Journal of Food and Nutrition Sciences
2023; 11(5): 146-153
http://www.sciencepublishinggroup.com/j/jfns
doi: 10.11648/j.jfns.20231105.12
ISSN: 2330-7285 (Print); ISSN: 2330-7293 (Online)

Influence of Maturity Stage and Cultivar on the Proximate, Mineral and Amino-Acid Composition of *Cocos nucifera* L. Kernel from Côte d'Ivoire Coconut Germplasm

Kouadio Marcellin Konan[1, 2], Koné Fankroma Martial Thierry[1, *], Soro Pégnonsienrè Lacina[3], Doubi Bi Tra Serges[2], Konan Konan Jean Louis[2]

[1]Department of Food Science and Technology, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire

[2]Marc Delorme Coconut Research Station Port-Bouët, Centre National de Recherche Agronomique (CNRA), Abidjan, Côte d'Ivoire

[3]Department of Agriculture, Fisheries Resources and Agro-Industries, University of San Pedro, San Pedro, Côte d'Ivoire

Email address:

kouadio.marcellin@univ-na.ci (Kouadio Marcellin Konan), fankrom@yahoo.fr (Koné Fankroma Martial Thierry), sorolacina81@gmail.com (Soro Pégnonsienrè Lacina), doubitraserge@gmail.com (Doubi Bi Tra Serges), konankonanjeanlouis@gmail.com (Konan Konan Jean Louis)

[*]Corresponding author

To cite this article:

Kouadio Marcellin Konan, Koné Fankroma Martial Thierry, Soro Pégnonsienrè Lacina, Doubi Bi Tra Serges, Konan Konan Jean Louis. Influence of Maturity Stage and Cultivar on the Proximate, Mineral and Amino-Acid Composition of *Cocos nucifera* L. Kernel from Côte d'Ivoire Coconut Germplasm. *Journal of Food and Nutrition Sciences*. Vol. 11, No. 5, 2023, pp. 146-153. doi: 10.11648/j.jfns.20231105.12

Received: August 18, 2023; **Accepted**: September 8, 2023; **Published**: September 20, 2023

Abstract: *Cocos nucifera* L. is the most important coastal crop in Côte d'Ivoire and its production is the main source of income for farmers. Some 53 coconut cultivars have been developed by the Marc Delorme Coconut Research Station of the Centre National de Recherche Agronomique to provide producers with high-yielding, disease-resistant planting material. However, few data on the biochemical variability of the kernels of these coconut cultivars is known. Therefore, the nutritive characterization of coconut kernels is necessary for the selection of nutrient-rich cultivars for coconut breeding programs and for coconut food valorization. The present study was carried out to evaluate the nutritive composition of four coconut kernel cultivars selected at different maturity stages at the Marc Delorme Coconut Research Station of the National Centre for Agricultural Research. The ANOVA results show a significant effect ($p<0.05$) of coconut cultivar and maturity stage on kernel nutritive parameters. Moisture, carbohydrate and soluble sugars contents were maximal at 10 months and decreased significantly ($p<0.0001$) during kernel maturation. Protein, fat, fibre, ash, minerals and amino acids increased significantly ($p<0.05$) and were maximal at 12 months. The improved West African Tall (WAT^+) coconut kernel contains minimum moisture (5.07%), maximum fibre (11.29%), fat (55.42%) and energy (607,41 kcal/100g), while the improved Rennell Island Tall (RIT^+) contains maximum carbohydrates (32.13%), reducing sugars (2.78%) and protein (8.63%). The improved hybrid $PB113^+$ also contains maximum ash (1.56%), total sugars (7.24%) and non-reducing sugars (4.98%). Potassium (62488.50 – 74104.34 ppm) and histidine (654.66 – 1287.44 mg/100g) were the predominant minerals and amino acids in coconut kernel. The hybrid cultivars ($PB113^+$ and $PB121^+$) generally had higher mineral and amino acid contents than the tall cultivars (WAT^+ and RIT^+). These results suggest that there are differences in the nutritional composition of *Cocos nucifera* kernels between cultivars depending on the stage of maturity. The data obtained will provide useful information for the selection of coconut cultivars and their use in food products.

Keywords: *Cocos nucifera*, Côte d'Ivoire, Kernel, Cultivar, Maturity, Nutritive, Valorization

1. Introduction

The coconut palm (*Cocos nucifera* L.) is a resilient fruit tree with social, cultural, economic and environmental importance to communities and contributes to sustainable development [1, 2]. It is a multifunctional resource that provides livelihoods for more than 100 million people living in fragile coastal areas [2, 3]. Its fruit provides several food co-products. All these co-products of coconut make it an important food system for food security. In Côte d'Ivoire, coconut is grown on 50,000 ha and is the main cash crop, providing income for more than 20,000 families living in coastal areas [4]. Much research has been conducted to improve the profitability of this coconut palm by developing more than 53 coconut cultivars with high nut yields [5]. However, the profitability of coconut remains low because copra, a non-food product without quality standards, is the main valorization of the coconut, although the coconut kernel is a rich source of nutrients. Thus, for a better valorization of coconut, some biochemical characterizations of coconut kernel cultivars have been carried out by several authors [6-9] in order to know the nutritive potentials of Ivorian coconut kernel. However, few data on the biochemical composition of coconut kernel such as nutrients, minerals, amino acids and bioactive compounds during kernel maturation of many other cultivars remain unknown and yet the quality of coconut kernel varies considerably among cultivars, because some cultivars are known to produce good quality coconut kernel with high oil content, total sugar in water and tasty white kernel [10]. Therefore, the aim of this study was to evaluate the inter-cultivar differences in the nutritive composition of the coconut kernel of four selected improved cultivars during coconut maturation. The results of this study will be useful as information for coconut breeders in cultivar selection programs, and for better valorization of coconut kernel-based food products and by-products.

2. Materials and Methods

2.1. Plant Materials

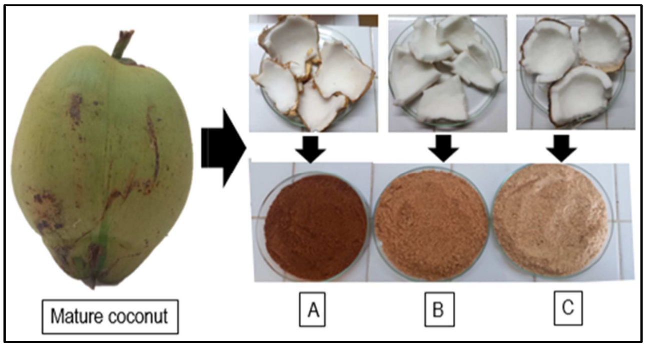

Figure 1. *Sample of coconut powders at 10th (A), 11th (B) and 12th (C) month of maturity.*

Fresh mature coconut at 10, 11 and 12 months per cultivar from four improved coconut, West African Tall (WAT+), Rennell Island Tall (RIT+), PB121+ (Malayan Yellow Dwarf × West African Tall+) and PB113+ (Cameroon Red Dwarf × Rennell Island Tall+) hybrids were randomly harvested from healthy adult, asymptomatic and selected palms, all of the same age and under similar management practices at the Marc Delorme Coconut Research Save Experimental Station. They were cleaned, dehusked and deshelled to separate the fresh kernel from the shell, while the coconut water was poured into a container and stored for future use. The kernels were cut into small pieces and bleached in a hot water bath for 5 minutes. After bleaching, the kernels were ground in a Moulinex, dried in a hot air oven at 40°C for 6 hours and sieved through a 250 µm sieve to obtain powders (Figure 1).

2.2. Proximate Composition Analysis

Proximate composition was determined using standard analytical methods [11]. Briefly, moisture content was determined by drying samples in a hot air circulating oven (Eagle, WI, USA) at 105 ± 2°C until a constant weight was obtained. Total nitrogen was determined by the Kjeldahl method using a digestion and distillation apparatus and the nitrogen to protein content was calculated using a conversion factor of 6.25 for all samples. Crude Fat content was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent. Crude ash content was determined by burning powder in a muffle furnace at 550°C until the sample was free of carbon, cooling in a desiccator and calculating the amount of ash. Crude fibre was determined after digestion of a known weight of fat-free sample in refluxing 1.25% sulphuric acid and 1.25% sodium hydroxide. The amount of total soluble sugars was estimated using the phenol-sulphuric acid reagent method [12]. and reducing sugars using 3,5-dinitro-salicylic acid [13]. The available carbohydrate and non-reducing sugars content was calculated by difference. Energy value was calculated using the conversion factors [14].

2.3. Mineral Analysis

The mineral content was estimated by ashing the kernel powder sample (5 g) at 550°C in a muffle furnace (Pyrolabo, France). The ash was boiled in a beaker with 10 mL of 20% hydrochloric acid and then filtered into a 100 mL standard flask. This was made up to the mark with deionized water. The minerals were determined by inductively coupled plasma mass spectrometry (ICP-MS, Thermo Scientific). All values are expressed as ppm.

2.4. Amino Acid Analysis

Amino acid analysis of each coconut kernel sample was performed on an Applied Biosystems Model 172 A high-performance liquid chromatograph (Applera Corp, Foster City, Calif., U. S. A.) equipped with a PTC RP-18 column (2.1 mm × 22 cm). Prior to injection, the proteins of each sample were hydrolyzed by 6 M HCl with phenol (1%) at 150°C for 60 min in the Pico-Tag system (Waters, Milford, Mass., U. S. A.). The resulting phenyl isothiocyanate amino acid derivatives were eluted by HPLC. Sodium acetate (45 mM, pH 5.9) and sodium acetate (105 mM, pH 4.6; 30%) and acetonitrile (70%) were used as buffers. All values are expressed in mg/100g.

2.5. Statistical Analysis

All experiments in this study were performed in triplicate (n

= 3) and results are expressed as mean ± standard deviation. Two-way analysis of variance ANOVA was performed on the complete data set to test the main effects of cultivar and maturity stage on the nutritive characteristics of coconut kernel. Means with significant differences were separated using Student Newman-Keuls post hoc test. Analyses were carried out using XLSAT statistical software.

3. Results and Discussion

3.1. Results

3.1.1. Proximate Composition

The proximate composition (g/100g) of coconut kernel samples according to maturity are tabulated in Tables 1 and 2. The improved West Africa Tall (WAT^+) coconut kernel had minimum moisture (5.07), maximum fibre (11.29), and fat (55.42) at 12 months. The improved Rennell Island Tall (RIT^+) coconut kernel had maximum carbohydrates (32.13), reducing sugars (2.78) both at 10 months and protein (8.63) at 12 months. The improved hybrid $PB113^+$ coconut kernel had maximum ash (1.56) at 12 months, maximum total sugars (7.24) and non-reducing sugars (4.98) at 10 months. The fibre, ash, fat and protein contents in coconut kernel increased with coconut maturation, while the moisture, carbohydrate and soluble sugar contents decreased. Based on the results of the analysis of variance test, cultivar and maturity factors had significant effects ($p<0.05$) on the proximal composition of coconut kernel.

Table 1. *Inter-cultivar differences in proximate composition (g/100g dry matter) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Moisture	Fibre	Ash	Protein	Fat
	10	9.13 ± 0.05^b	5.09 ± 0.05^g	0.96 ± 0.02^g	5.56 ± 0.10^h	47.13 ± 0.06^f
RIT^+	11	6.48 ± 0.04^d	9.01 ± 0.04^d	1.13 ± 0.02^e	8.16 ± 0.03^b	49.31 ± 0.10^d
	12	5.27 ± 0.02^h	9.78 ± 0.12^c	1.17 ± 0.02^e	8.63 ± 0.04^a	51.15 ± 0.04^c
	10	8.19 ± 0.07^c	6.27 ± 0.03^f	0.88 ± 0.02^h	4.43 ± 0.08^k	49.54 ± 0.16^d
WAT^+	11	5.35 ± 0.03^h	10.67 ± 0.13^b	0.96 ± 0.01^g	7.05 ± 0.05^g	52.08 ± 0.17^b
	12	5.07 ± 0.02^i	11.29 ± 0.06^a	1.06 ± 0.05^f	7.46 ± 0.03^e	55.42 ± 0.34^a
	10	10.45 ± 0.03^a	4.59 ± 0.05^h	1.29 ± 0.01^c	4.96 ± 0.10^j	47.27 ± 0.13^f
$PB113^+$	11	6.47 ± 0.02^d	7.78 ± 0.06^e	1.42 ± 0.03^b	7.22 ± 0.05^f	49.35 ± 0.70^d
	12	6.25 ± 0.04^e	8.88 ± 0.05^d	1.56 ± 0.03^a	7.68 ± 0.09^d	50.97 ± 0.41^c
	10	10.37 ± 0.03^a	4.87 ± 0.06^g	1.23 ± 0.06^d	5.13 ± 0.05^i	48.70 ± 0.24^e
$PB121^+$	11	6.15 ± 0.02^f	7.89 ± 0.06^e	1.39 ± 0.01^b	7.26 ± 0.03^f	50.44 ± 0.49^c
	12	6.02 ± 0.06^g	9.01 ± 0.09^d	1.42 ± 0.02^b	7.85 ± 0.06^c	51.04 ± 0.18^c
Statistical significance of the sources of variation (probability>F) from ANOVA						
Cultivar (C)		<0.05	<0.0001	<0.0001	<0.0001	<0.0001
Month (M)		<0.05	<0.0001	<0.0001	<0.0001	<0.0001
C × M		<0.05	<0.0001	<0.05	<0.0001	<0.0001

Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other ($p<0.05$)

Table 2. *Inter-cultivar differences in proximate composition (g/100g dry matter) and energy value (kcal/ 100g) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Carbohydrate	T. sugars	R. sugars	NR. sugars	Energy (kcal/100g)
	10	32.13 ± 0.15^a	6.72 ± 0.23^b	2.78 ± 0.16^a	3.94 ± 0.04^c	$574{,}90 \pm 0{,}11^f$
RIT^+	11	25.91 ± 0.22^f	5.30 ± 0.38^f	2.57 ± 0.25^b	2.73 ± 0.12^f	$580{,}10 \pm 0{,}22^e$
	12	24.01 ± 0.46^{gf}	4.75 ± 0.25^i	2.15 ± 0.32^d	2.60 ± 0.02^e	$590{,}88 \pm 2{,}08^{ab}$
	10	30.69 ± 0.19^b	4.72 ± 0.29^h	1.43 ± 0.33^i	3.28 ± 0.10^d	$586{,}37 \pm 1{,}05^{cd}$
WAT^+	11	23.89 ± 0.28^h	3.77 ± 0.32^j	1.14 ± 0.26^j	2.63 ± 0.07^{fe}	$592{,}51 \pm 0{,}51^b$
	12	19.71 ± 0.37^i	3.35 ± 0.33^k	0.85 ± 0.62^k	2.49 ± 0.02^g	$607{,}41 \pm 1{,}52^a$
	10	31.44 ± 0.13^a	7.24 ± 0.37^a	2.26 ± 0.54^c	4.98 ± 0.02^a	$571{,}02 \pm 0{,}45^g$
$PB113^+$	11	27.77 ± 0.72^d	6.04 ± 0.42^d	1.89 ± 0.52^e	4.15 ± 0.05^b	$584{,}08 \pm 3{,}42^d$
	12	24.67 ± 0.55^g	5.14 ± 0.44^f	1.65 ± 0.73^g	3.49 ± 0.25^f	$588{,}07 \pm 1{,}70^{bc}$
	10	29.69 ± 0.28^c	6.36 ± 0.29^c	2.25 ± 0.62^c	4.11 ± 0.02^{bc}	$577{,}63 \pm 1{,}26^{ef}$
$PB121^+$	11	26.86 ± 0.41^e	5.70 ± 0.36^e	1.75 ± 0.43^f	3.95 ± 0.08^c	$590{,}48 \pm 2{,}63^{ab}$
	12	24.66 ± 0.17^{gh}	4.97 ± 0.51^g	1.58 ± 0.42^h	3.39 ± 0.01^d	$589{,}41 \pm 0{,}96^{abc}$
Statistical significance of the sources of variation (probability>F) from ANOVA						
Cultivar (C)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Month (M)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C × M		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

T: total, R: reducing, NR: non-reducing. Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other ($p<0.05$)

3.1.2. Mineral Composition

The mineral concentration (ppm: parts per million) in the coconut kernel samples according to maturity stage are summarized in Tables 3 and 4. Mineral concentrations in kernels were generally high at 12 months for all coconut cultivars. Potassium was the predominant mineral. Potassium (62488.50 – 74104.34), sodium (3701.47 – 4391.47) and manganese (76.90 – 123.67) were maximum for hybrid PB113$^+$ kernel. Magnesium (3672.87 – 6458.40), calcium (2263.77 – 3768.28) and sulphur (2184.03 – 2905.73) were maximum for hybrid PB121$^+$ kernel. Based on the results of the analysis of variance test, cultivar and maturity factors had significant effects (p<0.05) on the mineral composition of the coconut kernels. With the exception of sodium, for which maturity had a non-significant effect. The hybrids generally had higher minerals contents than the tall coconut cultivars. Minerals concentrations in kernels increased during coconut maturation.

Table 3. *Inter-cultivar differences in mineral composition (ppm of dry matter) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Calcium	Magnesium	Potassium	Sodium
	10	2263.77 ± 80.79^{h}	3672.87 ± 115.49^{f}	62488.50 ± 359.27^{k}	3812.07 ± 110.13^{bc}
RIT$^+$	11	2471.85 ± 29.01^{g}	3827.23 ± 60.92^{e}	63855.03 ± 36.61^{j}	3781.10 ± 93.97^{bc}
	12	2593.06 ± 78.14^{g}	3881.80 ± 83.41^{e}	64081.00 ± 113.89^{hi}	3720.33 ± 69.91^{c}
	10	2461.86 ± 33.28^{g}	4762.27 ± 67.14^{d}	64334.03 ± 117.76^{h}	4121.13 ± 78.00^{ab}
WAT$^+$	11	2753.10 ± 113.70^{f}	4783.53 ± 35.80^{d}	64954.29 ± 70.70^{g}	4020.70 ± 139.80^{bc}
	12	2883.30 ± 108.09^{e}	4894.27 ± 118.64^{d}	65676.03 ± 112.73^{f}	3877.83 ± 103.55^{bc}
	10	3096.02 ± 92.14^{d}	4841.13 ± 56.02^{d}	72993.10 ± 77.91^{b}	4335.93 ± 361.23^{a}
PB113$^+$	11	3554.61 ± 28.65^{bc}	4946.63 ± 32.57^{d}	73070.83 ± 106.65^{b}	4391.47 ± 89.50^{a}
	12	3634.21 ± 60.23^{ab}	5111.57 ± 70.07^{c}	74104.34 ± 140.74^{a}	4350.27 ± 68.75^{a}
	10	3437.78 ± 45.69^{c}	6261.77 ± 36.35^{b}	69040.04 ± 145.91^{e}	3853.80 ± 147.25^{bc}
PB121$^+$	11	3666.05 ± 57.75^{ab}	6366.23 ± 55.74^{ab}	70245.14 ± 125.07^{d}	3813.67 ± 75.05^{bc}
	12	3768.28 ± 59.93^{a}	6458.40 ± 120.68^{a}	71150.37 ± 345.90^{c}	3701.47 ± 94.52^{c}
Statistical significance of the sources of variation (probability>F) from ANOVA					
Cultivar (C)		<0.0001	<0.0001	<0.0001	<0.0001
Month (M)		<0.0001	<0.0001	<0.0001	NS
C × M		NS	NS	<0.0001	NS

NS: non-significant. Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other (p<0.05)

Table 4. *Inter-cultivar differences in mineral composition (ppm of dry matter) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Sulfur	Phosphorus	Manganese	Zinc
	10	2184.03 ± 95.80^{e}	764.33 ± 10.00^{e}	81.23 ± 8.33^{c}	$22{,}94 \pm 0{,}48^{def}$
RIT$^+$	11	2361.43 ± 64.49^{de}	784.20 ± 22.12^{d}	89.27 ± 8.47^{abc}	$23{,}30 \pm 0{,}30^{de}$
	12	2507.40 ± 117.98^{cd}	791.43 ± 18.03^{d}	92.44 ± 7.54^{abc}	$23{,}50 \pm 0{,}50^{d}$
	10	2193.34 ± 91.92^{e}	659.60 ± 10.70^{h}	76.90 ± 15.68^{c}	$22{,}33 \pm 0{,}42^{f}$
WAT$^+$	11	2467.23 ± 22.62^{cd}	678.67 ± 11.94^{g}	86.90 ± 9.31^{bc}	$22{,}73 \pm 0{,}38^{def}$
	12	2524.07 ± 48.77^{cd}	692.97 ± 27.76^{f}	91.13 ± 14.48^{abc}	$22{,}60 \pm 0{,}36^{ef}$
	10	2612.43 ± 96.71^{bc}	786.87 ± 15.80^{d}	101.90 ± 7.90^{abc}	$21{,}00 \pm 0{,}10^{g}$
PB113$^+$	11	2718.59 ± 92.99^{ab}	844.17 ± 14.07^{c}	117.60 ± 11.66^{ab}	$22{,}37 \pm 0{,}31^{f}$
	12	2794.66 ± 92.51^{ab}	870.80 ± 18.35^{a}	123.67 ± 11.93^{a}	$22{,}80 \pm 0{,}20^{def}$
	10	2786.43 ± 100.99^{ab}	792.77 ± 15.61^{d}	96.57 ± 19.40^{abc}	$24{,}73 \pm 0{,}32^{c}$
PB121$^+$	11	2858.97 ± 79.86^{a}	836.97 ± 26.34^{c}	109.40 ± 9.25^{abc}	$25{,}42 \pm 0{,}07^{b}$
	12	2905.73 ± 113.34^{a}	857.10 ± 14.05^{b}	116.70 ± 18.29^{ab}	$25{,}66 \pm 0{,}04^{a}$
Statistical significance of the sources of variation (probability>F) from ANOVA					
Cultivar (C)		<0.0001	<0.0001	<0.0001	<0.0001
Month (M)		<0.0001	<0.0001	<0.05	<0.0001
C × M		NS	<0.0001	NS	<0.05

NS: non-significant. Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other (p<0.05)

3.1.3. Amino Acid Composition

Amino acid concentrations (mg/100g) in coconut kernel samples according to maturity stage are summarized in Tables 5 and 6. Amino acid concentrations in kernels were generally high at 12 months for all coconut cultivars. Lysine (420.11 – 858.22) and isoleucine (369.95 – 896.50) were maximum for WAT$^+$ kernel. Leucine (536.41 – 896.90) was maximum for RIT$^+$ kernel. Histidine (654.66 – 1287.44), threonine (195.78 – 895.36), phenylalanine (405.03 – 816.58) and tryptophan (355.39 – 793.57) were maximum for PB121$^+$ kernel. Based on the results of the analysis of variance test, cultivar and maturity factors had significant effects (p<0.05) on the amino acid compositions. The hybrids generally had higher amino acid concentrations than the Tall coconut cultivars. Amino acid concentrations in kernels increased during coconut maturation.

Table 5. *Inter-cultivar differences in amino acids (mg/100g of dry matter) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Lysine	Leucine	Histidine	Threonine
	10	566.09 ± 3.23^{f}	789.06 ± 7.13c	654.66 ± 14.03^{j}	195.78 ± 3.71^{k}
RIT^{+}	11	733.13 ± 3.87^{e}	872.24 ± 4.74b	679.72 ± 9.14^{i}	251.80 ± 5.82^{j}
	12	785.52 ± 2.88^{c}	896.50 ± 7.99^{a}	688.90 ± 7.98^{i}	275.13 ± 2.45^{i}
	10	762.74 ± 3.84^{d}	536.41 ± 7.23^{h}	935.24 ± 6.24^{h}	611.86 ± 3.02^{h}
WAT^{+}	11	816.81 ± 2.28^{b}	577.74 ± 11.14^{g}	1043.16 ± 9.49^{f}	732.93 ± 3.46^{g}
	12	858.22 ± 3.20^{a}	587.76 ± 8.50^{g}	1236.87 ± 9.31^{b}	797.72 ± 2.16^{f}
	10	420.11 ± 3.11^{i}	618.66 ± 6.68^{f}	954.78 ± 9.89^{g}	818.76 ± 1.78^{e}
PB113^{+}	11	467.16 ± 5.99^{h}	660.14 ± 8.57^{e}	1075.30 ± 15.15^{e}	861.18 ± 2.20^{c}
	12	484.12 ± 8.10^{g}	664.84 ± 5.55^{e}	1176.66 ± 15.26^{d}	879.87 ± 2.05^{b}
	10	458.61 ± 2.78^{h}	632.80 ± 13.52^{f}	1075.05 ± 12.82^{e}	838.71 ± 3.81^{d}
PB121^{+}	11	478.94 ± 9.07^{g}	676.55 ± 8.27^{e}	1195.07 ± 5.95^{c}	880.33 ± 4.05^{b}
	12	487.27 ± 7.80^{g}	696.69 ± 7.88^{d}	1287.44 ± 10.29^{a}	895.36 ± 5.62^{a}
Statistical significance of the sources of variation (probability>F) from ANOVA					
Cultivar (C)		<0.05	<0.0001	<0.0001	<0.05
Month (M)		<0.05	<0.0001	<0.0001	<0.05
C × M		<0.05	<0.0001	<0.0001	<0.05

Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other (p<0.05)

Table 6. *Inter-cultivar differences in amino acids (mg/100g of dry matter) of the coconut kernels from Côte d'Ivoire.*

Cultivar	Month	Tryptophan	Isoleucine	Phenylalanine	Valine
	10	355.39 ± 3.46^{k}	369.95 ± 3.60^{j}	405.03 ± 5.16^{k}	490.72 ± 3.79^{h}
RIT^{+}	11	385.06 ± 3.81^{j}	438.40 ± 3.62^{i}	466.21 ± 6.32j	524.80 ± 3.84^{g}
	12	396.85 ± 2.52^{i}	489.96 ± 6.91^{h}	497.37 ± 9.60^{h}	551.29 ± 2.75^{f}
	10	412.86 ± 5.48^{h}	772.09 ± 3.68^{e}	481.87 ± 6.28^{i}	391.63 ± 2.83^{j}
WAT^{+}	11	465.28 ± 5.00^{g}	871.64 ± 5.75^{b}	530.26 ± 8.95^{g}	423.26 ± 2.71^{i}
	12	474.42 ± 2.67^{f}	896.50 ± 6.41^{a}	585.94 ± 6.59^{f}	486.81 ± 7.25^{h}
	10	583.04 ± 2.50^{e}	728.77 ± 7.27^{g}	636.44 ± 7.63^{e}	678.42 ± 2.10^{c}
PB113^{+}	11	620.70 ± 2.61^{d}	791.47 ± 6.81^{d}	722.39 ± 5.42^{c}	739.40 ± 2.90^{b}
	12	674.26 ± 3.66^{c}	815.15 ± 6.73^{c}	775.69 ± 9.12^{b}	759.09 ± 7.50^{a}
	10	670.56 ± 6.04^{c}	758.06 ± 9.75^{f}	704.13 ± 8.60^{d}	596.44 ± 7.36^{e}
PB121^{+}	11	709.64 ± 3.29^{b}	825.25 ± 9.60^{c}	775.86 ± 9.21^{b}	641.58 ± 9.99^{d}
	12	793.57 ± 3.09^{a}	876.85 ± 8.23^{b}	816.58 ± 7.53^{a}	681.60 ± 8.30^{c}
Statistical significance of the sources of variation (probability>F) from ANOVA					
Cultivar (C)		<0.0001	<0.0001	<0.0001	<0.0001
Month (M)		<0.0001	<0.0001	<0.0001	<0.0001
C × M		<0.0001	<0.0001	<0.0001	<0.005

Values are expressed as Mean ± Standard Deviation (n = 3 trials). Mean values in the same column with different superscript letters were significantly different from each other (p<0.05)

3.2. Discussion

The physicochemical, phytochemical and nutritional composition of *Cocos nucifera*, as with many other fruits, depends on the variety, genotype, maturity of the fruit, the climatic conditions in which it is grown, soil type, nutrients available in the soil, agronomic management of the plantation and season [15-17]. The result of the proximate composition of 100 g of coconut kernel showed that it contains a considerable amount (5.07 – 10.45%) of moisture, which could promote the growth of microorganisms that cause kernel deterioration. Therefore, the kernel must be stored refrigerated or processed after shelling to avoid microbial spoilage. Previous reports showed similar moisture content (8.33%) in the kernel [18]. High moisture content implies that dehydration would increase the relative concentration of other nutrients in the food [19, 20]. The crude fibre content (4.87 – 11.29%) of kernels in this study was higher than that of mature coconut (2.38%) reported by authors in Nigeria [17] and similar (11.7%) to that reported by authors in India [21]. With adequate consumption, coconut kernels dietary fibre could promote good health by controlling blood sugar levels, promoting intestinal microflora, lowering cholesterol levels, reducing the risk of heart disease, hypertension, constipation, diabetes, and colon and breast cancer in the body [18].

The amount of protein content (4.43 – 8.63 %) found in this study was lower than that found (9.82 – 10.55%) by authors [22] in Nigeria and slightly identical to the previous report (7.2 – 8.77%) by authors [6] in Côte d'Ivoire. A similar coconut protein content (7.1%) was also reported for Indian coconuts [21]. Authors concluded that the protein content of coconut kernel increases during coconut maturation as we see it [23]. The protein content of coconut kernel was higher than that of most starchy roots and tubers such as cassava, sweet potatoes and yams reported by authors [24, 25] and higher than that of popular fruits such as bananas, apples and oranges [10].

Fat is the major macronutrient in coconut kernel [6, 7, 21, 26, 27]. In this study, fat was found to be higher than that found (35.01 – 38.80%) by authors [20, 26] and lower than previous results (66.37 – 73.01%) by authors [6, 7, 26]. However, these results indicate that the coconut kernel is a suitable raw material for the production of oil-based coconut products such as virgin coconut oil. It is widely recognized that coconut oil has health-promoting properties due to its content of lauric acid (C12: 0), a medium-chain fatty acid that is easily digested and is not stored in adipose tissue, but is readily oxidized in the body to provide rapid energy [28, 29].

The carbohydrate of the kernel in the present study was slightly similar to that reported (30.15 – 33.00%) by authors [22] and lower than that reported (36.57%) by authors [23]. Total soluble sugars were high compared to the previous study (2.47 – 4.28%) reported by the authors [7, 26]. Reducing sugar content was lower than that described (10.07%) by authors [18], while non-reducing sugars were slightly similar to those (3.11 – 5.12%) found by authors [6].

The ash content (4.92 – 6.40%) for various coconut kernels for hybrids previously studied by some authors were higher to our findings [7, 9]. However, our values were slightly similar to those studied by authors [10, 18, 22].

The mineral concentrations of the coconut kernels studied here showed the prevalence of many macro-minerals necessary for the body, including potassium, calcium, magnesium, sulphur and sodium. Potassium (62488.50 – 74104.34 ppm) was the predominant mineral in the coconut kernel studied here, as noted by some authors [10, 23, 30]. A similar level (50210.16 – 60925.56 ppm) of potassium in 11-12 month old coconut kernel varieties was found for Sri Lanka Tall, Malayan Yellow Dwarf and Hybrid in Pakistan [10]. Thus, the consumption of coconut kernels could provide potassium, which is an essential macro-mineral nutrient that prevents hypertension, a major risk factor for cardiovascular disease, by controlling blood pressure. Indeed, dietary potassium intakes of more than 4,700 mg/day do not result in increased health risk, health because excess potassium is easily excreted in the urine [31]. Mature coconut kernel is richer in minerals than water and could be an indispensable source of some essential minerals [32].

Although the amino acid content in coconut kernel is lower than those from plants, it is a mixture of some essential and non-essential amino acids [33]. The amino acid profile of the coconut kernels studied showed the presence of essential amino acids, and histidine (654.66 – 1287.44 mg/100g) was predominant. However, tyrosine (0.30 – 1.62 g/100g) and glutamate (1.30 – 4.30 g/100g) were the most predominant amino acids found in the Indonesian coconut kernel varieties [34]. Thus, the consumption of coconut kernels in this study could provide histidine, which is the most active and versatile amino acid with unique biochemical and physiological properties that play multiple roles (antioxidant function, anti-inflammatory potential, binding and chelation agent for compounds) [35, 36].

4. Conclusion

The results of the study showed significant differences between cultivars in the nutritive composition of kernels of coconut seed grown at the Coconut Research Station in Côte d'Ivoire coconut germplasm, with an influence of maturity stage. These coconut kernels are an important source of minerals and amino acids. The hybrid cultivars ($PB113^+$ and $PB121^+$) generally had higher mineral and amino acid contents than the tall cultivars (WAT^+ and RIT^+). This study showed that the coconut kernels studied are nutrient-rich foods with health benefits. Thus, the valorization of the coconut by processing the kernel into food by-products such as coconut milk, virgin coconut oil and coconut flour in Côte d'Ivoire could contribute to food security and generate income for Ivorian coconut farmers.

Acknowledgments

The authors are grateful to Marc Delorme, Manager of the Coconut Research Station, and the researchers for their guidance. The authors also thank the farmers and extension personnel from the research station for their cooperation.

References

[1] FAO (2014). The state of food and agriculture: Innovation in family farming. Rome, Italy.

[2] COGENT (2017). A global strategy for the conservation and use of coconut genetic resources 2018-2028. Montpellier, France.

[3] Daa-kpode U. A., Djedatin G., Sacla-Aide E., Salako K. V., Baba-Moussa F., and Adeoti K. (2021). Ethnobotanical study of the coconut palm in the coastal zone of Benin. *International Journal of Biodiversity and Conservation* 13 (3), 152-164.

[4] Assa R. R., Konan K. J.-L., Nemlin J., Prades A., Agbo N. G., and Sié R. S. (2006). Diagnostic de la cocoteraie paysanne du littoral ivoirien. *Sciences and Nature* 3 (2), 113-120.

[5] Konan K. J. L., Sié R. S., N'guette S. P., Lekadou T. T., and Allou K. (2010). Assessment of vegetative growth and production of new improved coconut (*Cocos nucifera* L.) hybrids. *Journal of Applied Biosciences* 26, 1664-1674.

[6] Assa R. R., Konan K. J. L., Prades A., and Nemlin J. (2010). Physicochemical characteristics of kernel during fruit maturation of four coconut cultivars (*Cocos nucifera* L.). *African Journal of Biotechnology* 9 (14), 2136-2144.

[7] Deffan A. B. Z., Konan K. J. L., Assa R. R., and Kouamé P. L. (2012). Caractérisation physico-chimiques des noix et de l'huile des premiers cocotiers (*Cocos nucifera* L.) PB 121 issus de la culture in vitro d'embryon zygotique plantés en Côte d'Ivoire. *International Journal of Biological and Chemical Sciences* 6 (6), 7013-7026.

[8] Kodjo N. F., Konan K. J. L., Yao S. D. M., Deffan A. B. Z., Koffi E.-B. Z., and Niamke S. (2016). Physicochemical characteristics of mature kernel from six progenies of coconut (*Cocos nucifera* L.) hybrid F1 malayan yellow dwarf x vanuatu tall tolerant to lethal yellowing disease of Ghana. *International Journal of Applied Biology and Pharmaceutical Technology* 7 (2), 213-222.

[9] Kodjo N. F., Konan K. J. L., Doue G. G., Yao S. D. M., Allou K., and Niamke S. (2015). Caractérisation physico-chimique des composantes de noix immature et mature de l'hybride de cocotier (*Cocos nucifera* L.) Nain Jaune Malaisie x Grand Vanuatu cultivé en Côte d'Ivoire. *Journal of Animal and Plant Sciences* 27 (1), 4193-4206.

[10] Solangi A. H., and Iqbal M. Z. (2011). Chemical composition of meat (kernel) and nut water of major coconut (*Cocos nucifera*) cultivars at coastal area of Pakistan. *Pakistan Journal of Botany* 43 (1), 357-363.

[11] AOAC (2005). Official Methods of Analysis of AOAC International. 18th ed. Gaithersburg, Maryland 20877-2417, USA.

[12] DuBois M., Gilles K. A., Hamilton J. K., Rebers P. A., and Smith F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry* 28 (3), 350-356.

[13] Bernfeld P. (1955). Amylase α and β methods. *Enzymology* 1, 149-158.

[14] FAO (2002). Food energy: Methods of analysis and conversion factors. Rome, Italy.

[15] Idris O. A., Wintola O. A., and Afolayan A. J. (2019). Comparison of the proximate composition, vitamins (ascorbic acid, α-tocopherol and retinol), anti-nutrients (phytate and oxalate) and the GC-MS analysis of the essential oil of the root and leaf of *Rumex crispus* L. *Plants* 8 (3), 1-15.

[16] Márquez Cardozo C. J., Molina Hernández D., Caballero Gutiérrez B. L., Ciro Velásquez H. J., Restrepo Molina D. A., and Correa Londoño G. (2021). Physical, physiological, physicochemical and nutritional characterization of pumpkin (*Cucurbita maxima*) in postharvest stage cultivated in Antioquia-Colombia. *Revista Facultad Nacional de Agronomia Medellin* 74 (3), 9735-9744.

[17] Islam M. M., Naznin S., Naznin A., Uddin M. N., Amin M. N., Rahman M. M., Tipu M. M. H., Alsuhaibani A. M., Gaber A., and Ahmed S. (2022). Dry matter, starch content, reducing sugar, color and crispiness are key parameters of potatoes required for chip processing. *Horticulturae* 8, 1-12.

[18] Ojobor C. C., Anosike C. A., and Ezeanyika L. U. S. (2018). Evaluation of phytochemical, proximate and nutritive potentials of *Cocos nucifera* (Coconut) seeds. *Journal of Experimental Research* 6 (2), 11-18.

[19] Nwofia G., Victoria N., and Nwofia B. (2012). Nutritional variation in fruits and seeds of pumpkins (Cucurbita Spp) accessions from Nigeria. *Pakistan Journal of Nutrition* 11 (10), 848-858.

[20] Gomez S., Kuruvila B., Maneesha P., and Joseph M. (2022). Variation in physico-chemical, organoleptic and microbial qualities of intermediate moisture pineapple (*Ananas comosus* (L.) Merr.) slices during storage. *Food Production Processing and Nutrition* 4 (5), 1-11.

[21] Appaiah P., Sunil L., Kumar P. K. P., and Krishna A. G. G. (2014). Composition of coconut testa, coconut kernel and its oil. *Journal of the American Oil Chemists Society* 91 (6), 917-924.

[22] Nnorom I. C., Nnadozie C., Ugwa R., and Obike A. I. (2013). Proximate and trace metal analysis of coconut (*Cocos nucifera*) collected from southeastern Nigeria. *ABSU Journal of Environment, Science and Technology* 3, 357-361.

[23] Wynn T. (2017). Nutrition studies on mature and immature coconut meat and coconut water. *Yadanabon University Research Journal* 8 (1), 1-8.

[24] Sánchez-Zapata E., Fernández-López J., and Angel Pérez-Alvarez J. (2012). Tiger nut *(Cyperus esculentus)* commercialization: health aspects, composition, properties, and food applications. *Comprehensive Reviews in Food Science and Food Safety* 11 (4), 366-377.

[25] Chandrasekara A., and Josheph Kumar T. (2016). Roots and tuber crops as functional foods: a review on phytochemical constituents and their potential health benefits. *International Journal of Food Science* 3, 1-15.

[26] Deffan A. B. Z., Konan K. J. L., Assa R. R., and Kouame P. L. (2011). Caractérisation physico-chimique de l'amande d'hybride de cocotier (*Cocos nucifera* L.) PB121 issus de vitroculture selon les stades de maturité et la durée de stockage des noix. *Sciences and Nature* 8 (1), 63-71.

[27] Adoyo G. O., Sila D. N., and Onyango A. N. (2021). Physico-chemical properties of kernel from coconut (*Cocos nucifera* L.) varieties grown at the Kenyan Coast. *African Journal of Food Science* 15 (8), 313-321.

[28] Djannah F., Massi M. N., Hatta M., Bukhari A., Handayani I., Faruk M., and Rahaju A. S. (2022). Virgin coconut oil and tuberculosis: A mini-review. *Pharmacognosy Journal* 14 (2), 464-469.

[29] Nimbkar S., Leena M. M., Moses J. A., and Anandharamakrishnan C. (2022). Medium chain triglycerides (MCT): state-of-the-art on chemistry, synthesis, health benefits and applications in food industry. *Comprehensive Reviews in Food Science and Food Safety* 21 (10), 843-867.

[30] Asaad A. N., Jailani F., and Mutalib S. R. A. (2022). Physicochemical properties and sensory acceptability of different varieties of coconut water and flesh. *Scientific Research Journal* 19 (1), 75-89.

[31] IPI (2013). Nutrition and Health − the Importance of potassium. Basel, Switzerland.

[32] Waziri M., Audu A. A., and Suleiman F. (2013). Analysis of some mineral elements in major coconut cultivars in Nigeria. *Journal of Natural Sciences Research* 3 (8), 7-11.

[33] Twishsri W., Runheem P., Usathit S., Watanayothin S., and Naka P. (2012). Study on fatty acid composition and amino acid content of coconut endosperm of selected coconut cultivars in Thailand. *Coconut Research and Development Journal* 28 (2), 43-54.

[34] Tenda E., Miftahorrachman, and Kumaunang, J. (2022). Profile of amino acids and fatty acids of some Indonesia tall coconut varieties. *IOP Conference Series: Earth and Environmental Science* 974 (1), 1-6.

[35] Vera-Aviles M., Vantana E., Kardinasari E., Koh N. L., and Latunde-Dada G. O. (2018). Protective role of histidine supplementation against oxidative stress damage in the management of anemia of chronic kidney disease. *Pharmaceuticals* 11 (4), 1-15.

[36] Thalacker-Mercer A. E., and Gheller M. E. (2020). Benefits and adverse effects of histidine supplementation. *The Journal of Nutrition* 150, 2588S-2592S.