 *chemistry*. 2002; 74: 1253-1261. doi: 10.1.1.522.6120
- 331
332 [12]. Bernal-Lugo I, Leopold A.C. Changes in soluble carbohydrates during seed
333 storage. *Plant Physiology*. 1992 ; 98 : 1207–1210. DOI:
334 <https://doi.org/10.1104/pp.98.3.1207>
- 335
336 [13]. Horbowicz M, Obendorf R.L. Seed desiccation tolerance and storability:
337 dependence on flatulence-producing oligosaccharides and cyclitols-review and
338 survey. *Seed Sci. Res.* 1994 ; 4 : 385–405.
339 <https://doi.org/10.1017/S0960258500002440>
- 340
341 [14]. Steadman K.J, Pritchard H.W, Dey P.M. Tissue-specific soluble sugars in
342 seeds as indicators of storage category. *Ann. Bot.* 1996; 77: 667– 674.
- 343
344 [15]. Sinniah U.R, Ellis R.H, John P. Irrigation and seed quality development in seed
345 rapid-cycling brassica: soluble carbohydrates and heat-stable proteins. *Ann. Bot.*
346 1998; 82: 647–655.
- 347
348 [16]. Lehner A, Bailly C, Flechel B, Poels P, Côme D, Corbineau F. Changes in
349 wheat seed germination ability, soluble carbohydrate and antioxidant enzyme
350 activities in the embryo during the desiccation phase of maturation. *J. Cerebr. Sci.* 2006;
351 43: 175–182.

352

353 [17]. Lin T.P, Huang N.H. The relationship between carbohydrate composition of
354 some tree seeds and their longevity. J. Exp. Bot. 1994 ; 45 : 1289–1294.

355

356 [18]. Hoekstra F.A, Crowe J.H, Crowe L.M. Effect of sucrose on phase behavior of
357 membranes in intact pollen of *Typha latifolia* L., as measured with Fourier transform
358 infrared spectroscopy. Plant Physiol. 1991; 97: 1073–1079. Doi: 0032-0889/91/97/1
359 073/07/\$01 .00/0

360

361 [19]. Obendorf R.L. Oligosaccharides and galactosyl cyclitols in seed desiccation
362 tolerance. Seed Sci. Res. 1997; 7: 63–74.

363 <https://doi.org/10.1017/S096025850000341X>

364

365 [20]. Tchoundjeu Z, Atangana A. *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke)
366 Baill. In: Van der Vossen, H.A.M. & Mkamilo, G.S. (Editeurs). PROTA 14:
367 Oléagineux. Ressources végétales de l'Afrique tropicale 14. 2007; 108-116.

368

369 [21]. Dominique S. Les bases de la production végétale. Tome3 : la plante et son
370 amélioration. Collection Sciences et Techniques Agricoles. 5^e édition. 2007 ; 304 p.

371

372 [22]. Santoso U, Kazuhiro K, Toru O, Tadahiro T, Akio M. Nutrient composition of
373 *kopyor* coconuts (*cocos nucifera* L.) Food Chemistry. 1996 ; 52 : 299-304.
374 [http://dx.doi.org/10.1016/0308-8146\(95\)00237-5](http://dx.doi.org/10.1016/0308-8146(95)00237-5).

375

376 [23]. Manciot R, Ollagnier M, Ochs R. Nutrition minérale et fertilisation du cocotier
377 dans le monde. Oléagineux. 1979 ; 34 : 563-576.

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379 **APPENDIX**