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Determination of Merchantability of Maize (*Zea mays* L.) as Epis, Spathes and Grains Stocked in the Production Areas of Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors HMGB and BS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YK, DS and YBN managed the analyses of the study. Author AC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aims to determine merchantability of maize produced and stocked as grains, epis and spathes of maize in five departments of Côte d'Ivoire.
Study Design: A total of 375 samples were collected at rate of 75 samples by department (Botro, Korhogo, Katiola, Agniblékro and Bondoukou). Then, the received samples were sent to the laboratory in order to analyse their merchantability.
Place and Duration of Study: The collection of samples was carried out on grains, epis and spathes maize from February 2013 to January 2014. Then, the analyzes were carried out at the Biochemistry and Food Sciences Laboratory of the Félix Houphouët-boigny University.

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Methodology: The humidity was determined by drying until constant weight when the losses and damages of grains have been quantified by counting and weighing.
Results: The results show that for maize grains, humidity levels vary from 8.59±0.11% to 14.18±0.52%. Concerning epis of maize, humidity levels are between 9.85±0.23% to 13.02±0.32%. For maize spathes, humidity levels fluctuate between 11.16±0.29% to 14.17±0.32%. The damages varies from 5.01±2.64% to 19.35±2.00% for maize grains, 9.05±5.27% to 21.29±7.17% for epis and 17.95±1.13% for spathes. As regards weigh losses, proportions of grains, epis and spathes are between 1.53±1.17% and 5.10±0.97%, 2.43±1.70% and 6.54±1.79% and 2.76±1.18% and 5.11±2.65%, respectively.
Conclusion: A significant variability from one department to another can be noticed at level of maize quality regardless the type of maize. The merchantability of maize seems to be tied to post-harvest treatments (drying), type of storage (epis, grains and spathes) and structure of storage.

Keywords: Merchantability; maize grains; maize epis; maize spathes; production area; Zea mays L.; Côte d'Ivoire.

1. INTRODUCTION

Legumes and cereals are the mainstay of many African people's diet [1]. Among the cereals, maize holds a very important place for human and animal food. Native to Central America, this cereal is largely cultivated in many parts of the world for its starchy grains which represents an excellent source of energy. Thus, maize is the first cereal crop with the most significant production volume before soft wheat and rice [2]. Its world production was estimated at around 843 million tonnes in 2014 [3]. America contributes for about one half of that production with a volume estimated to 419 million tonnes, about 48% of production. As for Asia, Europe and Africa, maize provides 28%, 7,5% and 4%, respectively of world production. It guarantees almost half of the caloric intake in southern and eastern Africa and also one-fifth in western Africa [4].

In Côte d'Ivoire, maize holds the seventh rank of agricultural food-crop production and the second in cereal production after rice [5]. It is cultivated alone or in combination with other cultures in diverse agro-ecological areas. The national production is estimated at around 760 000 tonnes in 2016 [5]. 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). Long regarded as a subsistence crop, maize today benefits from a strong support of agricultural research institutions [6-7]. The average yields of traditional varieties in rural area are of the order of 0.8 tonne per hectare versus 2 to 5 tonnes per hectare in controlled environment planted with varieties selected by research [8].

Despite its various uses, maize remains a seasonal crop in many area production. 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 [1,9-12]. 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 [1,12-13]. 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 creating a favorable environment for development of molds of genera *Aspergillus*, *Penicillium* and *Fusarium* responsible for production of mycotoxins [2,9-11,14,15]. These pests cause tremendous damages in stocks that can lead to qualitative and quantitative losses of grains [9-11,15]. In Côte d'Ivoire, many studies have been made on conservation techniques of maize in areas production [9-11,15]. But few studies tackle the issue of the quality of maize produced and sold in areas productions. The main objective of this study is to determine the merchantability of maize coming from the areas production of Côte d'Ivoire.

2. MATERIALS AND METHODS

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 from the major areas production of this resource in Côte d'Ivoire.

2.1.2 Study sites

The samples were collected from the localities of Botro (Center, Gbèkè), Korhogo (North, Poro), Katiola (North Center, Hambol), Agnibilekro (Northeast, Indenié-Djuablin) and Bondoukou (East, Gountougo). Each of these departments has a geographical specificity and climatic characteristics which influence the seasons of maize production. Indeed, the localities of Botro (7º50'nord 5º18'west), Katiola (8º10'nord 5º40'west), Agnibilekro (7º02'nord 3º12'west) and Bondoukou (8º30'N 3º20'West) are characterized by a humid tropical climate (*Baouléen* climate). It has four seasons including two rainy seasons favoring maize production twice a year and two dry seasons [16]. Except the other four departments, the climate of department of Korhogo (9º27' nord 5º38' west) is of Sudanese type characterized by a rainy season favorable to maize production and a dry season [16-17].

2.2 Methods

2.2.1Sampling

The samples were collected in 5 departments of production areas including Botro, Korhogo, Katiola, Agnibilekro and Bondoukou. This collection of samples was carried out on grains, epis and spathes maize from February 2013 to January 2014. A total of 375 samples were collected for each form of maize (125 grains, 125 epis, and 125 spathes, Table 1).Then, the received samples were sent to the laboratory in order to analyse their merchantability.

2.2.2 Determination of humidity content

After shattering, 5 g (m1) of maize broyat have been collected in a capsule of initial mass m0. The all capsule and sample was placed to dry at 105ºC±2ºC, until constant mass in an oven brand Memmert. Then, the all dried capsule and sample was weighed (m2) and the humidity (H) was expressed as a percentage of dry mass on the basis of following formula [18] :

$$\mathrm{H}\ (\%) = \frac{(\mathrm{m1} - \mathrm{m2}) \times 100}{(\mathrm{m1} - \mathrm{m0})}$$

H: humidity of sample; m_0: capsule mass; m_1: the total mass before shattering (capsule + powder sample); m_2: the total mass after shattering (capsule + powder sample).

Next, determined humidity levels were compared to Codex Alimentarius standard [19].

2.2.3 Evaluation of damages and weight losses

Based on counting and weighing method, the assessment of resulting damage by insects was carried out [20-21]. A 1 kg mass of grains maize containing approximatively 3500 grains has been collected. After sieving and the withdrawal of foreign material, grains were weighed again and sorted in order to separate damaged grains (attacked and starved) from sound grains. Then the two fractions have been separately counted and weighed. Grains damages and weight losses are estimated on basis of below formulas:

D (%) = (NGA/ NTG) x 100

D = Damages; NGA = Number of attacked grains; NTG = Total number of grains

W (%) = [[(NGA x PGS) – (NGS x PGA)] / (PGS x NTG)] x 100

W= weight losses; NGA = Number of attacked grains; NGS = Number of sound grains; NTG = Total number of grains; PGA=Weight of attacked grains; PGS = Weight of sound grains.

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

Departments	Grains	Epis	Spathes	Total
Botro	25	25	25	75
Korhogo	25	25	25	75
Katiola	25	25	25	75
Agnibilékrou	25	25	25	75
Bondoukou	25	25	25	75
Total	125	125	125	375

2.2.4 Statistical analysis

All the analyses were carried out in three fold test and data processed with software Statistical Product and Service Solutions, SPSS version 20.0, an IBM product since 2009. For each characteristic, the results were expressed in form of averages followed by their standard deviations as parameters of data spread. A two-way analysis of variance (ANOVA 2) was also made in order to test the impact of locality and the ways of preserving maize on assessed characteristics to 5% significant threshold statistical. For the statistically different averages, the Student-Newman-Keuls test served for the classification. Furthermore, the correlation between data and samples was estimated on basis of main components analysis (MCA), thanks to STATISTICA 7.1 software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Humidity level

The obtained humidity levels statistically vary (P=0.031) depending on the departments and for all maize types (grains, epis and spathes) as shown in Table 2. For the maize grains, the humidity average levels are between 8.58±0.48% and 14.18±2.63% with a high proportion observed at Bondoukou and the lower proportions at Botro and Korhogo.

The humidity of samples collected at the level of maize epis is also lower at Botro (9.85±1.19%) and Korhogo (10.61±1.70%) as compared with Agnibilékrou (13.20±1.63%), Bondoukou (14.18±2.63%) and Agnibilékrou (13.20±1.63%). With maize spathes, Table 2 shows that humidity levels of samples at Botro, Korhogo and Bondoukou are statistically different (11.17±1.58%, 11.16±1.45% and 11.53±1.49%, respectively) in comparison with Katiola (12.43±1.53%) and Agnibilékrou (14.17±1.61%).

3.1.2 Proportion of samples that do not conform to commercial standard

On grains moisture, the maximum moisture limit to ensure good marketability is set at 15%. Thus, the departments of Botro, Korhogo and Katiola do not present any sample (0%) with a moisture content higher than 15%, whether the maize is in grains, epis or spathes. On the other hand, Agnibilékrou has 8% of maize grain, 8% of maize epi and 28% of maize spathe with water contents greater than 15%. Concerning Bondoukou, 40% and 8% of non-conformity of maize grain and maize epi (respectively) are also observed (Table 3).

3.1.3 Maize damages level

For each type of maize, the average level of damages in localities (P<0,05) also differ. For grains the values fluctuate between 5.01±2.64% and 19.35±2,00% while epis and spathes show damages of 9.05±5.27% to 21.29±7.17% and 10.06±3,06% to 17.95±9.13%, respectively. The statistical analysis reveals lower percentages of damages of maize grains in the department of Botro (5.81±3.08%), Korhogo (5.01±2.64%) and Katiola (8.81±1.49%) as compared with departements of Bondoukou (13,41±7,83%) and specially Agnibilékrou (19.35±2.00%). The grains collected from epis and spathes maize are also more damaged at Bondoukou (19.20±1.50% and 17.95±9.13%) and Agnibilékrou (21.29±7.17% and 13.20±1.13%) but in the other localities the averages vary from 9.05±5.27% to 12.34±2.93%. Furthermore, among all the analysed samples, maize grains coming from Botro, Korhogo et Katiola is the least damaged (Table 4).

3.1.4 Maize weight losses

The analysed level of maize weight losses are presented in Table 5. These losses are statistically invariable (P>0.05) for the three types of maize in the localities of Botro (2.14±1.65% to 3.02±1.55%), Katiola (2.65±0.88% to 3.02±1.99%) and Bondoukou (4.22±2.17% to 6.24±4.72%). However, as compared with epis and spathes of maize, the weight loss is significantly lower (P<0.05) at Korhogo and Agniblékrou when maize is in grains form (1.53±1.17% and 5.10±0.87%, respectively).

Based on comparison of losses in localities, the results indicate fewer losses at level of maize grains and epis in the departments of Botro (2.14±1.65% to 3.02±1.55%) Korhogo (1.53±1.17% to 2.43±1.70%) and Katiola (2.65±0.88% to 2.87±1.50%) as compared with Agnibilékrou (5.10±0.90% to 6.54±1.79%) and Bondoukou (4.22±2.17% to 6.24±4.72%). Concerning the maize spathes, there is an important weight losses (P<0.05) at Bondoukou (5.11±2.65%) in comparison with other localities (2.76±1.18% to 3.20±0.87%).

Table 2. Maize humidity levels sold in studied production areas

Départments	Grains	Epis	Spathes	F_{-value}	P_{-value}
Botro	8.92±0.59^{aA}	9.85±1.19^{aB}	11.17±1.58^{aC}	22.49	<0.001
Korhogo	8.58±0.48^{aA}	10.61±1.70^{aB}	11.16±1.45^{aB}	27.23	< 0.001
Katiola	9.94±0.99^{bA}	11.90±1.34^{aB}	12.43±1.53^{bB}	46.33	< 0.001
Agnibilékrou	13.20±1.63^{cA}	13.02±1.63^{bA}	14.17±1.61^{cB}	3.62	< 0.031
Bondoukou	14.18±2.63^{dA}	12.41±1.90^{bB}	11.53±1.49^{aC}	10.75	< 0.001
F_{-value}	73.66	17.17	17.16	nd	nd
P_{-value}	< 0.001	< 0.001	< 0.001	nd	nd

nd: not determined;By column and line the averages bearing the same letters are statistically identical. Lowercase letters are representative of columns and uppercase letters represent lines

Table 3.Samples proportion (%) of maize having a humidity level not in accordance at standard

Départments	Grains	Epis	Spathes
Botro	0	0	0
Korhogo	0	0	0
Katiola	0	0	4
Agnibilékrou	8	8	28
Bondoukou	40	8	0

Table 4. Level of maize damages sold in production areas

Départements	Grains	Epis	Spathes	F_{-value}	P_{-value}
Botro	5.81±3.08^{aA}	12.34±2.93^{bC}	10.06±3.06^{aB}	25.29	<0.001
Korhogo	5.01±2.64^{aA}	9.05±5.27^{aB}	10.86±2.22^{aB}	17.09	< 0.001
Katiola	8.81±1.49^{bA}	9.85±1.44^{aB}	10.46±1.39^{aC}	8.08	< 0.001
Agnibilékrou	19.35± 2.00^{dB}	21.29±7.17^{cC}	13.20±1.13^{bA}	58.93	< 0.001
Bondoukou	13.41±7.83^{cA}	19.20± 1.50^{cA}	17.95±9.13^{cA}	1.98	0.15
F_{-value}	28.83	20.65	7.83	nd	nd
P_{-value}	< 0.001	< 0.001	< 0.001	nd	nd

nd : not determined; By column and row, the averages covering the same letters are statistically identical. The lower case letters are representative of columns and capital letters are representative of rows

Table 5. Level of maize weight losses sold in production areas

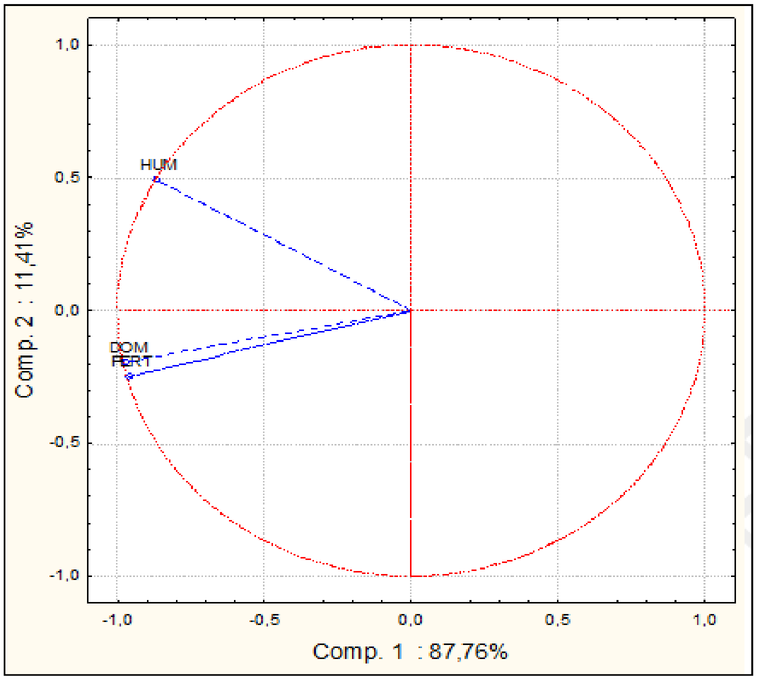
Départements	Grains	Epis	Spathes	F_{-value}	P_{-value}
Botro	2.14±1.65^{abA}	3.02±1.55^{aA}	2.94±0.59^{aA}	2.48	0.09
Korhogo	1.53±1.17^{aA}	2.43±1.70^{aB}	2.76±1.18^{aB}	5.32	0.006
Katiola	2.65±0.88^{bA}	2.87±1.50^{aA}	3.02±1.99^{aA}	0.36	0.55
Agnibilékrou	5.10±0.97^{cA}	6.54±1.79^{cbB}	3.20±0.87^{aC}	13.85	< 0.001
Bondoukou	4.22±2.17^{cA}	6.24±4.72^{bA}	5.11±2.65^{bA}	1.20	0.31
F_{-value}	13.50	9.68	5.09	nd	nd
P_{-value}	< 0.001	< 0.001	0.001	nd	nd

nd: not determined; By column and row, the averages covering the same letters are statistically identical. The lower case letters are representative of columns and capital letters are representative of rows

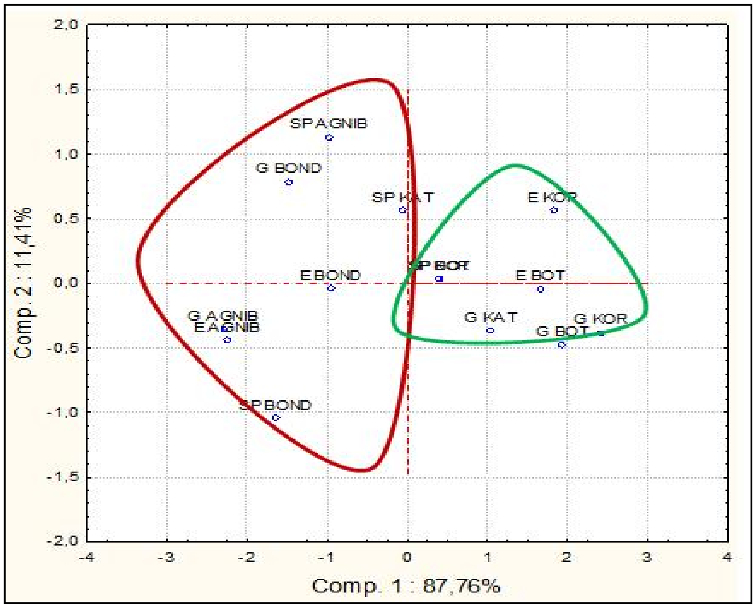
3.1.5 Variability of the charateristics of maize types

Table 6 shows that analysis of F1 and F2 factors of main components reveal 99.17% of total variability of studied parameters. The F1 factor with a proper value of 2.63 expresses 87.76% of total variability while F2 factor of proper value of 0.34 reveals 11.41%. The projection of analysed variables in factorial design F1-F2 shows strong positive correlation between humidity, damages and weight losses level of maize with F1 factor (Fig. 1, A). Based on the projection of samples in the same design, they are organised in two groups. Group 1 is composed of seven individuals presenting low humidity, weight losses and damages contents. It deals with spathes, epis and spathes maize coming from

Korhogo and Botro but also grains maize from Katiola, Korhogo and Botro. Group 2 includes individuals having high humidity, weight losses and damages contents. It deals with spathes, epis and grains maize coming from Katiola, Bondoukou and Agnibilékrou (see Fig. 1, B).



A



B

Fig. 1. Projection of merchants parameters (A) and individuals(B) of grains, epis and spathes of maize in factorial plan 1-2 of the analysis of main components
BOT : Botro ; KOR : Korhogo ; KAT : Katiola ; AGN : Agnibilékrou ; BON : Bondoukou; G : Grains ; E : Epis ; SP: Spathes ; HUM : Humidity ; DOM : Damages ; PERT: Weight losses

Table 6. Proper values of parameters

Components	Component 1	Component 2	Component 3
Proper values	2.63	0.34	0.02
Expressed variability (%)	87.76	11.41	0.82
Accumulation of expressed (%)	87.76	99.17	100

3.2 Discussion

The average humidity levels are all less than 15%, according to commercial standard of maize issued by Codex Alimentarius [19]. However, there is variability between the types of maize stored (grains, epis, spathes) as well as the departments visited. In fact, maize at grains remain the less humid type in most of the departments mainly in Botro, Korhogo and Katiola. Such data could result to the good practice of the drying of grains due to their easy handling. Some authors think that maize grains dry more easily and quickly and are more suitable for application of insecticides, compared to maize epis and spathes [22,23]. In the three localities mentioned above and even in Bondoukou, the humidity levels of samples taken from epis and spathes of maize are also less than 13%. This could make easier their conservation since the maximum humidity limit recommended for better maize conservation is 13% [22,13,14]. Furthermore, some samples of maize spathes collected in the departments of Katiola, as well as the three types of maize collected in Agnibilékrou and Bondoukou provided water contents which are above 15%. An ineffective drying associated with inappropriate storage conditions of harvests could have caused rehumidification of maize. In fact, the production and the post-harvest treatment of agricultural products are influenced by environmental conditions mainly climate, temperature and rainfall [24,25]. Bad environmental conditions can create high humidity and activity of water and therefore favour development of pests (insects, fungi) in stores [26,27]. As corollary of development of these living beings, the attacked products experiences serious damages summed up by weight losses and damages of grains.

Concerning these damages induced by insects, a variability is more observed at different forms of maize and in departments of maize production. In fact, maize grains coming from the departments of Botro, Korhogo and Katiola are less attacked by insects than epis and spathes maize. Furthermore, the grains, epis and spathes of these three departments could benefit better conditions (structures and methods) of conservation than those coming from Bondoukou and Agnibilékrou. The investigations led by Niamketchi, et al. [10] demonstrate a variability at level of structures of storage in area of production. According to these authors, the Botro's producers prefer polypropylene bags for storage of epis and grains maize in brick or clay stores. The palisades or palm leaf huts are used for storage of the maize spathes. As for the producers of korhogo, the conservation of grain, epis and spathe maize is done with cylindrical attic in clay. The use of trees whose branches serve as supports to hang spathes maize in the form of cluster. As for those of Katiola, they use polypropylene bags for the conservation of grains and palisades to hang the maize spathes. The producers of Agniblékrou and Bondoukou store maize either in Chinese bamboo granaries with shelf or polypropylene bags exposed in store or a room of house [10].

Other studies revealed that the storage of harvests in inappropriate structures also favours the growth of insects and mould, especially when the humidity is high [1,28,29]. Indeed, the increase of humidity strongly coincides with the amplification of damages leading to the significative losses of the harvests weight [9,10, 30,31]. Sankara, et al. [12] as well as Danso, et al.[29] revealed that the multiplication of insects pests is due to the storage conditions (grouped or isolated storage). They have also observed a diversity at the level of the number and the specie of insects pests according to the sites of studies.

Maizes coming from Bondoukou and Agnibilékrou are of lowest merchantability whatever the types of maize (epis, spathes, grains): they are more humid and has strong rates of damages and weight losses. Consequently, their germination capacity and health quality mainly mycotoxin contamination (ochratoxin A, patulin, aflatoxins, zearalenone, fumonisin, deoxynivalenone), could be unsatisfactory. Some authors have shown that the attack by insects is source of weight loss, reduction of nutritive and merchantability and sometimes loss of the germination capacity of grains [1,7,9,31-34]. According to them, the activity of the insects is also correlated with the development of moulds such as Penicillium, Fusarium and Aspergillus, responsible for the production of mycotoxins in stocks. The maizes stored in the form of grains or epis in the departments of Korhogo, Botro and Katiola are of better merchantability than those stored in spathes form. In fact, the grains and naked epis are better dried, less damaged by insects and have less weight losses.

4. CONCLUSION

This study investigated the merchantability of harvested and stored maize in five areas of production in Côte d'Ivoire. It shows that this merchantability is better in the departments of Botro; Korhogo and Katiola regardless of the maize form (grains, epis, spathes) except for the maize spathes in Katiola. In these localities, maize grains and epis have also better merchantability than in the form of spathe. It would be important to sensitize producers on good post-harvest practices and the use of structures suitable for storing different forms of maize in order to help improve the profitability of their agricultural production and insure food security.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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