Original Research Article

VITAMIN CONTENTS OF MAIZE (*Zea mays* L) PRODUCED AND STOCKED FROM RURAL CONDITIONS IN COTE D'IVOIRE

ABSTRACT

Aims: Maize is prized for its richness in nutrient compounds. Despite its socio-economic importance, maize faces a quality problem that is sometimes very delicate. Indeed, maize during different production, post-harvest processing, storage and transport conditions is exposed to bio-aggressors that can alter the quality of this cereal. With this in mind, this study was conducted to determinate the vitamins contents of maize produced and stored in five maize-producing regions of Côte d'Ivoire.

Study design: A total of 1 500 samples of maize as grains, epis and spathes were collected at rate of 500 samples by region (Gbêkê, Poro, Hambol, Indénié-Djuablin and Gontougo) and sent to the laboratory for analysis.

Place and Duration of Study: This study was carried out during March 2016 to January 2017. Then, the analyses of the collected sample took place at the Biotechnology, Agriculture and Valorisation of Biological Ressources Laboratory of the Félix Houphouët-Boigny's University, Abidjan.

Methodology: Vitamins determination was carried by HPLC. A total of twelve vitamins were evaluated namely 9 water-soluble vitamins (thiamin, riboflavin, niacin, choline, pantothenic acid, pyridoxine, biotin, folic acid and cobalamin) and 3 fat-soluble vitamins (β-carotene, vitamin E and K).

Results: Results show a significant difference between vitamins contents of the different maize forms and regions. The mean values ranged from 0.09 ± 0.04 to 557.24 ± 10.97 mg / kg for water-soluble vitamins and from 0.31±0.25 to 4.20±1.00 mg / kg for fat-soluble vitamins. Choline was the most abundant of the water-soluble vitamins while β-carotene and vitamin E were the most abundant of the fat-soluble vitamins. Maize grains and epis had the highest levels of these vitamins. Maize spathes samples, especially those from Indénié-Djuablin and Gontougo, showed the lowest concentrations.

Conclusion: A significant variability from one region to another can be noticed at level of vitamins regardless the type of maize. Maize vitamin contents seem to be related to maize variety, agronomic practices, post-harvest treatments and storage structure.

Keywords: vitamins, maize, producing regions, Cote d'Ivoire.

1. INTRODUCTION

Maize occupies an important place in the chain of agricultural values in developing regions such as subSaharan Africa. It is cultivated worldwide due to its demand as a high energy, rich micronutrient, value-added food, and it serves as food for humans and livestock [1]. In terms of nutrition, maize is reported to have high levels of carbohydrates, fats, proteins, minerals and contain vitamins B and E [2, 3]. A recent study conducted in India have permitted the development of multinutrient-rich maize with high vitamin-E, vitamin-A, lysine, and tryptophan to alleviate malnutrition [4]. Vitamins are regulators of synthetic and

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degradation processes and constitute the structural elements of coenzymes, hormones and other substances. They play a role in the growth, repair and proper functioning of the organism and have above all a catalytic function [5]. Furthermore, mild to moderate forms of micronutrient (vitamins and minerals) deficiency can severely affect human health and lead to mental impairment, thereby resulting in lower productivity in humans [6].
In Cote d'Ivoire, Maize represents the mainstay of many Ivorian people's diet. It is also used in animal food (poultry, pigs and bovines) and serves as raw material in some industries (brewery, soap and oil factory). Its national consumption is estimated at 28.4 g per capita and per day and is essentially in the form of flour (92%) [7]. Long regarded as a subsistence crop, maize today benefits from a strong support of agricultural research institutions [8, 9]. Despite its various uses, maize remains a seasonal crop in many area productions. Therefore, its availability during offseason is systematically linked to conditions of its preservation. However, a number of constraints are regularly observed during its preservation. Most of them are linked to bad post-harvest treatments [10]. These treatments include many activities such as drying and storage methods (attics, polypropylene and PICS bags). These activities are essential for a good preservation of the harvest quality [11, 12]. In fact, some studies revealed an increased insect activity when maize are insufficiently dried (a water content above 13%), stored in poor conditions (air humidity and high temperature) and in inappropriate structures. This contributes to lead qualitative and quantitative losses of grains [13]. In Côte d'Ivoire, studies tackle the issue of the quality of maize particularly for water- and fat-soluble vitamins produced and sold in areas productions, are scarce in the literature. The main objective of this study is to determine the levels of water- and fat-soluble vitamins of maize coming from the areas production of Côte d'Ivoire.

2. MATERIAL AND METHODS

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2.1 Materials

2.1.1 Biological material

The biological material is composed of dry maize in the form of grains, epis and spathes deriving the major region production of this resource in Cote d'Ivoire.

2.1.2 Study site

The samples were collected from the regions of Gbêkê (Center), Poro (North), Hambol (North - Center), Indénié-Djuablin (Northeast) and Gontougo (East). Each of these regions has a geographical specificity and climatic characteristics which influence the seasons of maize production. Indeed, the regions of Gbêkê (7º50'nord 5º18'west), Hambol (8º10'nord 5º40'west), Indénié-Djuablin (7º02'nord 3º12'west) and Gontougo (8º30'N 3º20'West) are characterized by a humid tropical climate (Baouléen climate). It has four seasons including two rainy seasons favouring maize production twice a year and two dry seasons. Except the other four regions, the climate of region of Poro (9º27' Nord 5º38' west) is of Sudanese type characterized by a rainy season favourable to maize production and a dry season [14, 15]. Maize (*Zea mays* L.) is the main food crop in these regions taken into account in the study.

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2.2 Methods

2.2.1 Sampling of stored maize

The strategy adopted consisted of two phases. The first phase consisted in identifying the regions where maize cultivation constitutes the main subsistence activity. In each region,

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Table 1. Number of samples collected according to maize variety and department

Regions	Grains	Epis	Spathes	Total
Gbêkê	100	100	100	300
Poro	100	100	100	300
Hambol	100	100	100	300
Indénié-Djuablin	100	100	100	300
Gontougo	100	100	100	300
Total	500	500	500	1500

2.2.2 Vitamins analysis of stored maize

The concentrations of water-soluble vitamins and fat-soluble vitamins were determined according to [4] method using a high performance liquid chromatographic system.

Extraction and purification of water-soluble and fat-soluble vitamins

Two grams of finely ground maize samples (as grains, epis and spathes) were extracted vigorously with five excess of n-hexane solvent followed by centrifugation in the cold for 5 min at 3000 rpm. The supernatant was filtered and saved. The residue was re-extracted with the same solvent and the same steps were repeated until the extract was almost colorless. The total volume of the n-hexane used was calculated and then packaged in a chromatographic tube for analysis.

Quantification of water-soluble and fat-soluble vitamins

Vitamins have been detected and quantified by a HPLC chromatograph (Water Alliance) including a Water pump, an automatic injector, a UV/PDA detector and a servotor recorder in the operating conditions described in Table 2**.**

Table 2 Operating conditions for the HPLC determination of the vitamins studied

ITEM	Water-soluble vitamins	Fat-soluble vitamins
Column	Zorbax Rx 150 mm x 4,6 mm	Kromasil C18 300 mm x 4,6 mm
Detector	UV/PDA Water	UV/PDA Water
Wavelength	Thiamin (270 nm); riboflavin (265 nm); niacin (256 nm); choline (260 nm); pantothenic (266 nm); pyridoxine (257 nm); biotin (275 nm); Folic (280 nm); cobalamin	β-carotene (445 nm); vitamin E (295 nm); vitamin K (245nm);

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	(230 nm) ;	
Mobile phase	Ammonium acetate / methanol	Acetonitrile/methanol (80/20, v/v)
Injected volume	0.1 to 12 µL	0.2 to 5.5 µL
Flow	2 mL/min in gradient	1.2 mL/min in isocratic
Column temperature	30°C	30°C
Rinse solvent	Acetonitrile	Acetonitrile
Analysis duration	20 min	35 min

2.2.3 Estimate of nutritive supply at the consumer

The contributions in vitamins supply have been estimated according to the method of the Codex Alimentarius that takes into account the concentrations in vitamins recovered in maize sample and the maize daily consumption of 1- to 3-year-old. The contribution of maize in daily requirement has been calculated also from the values of daily recommended intakes [16, 17]:

Estimated Daily Intake (EDI) = C × Q
Contribution (%) = (EDI × 100)/DRI

With: C, Vitamin concentration measured; Q, Maize daily consumption, DRI: Daily Recommended Intake.

2.2.4 Statistical analysis

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All analyses were carried out in triplicate and the data processed using the Statistical Program for Social Sciences (SPSS version 20.0, SPSS for Windows, USA). For each characteristic, the results were expressed as means followed by their standard deviations. A two-factor analysis of variance (ANOVA 2) was also performed to test the effect of regions and maize shapes on the parameters, at the 5% significance level. Using STATISTICA, multivariate exploratory techniques such as principal component analysis (PCA) and hierarchical clustering (HCA) were used to classify individuals with similar behaviour on a set of variables. Thus, the analyses were done with components (or factors) that recorded an eigenvalue greater than or equal to 1, according to the Kaïser rule.

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3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Validation of the method of determining vitamins

The results of the validation tests are presented in Table 3. The determination coefficient (R^2) recovered from the standard lines are included between 0.996 and 0.999. The vitamins limits of detection (LOD) vary from 25 ± 0.38 µg/kg to 125 ± 0.69 µg/kg, while the limits of quantification (LOQ) range from 75 ± 0.4 µg/kg to 444 ± 0.03 µg/kg. The coefficients of variation (CV) determined for the repeatability and reproducibility tests ranged from 1.0 ± 0.05% to 1.7 ± 0.04% and from 2.5 ± 0.47% to 4.4 ± 0, 60%, respectively. About vitamins added, the extraction yields run from 96.8% to 100.5 ± 0.07%, revealing vitamins extraction defaults between 0.05% and 0.98%. These results indicate a satisfactory stability and accuracy of the chromatographic Water Alliance HPLC system. The method is therefore reliable and accurate.

Table 3 Data from validation parameters for evaluation of vitamins contents using HPLC

Vitamins	Linearity Etalon	CD (R^2)	CV Repet (%, n=10)	CV Repr (%, n=15)	Ext yield (%, n=10)	LOD (µg/kg)	**LOQ** (µg/kg)
β-carotene	**Y = 326.6x+152.9**	**0.99**	**1.5±0.12**	**4.4±0.60**	**98.7±0.88**	**125±0.69**	**416±0.25**
Vitamin E	**Y = 836.2x-5800**	**0.99**	**1.7±0.04**	**3.1±0.51**	**100.5±0.07**	**98±0.23**	**326±0.41**
Vitamin K	**Y = 139.4x+55.5**	**0.99**	**1.2±0.68**	**3.3±0.02**	**98.1±0.33**	**135±0.08**	**444±0.03**
Thiamin	**Y = 723.4x+1346**	**0.99**	**1.3±0.10**	**3.2±0.98**	**97.3±0.55**	**62±0.17**	**206±1.09**
Riboflavin	**Y = 4787x+7107**	**0.99**	**1.6±0.94**	**3.6±0.22**	**96.8±0.14**	**54±0.29**	**179±0.76**
Niacin	**Y = 462.5x-331.5**	**0.99**	**1.4±0.73**	**3.4±0.63**	**99.1±0.18**	**64±0.01**	**213±1.62**
Choline	**Y = 325 + 6543x**	0.99	**1.2±0.25**	**2.7±0.32**	**99.2±0.05**	**67±0.31**	**197±0.45**
Pantothenic	**Y = 511 + 807x**	**0.99**	**1.8±0.02**	**3.0±0.01**	**98.8±0.41**	**51±0.38**	**88±0.34**
Pyridoxine	**Y=550.9x+627.1**	**0.99**	**1.0±0.05**	**2.8±0.41**	**97.8±0.59**	**25±0.38**	**83±0.47**
Biotin	**Y = 342 + 402x**	0.99	**1.7±0.87**	**3.1±0.04**	**97.8±0.98**	**48±0.05**	**87±0.15**
Folic acid	**Y=942.4x-1615**	**0.99**	**1.2±0.21**	**2.5±0.47**	**98.6±0.44**	**33±0.75**	**109±0.15**
Cobalamin	**Y = 342.5 + 821x**	0.99	**1.4±0.32**	**3.2±0.01**	**99.9±0.56**	**52±0.05**	**75±0.40**

***CD**, coefficient of determination; **CV rep**, coefficient of variation of repeatability**; CV repr**, coefficient of variation of reproducibility; **Rend Ext**, extraction yield; **LOD,** limit of detection; **LOQ**, limit of quantification*

3.1.2 Vitamin contents of maize samples

3. 1.2.1 Water soluble vitamin contents

Maize samples contain statistically different water-soluble vitamin content (P <0.005). The concentrations of these vitamins are mentioned in Table 4. Among these vitamins, choline is the most abundant with concentrations vary between 475.91 ± 54.02 mg / kg to 557.1 ± 16.10 02 mg / kg. After the choline, it is pantothenic, niacin and pyridoxine which expressed high quantities of vitamins with contents ranging from 22.86 ± 6.99 mg / kg to 28.98 ± 2 mg / kg, 13.56 ± 7.91mg / kg to 15.5 ± 3.1 mg / kg and 12.78 ± 7.08 mg / kg to 15.10 ± 2.1 mg / kg respectively. The concentrations of the other vitamins at least abundant to the most abundant and turn around 0.06 ± 0.04 mg / kg to 0.10 ± 0.01 mg / kg; 0.17 ± 0.15 mg / kg to 0.27 ± 0.08 mg / kg; 0.59 ± 0.51 mg / kg at 0.81 ± 0.30 mg / kg; 2.00 ± 1.67 to 3.57 ± 2.01 and 3.32 ± 2.12 mg / kg at 3.66 ± 0.97 mg / kg respectively for Biotin, Folic acid, Cobalamin, Riboflavin and Thiamin.

Table 4 Water-soluble vitamins of stored maize samples from five collection regions

Parameters	Regions	Grains	Epis	Spathes

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Thiamin (mg/kg)	Gbêkê	3.60±0.97^{abA}	3.58±1.09^{bA}	3.60±1.01^{aA}
	Poro	3.66±0.97^{aA}	3.63±0.99^{aA}	3.57±1.03^{abA}
	Hambol	3.65±1.00^{aA}	3.65±1.09^{aA}	3.54±1.29^{bB}
	Indenié-Djuablin	3.59±1.45^{bA}	3.57±1.28^{bA}	3.34±2.56^{cB}
	Gontougo	3.57±2.01^{bA}	3.57±1.75^{bA}	3.32±2.12^{cB}
Riboflavin (mg/kg)	Gbêkê	2.90±1.00^{aA}	2.87±0.98^{aAB}	2.65±1.01^{AB}
	Poro	2.80±0.08^{aA}	2.79±1.00^{bA}	2.75±1.00^{aC}
	Hambol	2.80±0.07^{aA}	2.76±0.97^{bB}	2.57±0.10^{bC}
	Indenié-Djuablin	2.27±0.99^{bA}	2.27±1.13^{cA}	2.00±1.67^{cB}
	Gontougo	2.30±1.10^{bA}	2.30±1.08^{cA}	1.97±1.75^{cB}
Niacin (mg/kg)	Gbêkê	14.57±3.08^{aA}	14.45±3.87^{abB}	14.57±4.02^{aA}
	Poro	14.70±2.07^{aB}	15.5±3.1^{aA}	14.35±4.78^{aC}
	Hambol	14.59±2.08^{aC}	15.01±2.87^{aA}	14.75±5.97^{aB}
	Indenié-Djuablin	14.58±3.97^{aA}	13.99±5.87^{bB}	13.56±7.91^{bC}
	Gontougo	14.54±5.82^{aA}	14.00±5.98^{bA}	13.65±6.97^{bB}
Choline (mg/kg)	Gbêkê	557.20±9.08^{aA}	557.1±16.10^{aA}	550.00±27.01^{aB}
	Poro	557.24±10.97^{aA}	556.00±15.08^{abA}	499.99±31.10^{aB}
	Hambol	557±12.01^{aA}	555.97±14.08^{bA}	501.86±26.01^{aB}
	Indenié-Djuablin	552.45±20.16^{bA}	552.45±26.08^{cA}	468.97±42.88^{bB}
	Gontougo	556.21±19.08^{aA}	554.1±30.02^{bB}	475.91±54.02^{bC}
Pantothenic (mg/kg)	Gbêkê	27.99±5.09^{abA}	26.99±4.97^{bB}	26.87±3.09^{aC}
	Poro	28.98±2.00^{aA}	26.7±4.97^{bB}	26.57±4.97^{aB}
	Hambol	27.99±5.08^{abA}	27.99±3.97^{aA}	25.97±4.97^{bB}
	Indenié-Djuablin	27.90±5.97^{bA}	26.00±6.87^{cB}	22.86±6.99^{cC}
	Gontougo	27.89±7.12^{bA}	25.99±7.02^{cB}	23.86±8.67^{cC}
Pyridoxine (mg/kg)	Gbêkê	15.10±1.08^{aA}	14.10±3.08^{bB}	14.00±3.97^{aB}
	Poro	15.10±2.10^{aA}	14.88±2.89^{aB}	13.97±5.08^{aC}
	Hambol	15.09±1.89^{aA}	14.12±3.10^{bB}	13.89±4.79^{aC}
	Indenié-Djuablin	14.98±4.08^{aA}	13.78±5.10^{bB}	12.87±6.08^{bC}
	Gontougo	15.00±4.01^{aA}	13.87±4.99^{bB}	12.78±7.08^{bC}
Biotin (mg/kg)	Gbêkê	0.09±0.01^{aA}	0.08±0.02^{aA}	0.08±0.02^{aA}
	Poro	0.09±0.02^{aA}	0.08±0.04^{aA}	0.07±0.03^{aA}
	Hambol	0.10±0.01^{aA}	0.10±0.01^{aA}	0.07±0.03^{aB}
	Indenié-Djuablin	0.09±0.04^{aA}	0.07±0.05^{aB}	0.06±0.04^{aB}
	Gontougo	0.09±0.04^{aA}	0.07±0.05^{aB}	0.06±0.05^{aB}
Folic (mg/kg)	Gbêkê	0.22±0.01^{bB}	0.27±0.08^{aA}	0.20±0.10^{aB}
	Poro	0.26±0.02^{aA}	0.25±0.10^{bA}	0.21±0.08^{aB}
	Hambol	0.23±0.07^{bA}	0.23±0.10^{bcA}	0.22±0.12^{aA}
	Indenié-Djuablin	0.22±0.19^{bA}	0.20±0.18^{cA}	0.17±0.15^{bB}
	Gontougo	0.21±0.07^{bA}	0.20±0.18^{cA}	0.19±0.16^{cB}
Cobalamin (µg/kg)	Gbêkê	0.78±0.02^{aA}	0.78±0.28^{abA}	0.70±0.28^{aA}
	Poro	0.78±0.05^{aB}	0.81±0.30^{aA}	0.69±0.30^{aA}
	Hambol	0.77±0.07^{aB}	0.81±0.28^{aA}	0.72±0.34^{aB}
	Indenié-Djuablin	0.75±0.21^{aA}	0.75±0.42^{bA}	0.60±0.51^{bB}
	Gontougo	0.74±0.31^{aB}	0.76±0.50^{bA}	0.59±0.51^{bC}

By column and row the averages with the same letters are statistically identical. Lower case letters are representative of columns and upper case letters are representative of rows

Overall, concerning maize forms, maize spathes recorded the lowest levels. For the collections regions, lowest values of water-soluble vitamins are observed in Gontougo and Indénié-Djuablin regions (Table 4).

3. 1.2.2 Fat soluble vitamin contents

Significant differences between means of maize forms on the one hand and regions on the other hand were recorded (P <0.05) (Table 5). Regardless of regions, samples of whole maize spathes exhibited the lowest concentrations of fat-soluble vitamins. With regard to β-carotene, concentrations ranging from 3.78 ± 1.99 mg / kg to 4.20 ± 1.00 mg / kg for maize grains, from 3.78 ± 1.65 mg / kg to 3.90 ± 0.78 mg / kg for maize epis and from 3.59 ± 2.89 mg / kg to 3.76 ± 2.19 mg / kg for maize spathes. As regards for vitamin E, concentrations vary between 3.65 ± 2.43 mg / kg and 3.95 ± 0.89 mg / kg for the different maize samples. Concerning vitamin K, values obtained are between 0.41 ± 0.18 mg / kg and 0.54 ± 0.03 mg / kg; 0.39 ± 0.20 mg / kg and 0.53 ± 0.10 mg / kg; 0.31 ± 0.25 mg / kg and 0.53 ± 0.10 mg / kg respectively for maize grains, epis and spathes.

Table 5 Fat-soluble vitamins of stored maize samples from five collection regions

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Parameters	Regions	Grains	Epis	Spathes
β-carotene (mg/kg)	Gbêkê	3.91±1.19a^{bA}	3.86±1.01a^{bA}	3.76±2.19^{aB}
	Poro	3.89±1.08^{bA}	3.80±0.98^{bA}	3.74±2.10^{bB}
	Hambol	4.20±1.00^{aA}	3.90±0.78^{aA}	3.75±2.00^{abB}
	Indenié-Djuablin	3.78±1.99^{cA}	3.78±1.65^{bA}	3.65±2.97^{bA}
	Gontougo	3.80±1.68^{cA}	3.79±1.97^{bA}	3.59±2.89^{cB}
Vitamin E (mg/kg)	Gbêkê	3.89±0.10^{abA}	3.93±1.01^{aA}	3.70±2.00^{bB}
	Poro	3.95±0.89^{aA}	3.92±1.00^{aA}	3.81±1.78^{aA}
	Hambol	3.80±0.99^{bA}	3.89±0.88^{aA}	3.80±2.01^{aA}
	Indenié-Djuablin	3.76±1.09^{bcA}	3.76±1.86^{bA}	3.65±2.43^{cB}
	Gontougo	3.65±1.86^{cA}	3.65±1.78^{cA}	3.66±2.51^{cA}
Vitamin K (mg/kg)	Gbêkê	0.54±0.2^{aA}	0.44±0.12^{bB}	0.44±0.08^{bB}
	Poro	0.54±0.03^{aA}	0.54±0.19^{aA}	0.53±0.10^{aA}
	Hambol	0.50±0.03^{aA}	0.50±0.2^{aA}	0.48±0.20^{Ba}
	Indenié-Djuablin	0.41±0.18^{bA}	0.39±0.20^{cAB}	0.31±0.25^{Cb}
	Gontougo	0.45±0.23^{bA}	0.40±0.20^{bcA}	0.33±0.21^{Cb}

By column and row the averages with the same letters are statistically identical. Lower case letters are representative of columns and upper case letters are representative of rows

3.1.3 Grouping of maize samples according to vitamins

Principal component analysis (PCA) was carried out by considering components F1 and F2 (Table 6), which have an eigenvalue greater than 1, according to the Kaïser statistical rule. Emphasized groupings of the PCA were then clarified by the hierarchical ascending classification (CAH) using the Unweighted Pair Group Method with Arithmetic Means (UPGMA).

3.1.3. 1 Principal component analysis (PCA)

Fig. 1.A shows the circle of correlations of the factorial axes F1 and F2, which express 82.90% of the total variability of the studied parameters. The component F1 with an eigenvalue of 8.63, expresses 71.95% of the variance. It is shows strong negative correlations between the contents of water-soluble and fat-soluble vitamins of all maize samples. The component F2, with its own value 1.31, expresses 10.95% of the variance and is associated with factor F1 for the representation of PCA (Table 6).
The projections of the characteristics and of the samples in the plane formed by the components F1 and F2 highlight three groups of maize. Group 1 consisted essentially of maize grains and epis from the five regions and maize spathes from Gbêkê and stand out for their high vitamins (water-soluble and fat-soluble) contents. Group 2 contains maize spathes samples from Poro and Hambol regions characterized by similar composition to the first group. Group 3 consists of maize spathes samples from Indénié-Djuablin and Gontougo regions. They differ from the first two groups by low values for the said vitamins (Fig 1.B).

Table 6. Eigenvalue matrix and correlations of the mineral parameters of flours studied with components F1 and F2 of the principal component analysis

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Components	F1	F2
Eigenvalues	8.63	1.31
Validity expressed (%)	71.95	10.95
Cumulative validity expressed (%)	71.95	82.90
ß- carotene	**-0.74**	0.39
Vitamin E	**-0.73**	-0.55
Vitamin K	**-0.79**	-0.29
Thiamin	**-0.95**	0.09
Ribofavin	**-0.86**	-0.31
Niacin	**-0.83**	-0.31
Choline	**-0.83**	0.32
Pantothenic	**-0.93**	0.20
Pyridoxine	**-0.92**	0.25
Biotin	**-0.82**	0.46
Folic	**-0.82**	-0.39
Cobalamin	**-0.91**	0.05

3.3.2 Hierarchical ascending classification

Hierarchical classification also reveals three classes of maize samples from the five regions, with the Euclidean distance from aggregation of 10. Class 1 represents maize grains and epis from the five regions and maize spathes from Gbêkê. Samples in this class are distinguished by higher levels of water-soluble and fat-soluble vitamins contents than other analyzed samples. Class 2 contains maize spathes from Poro and Hambol regions. Samples in this class have also similar character to the first group. Class 3 had the lowest contents of all revealed vitamins. Samples consist of maize spathes from Indénié-Djuablin and Gontougo regions (Fig. 2).

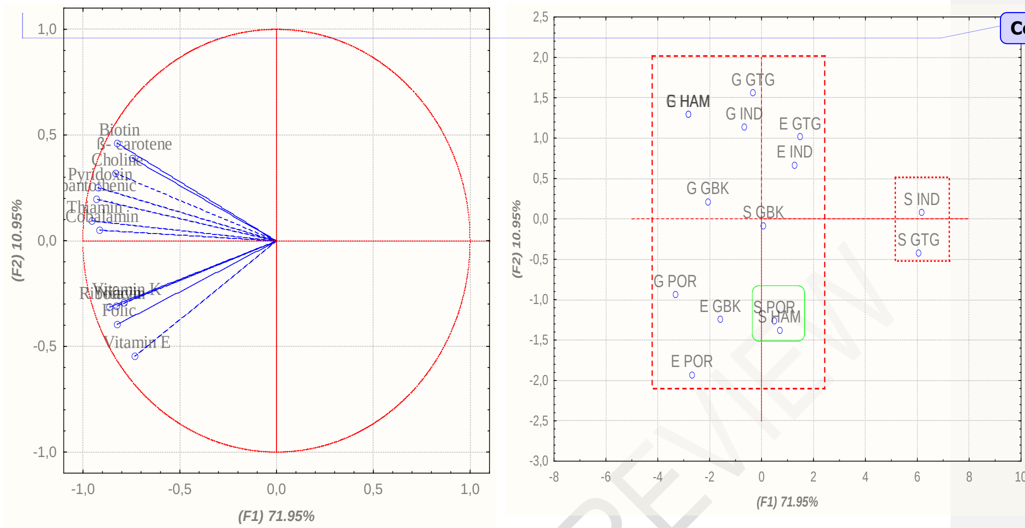

Figure 1: Projection of vitamins (a) and regions (b) in the factorial plane F.1 and F.2 of the principal component analysis (PCA)

GBK : Gbêkê ; POR : Poro ; HAM : Hambol ; IND : Indénié-Djuablin ; GTG : Gontougo; G : Grains ; E : Epis ; S:Spathes; thiamin; riboflavin; niacin; choline; pantothenic acid; pyridoxin; biotin; folic acid; cobalamin

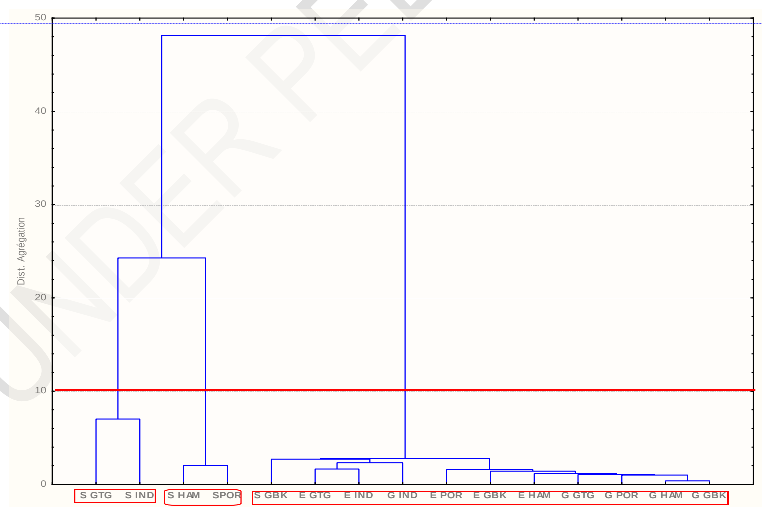

Figure 2: **Dendrogram representing ascending hierarchical classification of the parts of maize samples regions according to vitamin contents**

GBK : Gbêkê ; POR : Poro ; HAM : Hambol ; IND : Indénié-Djuablin ; GTG : Gontougo; G : Grains ; E : Epis ; S:Spathes

3.4. Estimated intakes of water-soluble and fat-soluble vitamins in 1- to 3-year-old

The water-soluble vitamins daily intakes are presented in Table 7. Maize samples provide quantities of thiamine between 0.09 mg / day and 0.10 mg / day. The contributions in riboflavin are estimated between 0.06 mg / day and 0.08 mg / day. Niacin contributions are ranging from 0.39 mg / day to 0.42 mg / day. Concerning choline, pantothenic acid, pyridoxine, biotine, folic acid and cobalamin, daily intakes oscillating respectively between 13.32 mg and 15.82 mg, 0.68 mg and 0.82 mg, 0.36 mg and 0.43 mg, 0.002 mg and 0.003 mg, 0.005 mg and 0.008 mg and 0.002 are estimated.

Regarding fat-soluble vitamins, maize samples from the five regions recorded the daily intakes of β-carotene, vitamin E, respectively of (0.10 to 0.11 mg / day), (0.10 to 0.11 mg / day) and (0.01 to 0.02 mg / day) for vitamin K (Table 7).

On the daily recommended intakes basis for 1- to 3-year-old, all maize samples provide a significant contribution of vitamins with percentages ranging from 0.03% to 255.60%. Concerning water-soluble vitamins, biotin and cobalamin have higher needs fitting contributions from maize samples with percentages ranging from 72.60% to 85.77% and 186.49% to 255.60% respectively. With regard to fat-soluble vitamins, vitamin K recorded the highest contributions with percentages oscillate between 31.24% and 50.70% as shown in Table 8.

3.2. DISCUSSION

The R² determination coefficients got from the calibrations tests were close to 1, forecasting a quasi-linear estimation of the vitamins according to their concentration from in maize samples. Also, the lower coefficients of variation (<5%) resulting from reproducibility and repeatability translate quite stability of the HPLC method used, which is as fitted as the full amount of each water soluble and fat soluble vitamin is revealed, as shown by the weak extraction defaults below 0.98% from the added vitamins. Thus, these characteristics highlight the reliability and precision of the outcomes in the vitamins contents determination using HPLC method [4]. Vitamins are important food receptors that are needed to utilize the proximate principles of food as well as the maintenance of good health [2]. In fact, vitamins deficiency are responsible for a number of disorders that range from impaired minerals mobilization, growth retardation, a depressed immune response, increased susceptibility to infectious disease and increased childhood mortality and morbidity affecting several children and pregnant women worldwide [18]. Analysis of vitamins parameters showed that the compositions of maize samples vary significantly from one region to another but also from one maize form to another. This result could be explained by the growing conditions and climatic (type of soil, fertilizer input, crop period) and also by genetics varietal differences in cultivated maize [19]. Studies carried out in Benin have shown the existence of around twenty varieties of maize cultivated in the West African sub-region [20]. Also, this variability can be explained by the difference in postharvest maize storage technology [21]. Thirteen maize storage typologies and techniques have been recorded in these five regions of Côte d'Ivoire [22]. Maize samples as grains and epis from the different regions exhibited high concentrations of water-soluble and fat-soluble vitamins, unlike maize spathes. However, vitamins concentrations obtained in this study are higher than those (0.84 mg / kg for β-carotene; 0.98-1.65 mg / kg for vitamin E) reported by [23] for ordinary and QPM maize varieties grown in Côte d'Ivoire.

Vitamins analysis showed also a heterogeneous distribution of fat-soluble and water-soluble vitamins in the maize samples. Regarding fat-soluble vitamins, β-carotene and vitamin E are the most abundant in maize samples. Fat-soluble vitamin as β -carotene plays an essential role in reproduction, children growth, maintenance of eye health and night vision. It strengthens the immune system against infections [24].

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Table 7 Estimated daily intake in vitamins resulting from the consumption of maize by an Ivorian of 1- to 3-year-old

Regions	Maize forms	Water soluble vitamins									Fat soluble vitamins		
		Thiamin (mg/day)	Riboflavin (mg/day)	Niacin (mg/day)	Choline (mg/day)	Pantothenic (mg/day)	Pyridoxine (mg/day)	Biotin (mg/day)	Folic (mg/day)	Cobalamin (mg/day)	β-carotene (ER/day)	Vitamin E (mg/day)	Vitamin K (mg/day)
Gbêkê	Grains	0.10	0.08	0.41	15.82	0.79	0.43	0.003	0.006	0.002	0.11	0.11	0.01
	Epis	0.10	0.08	0.41	15.82	0.77	0.40	0.002	0.008	0.002	0.11	0.11	0.01
	Spathes	0.10	0.08	0.41	15.62	0.76	0.40	0.002	0.006	0.002	0.11	0.11	0.02
Poro	Grains	0.10	0.08	0.42	15.83	0.82	0.43	0.003	0.008	0.002	0.11	0.11	0.02
	Epis	0.10	0.08	0.44	15.79	0.76	0.42	0.002	0.007	0.002	0.11	0.11	0.02
	Spathes	0.10	0.08	0.41	15.62	0.76	0.40	0.002	0.006	0.002	0.11	0.11	0.02
Hambol	Grains	0.10	0.08	0.41	15.82	0.79	0.43	0.003	0.007	0.002	0.12	0.11	0.01
	Epis	0.10	0.08	0.43	15.79	0.79	0.40	0.003	0.007	0.002	0.11	0.11	0.01
	Spathes	0.10	0.07	0.42	14.25	0.74	0.39	0.002	0.006	0.002	0.11	0.11	0.01
Indenié-Djuablin	Grains	0.10	0.06	0.41	15.69	0.79	0.43	0.003	0.006	0.002	0.11	0.11	0.01
	Epis	0.10	0.06	0.40	15.69	0.74	0.39	0.002	0.008	0.002	0.11	0.11	0.01
	Spathes	0.09	0.06	0.39	13.32	0.65	0.37	0.002	0.005	0.002	0.10	0.10	0.01
Gontougo	Grains	0.10	0.07	0.41	15.80	0.79	0.43	0.003	0.006	0.002	0.11	0.10	0.01
	Epis	0.10	0.07	0.40	15.74	0.74	0.39	0.002	0.006	0.002	0.11	0.10	0.01
	Spathes	0.09	0.06	0.39	13.52	0.68	0.36	0.002	0.005	0.002	0.10	0.10	0.01
DRI (mg/day)		**0.5**	**0.5**	**6**	**200**	**2**	**0.5**	**0.008**	**0.15**	**0.0009**	**400**	**6**	**0.03**

ER, equivalent retinol; *DRI, daily recommended intake (mg/day)*

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Table 8 Contribution (%) of maize samples to the satisfaction of the advisable contributions

Regions	Samples	Water-soluble vitamins									Fat-soluble vitamins		
		Thiamin	Riboflavin	Niacin	Choline	Pantothenic	Pyridoxine	Biotine	Folic	Cobalamin	β-carotene	Vitamin E	Vitamin [illegible]
Gbêkê	Grains	20.45	16.47	6.90	7.91	39.75	85.77	31.95	4.17	246.13	0.03	1.84	41.65
	Epis	20.33	16.30	6.84	7.91	38.33	80.09	28.40	5.02	246.13	0.03	1.86	41.65
	Spathes	20.45	15.06	6.90	7.81	38.16	79.52	27.16	3.79	220.89	0.03	1.75	51.12
Poro	Grains	20.77	15.90	6.96	7.91	41.15	85.77	31.10	5.06	246.96	0.03	1.87	50.70
	Epis	20.6	15.85	7.34	7.90	37.91	84.50	27.16	4.81	255.60	0.03	1.86	50.39
	Spathes	20.28	15.63	6.79	7.10	37.73	79.35	26.36	3.98	217.73	0.03	1.80	50.70
Hambol	Grains	20.72	15.90	6.91	7.91	39.75	85.71	35.23	4.31	243.36	0.03	1.80	47.33
	Epis	20.72	15.68	7.10	7.89	39.75	80.22	35.23	4.31	255.60	0.03	1.84	47.33
	Spathes	20.11	14.58	6.98	7.13	36.88	78.90	25.25	4.17	227.20	0.03	1.80	45.44
Indenié-Djuablin	Grains	20.39	12.87	6.90	7.84	39.62	85.09	32.76	4.17	237.07	0.03	1.78	38.99
	Epis	20.28	12.87	6.62	7.84	36.92	78.27	26.27	3.79	237.07	0.03	1.78	36.92
	Spathes	18.97	11.36	6.42	6.66	32.46	73.11	22.79	3.28	189.33	0.03	1.73	29.35
Gontougo	Grains	20.28	13.06	6.88	7.90	39.60	85.20	31.60	3.98	233.51	0.03	1.73	42.6
	Epis	20.28	13.06	6.63	7.87	36.91	78.78	24.50	3.75	240.14	0.03	1.73	37.87
	Spathes	18.86	11.20	6.46	6.76	33.88	72.60	20.53	3.53	186.49	0.03	1.73	31.24
DRI		**0.5**	**0.5**	**6**	**200**	**2**	**0.5**	**0.008**	**0.15**	**0.0009**	**400**	**6**	**0.03**

DRI, daily recommended intake (mg/day)

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Comment [u45]: Units should be included as in table 7

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Its prolonged visual impairment which can cause blindness and severe infections that is often fatal for children and pregnant women worldwide [25]. Vitamin E is an antioxidant involved in the protection of tissues and skin against oxidation and infection**.** Vitamin-E quenches free radicals in the cell membrane, thereby protecting the polyunsaturated fatty acids (PUFA) from damage; besides, it also serves as an essential micronutrient for the proper functioning of the reproduction system. It further protects from cardiovascular disease, Alzheimer's disease, neurological disorder, and many age-related degenerations [3, 26]. As for the water-soluble vitamins, it is choline, niacin, pantothenic and pyridoxine which provided in large quantities in maize samples. Choline helps maintain optimal liver function. It is essential for the formation of red globules and for the proper functioning of the central nervous system [27]. Niacin has a co-enzymatic action in redox reactions where it serves as an electron transporter. It is necessary for the biosynthesis of fatty acids and cholesterol. Pyridoxine is a coenzyme implied in the metabolism of proteins, the amino acids, glycogen, and the synthesis of the neurotransmitters. It also helps regulate hormonal activity, reduce fatigue and contributes to the normal functioning of the immune system [4]. In the body, thiamine intervenes in the reactions of oxidative decarboxylation of the cetoacides and of transcetolisation. Riboflavin is involved in energy metabolism, contributing to tissue growth and repair, hormone production, and red blood cell structure. Folic acid is a basic component of the coenzymes of the synthesis of certain amino acids. It is essential with the formation of the globules red and necessary to the correct operation of the central nervous system [18]. The average daily quantity of maize consumed by a child aged 1 to 3 years in Côte d'Ivoire is 24.8 g. Using the World Health Organization's established daily intake for the water- and fat-soluble vitamins that were reported, this study suggests that maize samples from the five regions were a good source of water- and fat-soluble vitamins: vitamin K, thiamin, riboflavin, niacin, choline, pantothenic acid, pyridoxine, biotin, folic acid and Cobalamin. Therefore, eating maize with respect to the considerable amount of soluble and fat-vitamins in it could be relevant in the prevention of vitamins deficiency for children and pregnant women that reside in the five regions.

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4. CONCLUSION

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This study assessed vitamin content of maize produced and stored in the form of grains, epis and spathes in five production regions of Côte d'Ivoire. The results show that regardless of the region, the grains and epis of maize indicated high levels of fat-soluble and water-soluble vitamins. Also spathes, especially those from Indénié-Djuablin and Gontougo, showed low levels of vitamins studied. Thus, the implementation of efficient technical routes throughout the maize distribution chain, both during their production, post-harvest treatment, and conservation will be able to guarantee better quality for this agricultural food product and ensure the Food Safety.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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