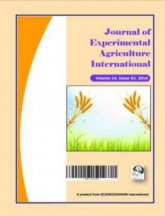

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Chemical Composition and Nutritive Value during Grain Development of Three Varieties of Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Two improved varieties of maize (OBA SUPER II and SWAN) and one local variety were grown in the University of Ado Ekiti during the early cropping season of year 2016 to study the changes in their chemical and nutritional quality as the maize kernel develops.
The chemical composition of the three varieties shows a decrease in carbohydrate content and an increase in protein and fat content as the kernel matures while the concentration of Ash and fibre in the three varieties varies and does not follow a consistent pattern as the kernel matures.
The most abundant mineral elements are phosphorus, calcium, magnesium and zinc. Maize grains are low in trace elements.

Keywords: Maize kernel; nutritional quality; mineral element; maize grains; trace elements.

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1. INTRODUCTION

The word “maize” is from the Spanish connotation “maiz” which is the best way of describing the plant. Various other synonyms like zea, silk maize, makka, barajovar, etc. are used to recognize the plant [1].

Maize (*Zea mays* L.), monoceous plant belongs to the family Poaceae and is commonly cultivated in tropical areas and grown as summer crop in temperate regions [2]. On the other hand, maize is grown in limited area because it is not a common animal feed, except in case of shortage of other cereal forage [3].

Maize (*Zea mays* L.) is the third most important cereal grain in the world, the majority of which is produced in developing countries for human consumption. In the developed world it is mainly used for industrial purposes and animal feed [4]. Maize is GRAS (generally recognized as safe), nontoxic, and biodegradable protein. It possesses great potential to provide important health benefits to human beings [5]. It acts as a nanoscale biomaterial that has unique solubility and film-forming properties. It has novel applications in pharmaceutical and nutraceutical areas to coat nanoparticles, develop promising nanocomposite antimicrobial agents, produce novel food packaging, encapsulate nutrients, and provide target delivery with controlled release [6,7,8,9,10,11,12].

Due to its value and importance, the genetic improvement of maize has played a key role in the development of genotypes with high technological and nutritional values. Specialty maize hybrids are the result of selection for improved chemical composition of the grain compared to standard hybrids.

Physically, the yellow flint maize has a high content of proteins and ß-carotene. Field maize contains approximately 4% of sucrose up to immature milky stage. Standard sweet maize with the *sugary1* (*su1*) mutant at the same stage contains approximately 10% sucrose. Following harvest or if left on the stalk too long, sucrose in *su1* standard sweet maize is rapidly conversed to starch. Grains can lose as much as 50% of their sucrose at room temperature 24 hours after harvest [13]. Waxy maize is a starch variant of normal maize which contains 100% amylopectin whereas normal maize contains 75% amylopectin and 25% of amylose. Waxy maize is used by wet-maize millers to produce waxy starch which is utilised by the food industry as a stabiliser and in the paper industry as an adhesive [14]. Popping maize has a hard, flinty endosperm that surrounds a small amount of soft moist starch in the centre. Heating the grain turns this moisture into steam which expands, splits the pericarp and causes the endosperm to explode, turning the grain inside out. Most commercial varieties expand 30-40 times their volume. Among the most important types of maize are high lysine maize, namely *opaque 2* and quality protein maize (QPM) and high-oil content genotypes with more than 6% of oil high in polyunsaturated essential fatty acids [15].

In Nigeria, specifically in the Northern part of the country, cereal provides a major food resource for man. They are the major source of energy and protein in the diet of many people. Maize is the second most important cereal crop in Nigeria ranking behind sorghum in the number of people it feeds. Estimated annual production of maize is about 5.6 million tones [16]. Maize is a multipurpose crop, providing food and fuel for human being and feed for animals (poultry and livestock). Its grain has great nutritional value and can be used as a raw material for manufacturing many industrial products [17]. Due to nutritional composition of maize, it serves as a good substrate for fungi development many of which cause nutritional losses and production of toxic substances known as mycotoxins [18].

In view of all this, global food security and environmental preservation as well as farmer’s livelihood should be the main goals of a sustainable farming system in today’s world of maize plantation which can be plagued by degraded soils as a result of unsustainable crop management practices [19] and also as result of biotic factors: Such as indiscriminate effluent discharge, smelting of iron, refuse disposal etc. [3].

The objective of this research work is to investigate the changes in the chemical composition and nutritive value during grain development in maize.

2. MATERIALS AND METHODS

The study was conducted at the back of the Plant Science Laboratory of the University of Ado Ekiti under the rainy season condition during the 2016 early planting season.

Table 1. Common phenotypic characteristics of the maize cultivars used

S/N	Cultivars	Breeds	Testa colour
1.	OBA SUPER II	HYBRID	YELLOW
2.	SWAN	HYBRID	YELLOW
3.	LOCAL VARIETY	OPEN POLLINATED	WHITE

2.1 Seed Materials

Two improved varieties (OBA SUPER II and SWAN) collected from IITA (International Institute of Tropical Agriculture) Ibadan, Nigeria and one local variety collected from Ado Ekiti market were used for the study.

The description of the features of the three cultivars used is shown in the Table 1.

2.2 Land Preparation

The land preparation was done by clearing the bush with cutlass and filled on 8th of April, 2016. The experimental design was a Complete Randomized Block Design (CRBD) with four replicates. The plot used was divided into twelve sub plots measuring 1.2 m by 4.5 m per sub plot. Seeds were sown on April 10, 2016 at the rate of two seeds per hill and at a spacing of 0.3 m within rows and 0.9 m across rows. Weeding was done to reduce competition for the available soil nutrients, water and light.

2.3 Data Collection

Agronomic characters such as Days to tasselling, Days to anthesis, Days to silking, plant height, cob height, kernel rows per cob, and 250-kernet weight were taken for the varieties while bulk samples for the proximate composition and mineral analysis were taken at 4,5,6,7 and 8 weeks after tasselling.

2.4 Determination of Proximate

The proximate parameters such as moisture, ash, crude fiber, protein and carbohydrate contents of the samples were carried out as follows:

(i) Determination of moisture content

Drying method was the common method used in estimating the moisture content of foods in which the percentage weight loss of water was estimated; usually after removal by heating by oven drying at 105^{o}C (the oven used was DHG-9023A model, made by B. BRAN Scientific and Instrument Company England). This method is considered to be reliable, provided that there is no chemical decomposition of the sample [20].

Cleaned and dried Petri dishes were weighed by using OHUS Adventure analytical balance and respective weight was recorded (W1). 3.0 g of the sample was weighed into the dishes spreading as much as possible. The Petri dish and sample were weighed and recorded as W2. The Petri dishes with the samples were transferred into the thermosetting oven maintained at 105°C, and dried for about three hours. It was later transferred to the desiccator for effective cooling and then reweighted. This process was performed repeatedly until a constant weight (W3) was obtained [20]. The loss in weight during drying in percentage was taken to be the percentage of moisture content.

$$\% \text{ Moisture content} = (\text{Loss in weight})/(\text{Weight of sample}) \times 100$$

$$\% \text{ Moisture content} = (W2 - W3)/3 \times 100$$

Where 3 represent weight of sample

W1 = Weight of empty evaporating dish
W2 = Weight of empty evaporating dish + sample
W3 = Constant weight, evaporating dish and dried sample.

(ii) Determination of crude fat

The crude fat was determined by Soxhlet extraction system. A previously dried filter paper was weighed as (W1). 2.5 g of the sample was added in the filter paper, weighed as (W2). This was tightened very well with white thread and transferred into a thimble. A 500 ml round bottom flask was filled up to two-third of its capacity with n-hexane. The Soxhlet extractor was then fitted with a reflux condenser and the heat source of the extractor was adjusted so that the solvent boils gently and it was left to siphon for 8 hours, after which the paper was removed. The filter paper and defatted samples were dried in the oven at 50°C for about 30 minutes. The sample was allowed to cool down in desiccators and weighed as (W3). The percentage of fat content was thus calculated:-

% Crude fat = (W2 – W3)/ (W2-W1) x 100

Where,

W1 = weight of the filter paper
W2 = weight of the filter paper and the sample
W3 = weight of the defatted sample and the filter paper

(iii) Determination of total ash

Clean flat bottom crucibles were placed in muffle furnace for about 15 minutes at 350°C, the crucibles were removed, allowed to cool in desiccators, properly labelled with lead pencil and each was weighed as (W1). 1 g of the sample was added to each labelled crucibles and samples were then transferred into the muffle furnace to ash at 550°C for 4 hours. After complete ashing i.e when the samples become whitish in colour, the crucibles were allowed to cool in a desiccator and reweighed as (W3). Percentage ash was calculated and the ash used for mineral analysis.

% Ash Content = (weight of ash) / (weight of sample) × 100

% Ash Content = (W3-W1)/ (W2-W1) × 100

Where,

W1 = weight of empty crucible,
W2 = weight of the crucible and sample,
W3 = weight of the crucible and ash sample

(iv) Determination of Crude Protein (Using Kjeldhal Method)

The stages involved are:

Digestion Stage

In this stage, 1 g of the sample was weighed into a Kjedhal flask and 10 ml of H_2SO_4 with Kjedhal catalyst was added. The weight is taken to be W1. This was then heated on a heater until it was digested. The flask was rotated at intervals until the digest was clear (light green) and the heating was continued after that to ascertain complete digestion. This was allowed to cool and the digested sample was made to 50 ml (V1). The sulphuric acid action result in complete digestion of organic matter and the conversion of nitrogen into ammonium salt (ammonium sulphate).

$2NH_3\,(aq) + H_2SO_4\,(aq)$ catalyst $\longrightarrow$ $(NH_4)_2SO_4(aq)$

The digested sample was then diluted with 50ml distilled water after which 25 ml was pipetted into a clean distilled flask and neutralized with 50ml 40% sodium hydroxide.

$(NH_4)_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2NH_3(g) + 2H_2O(l)$

Distillation Stage

In this stage, the digested ammonia was trapped into 5 ml 2% boric acid that is contained in a receiving flask in which 4 drops of mixed indicator (0.198 g bromocresol green plus 0.132 g methyl red in 200 ml alcohol) has been added.

$NH_3\,(g) + H_3BO_3(aq) \quad NH_4^+(aq) + H_2BO_3(aq)$

Titration Stage

The titration stage which is the last stage involves titrating the distillate against 0.01 M HCl until the colour changes from bluish to pink/red.

$(NH_3)_3\,BO_3\,(aq) + 3HCl(aq) \quad 3NH_4Cl\,(aq) + H_3BO_3(aq)$

% Nitrogen = ((T-B)×14 ×0.01×V1)/(Weight of sample ×V2) × 100

where

T = the titre value
B = blank
V1 = volume of digest
V2 = volume of digest used
% Crude Protein = % Nitrogen × 6.25

Crude Protein

The amount of crude protein contained in seeds is obtained by multiplying the nitrogen content of the food by 6.25. The factor 6.25 owes its origin to the assumption that all food protein contains 16% nitrogen, and that all nitrogen in a food is present as protein.

Determination of Crude Fiber

Crude fibre is the remaining organic component when the defatted sample has been successfully treated with diluted acid (H_2SO_4) and dilute base (NaOH). Crude fibre is the indigestible portion of any main food. It is known that fibre consists of cellulose, which can be digested to considerable extents by both ruminants and non-ruminants [21]. The determination of fibre content in plant tissue provides a distinction between the most digestible carbohydrate.

Preparation of reagents:-

1.25% H2SO4:- this was prepared by measuring 6.25 ml of concentrated H_2SO4 with the aid of measuring cylinder, and pour in 500 ml volumetric flask that has about 200ml distilled water, properly mixed and make up to the mark with more distilled water labeled.

1.25% NaOH:- 6.25g of NaOH pellets was weighed with Ohus analytical balance and dissolved water in a beaker and transferred to 500 ml volumetric flask, then make up to the mark with distilled water labeled.

HCl:- measuring cylinder was used to measure 10 ml concentrated HCl into 100ml volumetric flask which already contain distilled water, mixed and make up to mark with distilled water and labeled.

About 3.0 g (W1) of defatted sample was weighed into 500 ml conical flask, 200 ml of 1.25% of H_2SO_4 was added to the sample, placed on heating mantle and bring to boiling within 2 minutes, then allowed to boil gently for 30 minutes. The mixture was filtered through Whatman filter paper, in Buchner funnel and rinsed well with hot distilled water. The sample was scrapped back into the flask with spatula, placed on a heating mantle and 200 ml of 1.25% NaOH was added and allowed to boil for few minutes and then boiled gently for 30 minutes. It was filtered through Whatman filter paper, in Buchner funnel and rinsed well with hot distilled water for four times and once with 10% HCl to neutralize the NaOH remaining in the sample. Then it was rinsed with hot distilled water for four times and twice with ethanol. The residue was scrapped into a crucible and weighed (W2), dried in a thermosetting drying oven at 105°C, ashed at 550°C in a muffle furnace, cooled in a desiccator and reweighed (W3).

(%) Crude fibre = (weight loss) / (weight of sample) × 100

(%) Crude fibre = (W2-W3)/(W2-W1)× 100 (5)

Where,

W1 = weight of empty crucible,
W2 = weight of the crucible and sample,
W3 = weight of the crucible and ash sample

2.5 Mineral Analysis

Determination of soluble carbohydrate (Nitrogen free extractive).

Carbohydrate is the most abundant constituent of plants and animals. The most common approach for determination of carbohydrate content of food is the difference between the total predominant content in percentages (ash, crude protein, fat, crude fibre, moisture) and one hundred [22] % Carbohydrate = 100 – (% ash + % crude protein + % fat + % crude fibre + % moisture).

3. RESULTS AND DISCUSSION

Plant growth and development is the primary source of energy for stability and functionality for plants which is photosynthesis [23].

The germination percentage of a seed may be influenced by the living environment [23].

The mean values of different growth and developmental characters of the three varieties of maize grown during the experiment are shown in Table 2.

Table 3 shows the mean values of different grain yield compound and the total grain yield of the three maize varieties. From the table, there were significant differences in the cob length, row number and 250 kernel weight at P≤0.05 for the three cultivars. Local variety recorded the highest cob length and 250 kernel weight while OBA SUPER II and SWAN are not significantly different from each other. SWAN recorded the highest row number per cob (17.00) while local variety recorded the lowest row number per cob.

The proximate composition (percentage Dry-weight) of the three maize varieties at 4,5,6,7 and 8 weeks after tasselling is presented in Tables 4, 5 and 6.

The carbohydrate content in the cultivars ranged between 69.92% at 8 week after tasselling in the local variety to 11.29% at 8 weeks after tasselling in OBA SUPER II. The protein content appears to be inversely correlated to the carbohydrate content and increases as the kernel matures. The fat content ranged between 2.65 in the local variety at 4 weeks after tasselling to 4.30% in SWAN at 8 weeks after tasselling and like protein increased as the kernel matured. The ash and fiber percentages did not follow a consistent trend as the kernel matured.

The mineral element of the three varieties of maize grain on dry weight basis in mg/kg at 4,5,6,7 and 8 weeks after tasselling is shown in Tables 7, 8 and 9.

Table 2. Mean values of different growth and developmental characteristics of the three varieties grown

S/N	Varieties	Days to tasselling	Days to anthesis	Days to silking	Plant height (CM)	Ear height (CM)
1	OBA SUPER II	51.30a	54.33a	56.67a	191.10b	151.50b
2	SWAN	55.30b	57.33b	59.33b	180.73a	132.87a
3	LOCAL VARIETY	58.00c	61.00c	62.67c	264.67c	171.00c

Means with the same letter within a column are not significantly different (p=0.05) based on Fisher Least significant Difference (LSD)

Table 3. Mean values of different grain yield components and total grain yield of the three maize varieties grown

S/N	Varieties	COB LENGTH (cm)	ROW NUMBER	250-KERNEL WEIGHT (g)
1	OBA SUPER II	18.90a	14.33b	87.90b
2	SWAN	18.53a	17.00c	87.30b
3	LOCAL VARIETY	34.37b	13.00a	84.50a

Means with the same letter within a column are not significantly different (p=0.05) based on Fisher Least significant Difference (LSD)

Table 4. Proximate composition (% Dry weight) of OBA SUPER II grains at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	ASH%	FAT%	FIBRE%	PROTEIN%	Soluble carbohydrate%
4	3.21	3.42	1.29	8.85	74.48
5	6.54	3.51	1.30	9.82	72.81
6	3.68	4.11	1.33	10.80	70.44
7	3.66	4.18	1.32	10.91	70.46
8	3.59	4.26	1.26	11.29	69.92

Table 5. Proximate composition (% Dry weight) of SWAN grains at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	ASH%	FAT%	FIBRE%	PROTEIN%	Soluble carbohydrate%
4	3.30	3.36	1.32	8.35	75.05
5	3.48	3.48	1.35	9.40	73.34
6	3.66	4.21	1.33	10.62	70.54
7	3.62	4.27	1.30	10.82	70.34
8	3.55	4.30	1.25	11.05	70.18

Table 6. Proximate composition (% Dry weight) of LOCAL VARIETY (WHITE) grains at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	ASH%	FAT%	FIBRE%	PROTEIN%	soluble carbohydrate%
4	3.28	2.65	2.45	8.05	75.11
5	3.30	2.70	2.51	8.34	74.61
6	3.58	3.95	2.18	9.57	71.80
7	3.56	3.92	2.16	10.90	70.89
8	3.45	3.99	2.16	10.90	70.61

Table 7. Mineral elements of OBA SUPER II grains on dry weight basis in mg/kg at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	Na	K	Ca	Mg	Zn	Fe	Cu	Mn	Co	P
4	65.11	52.66	296.82	344.70	480.87	18.19	21.06	5.74	6.70	2560.32
5	87.63	59.40	344.69	554.04	461.54	20.45	23.37	5.84	3.89	2692.31
6	87.34	70.25	818.30	684.45	636.99	24.68	27.53	9.49	9.49	2954.24
7	85.58	46.20	954.16	688.57	642.34	25.58	29.51	10.82	9.84	3000.20
8	86.82	73.01	952.05	714.29	542.62	25.65	29.60	15.79	13.81	3020.92

Table 8. Mineral elements of SWAN grains on dry weight basis in mg/kg at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	Na	K	Ca	Mg	Zn	Fe	Cu	Mn	Co	P
4	65.15	39.09	318.32	317.39	232.69	18.62	18.62	5.58	6.54	2559.57
5	84.17	56.11	355.07	580.50	436.34	24.19	24.19	11.06	11.61	2481.62
6	87.24	67.32	883.75	649.54	451.36	27.65	27.65	11.38	9.22	2803.69
7	82.95	85.44	941.94	803.69	634.10	28.45	28.45	12.58	9.48	5963.21
8	90.94	31.31	950.08	727.55	507.93	29.02	29.02	15.48	13.54	2970.20

Table 9. Mineral elements of LOCAL VARIETY (WHITE) grains on dry weight basis in mg/kg at 4,5,6,7 and 8 weeks after tasselling

Weeks after tasselling	Na	K	Ca	Mg	Zn	Fe	Cu	Mn	Co	P
4	66.63	43.17	328.45	321.88	220.53	17.83	18.77	4.69	2.82	2385.51
5	69.82	44.95	350.04	444.72	36.64	18.17	19.13	15.30	8.26	2534.43
6	78.87	55.00	398.51	965.59	373.60	23.87	25.37	15.57	13.49	2849.49
7	77.04	47.91	436.87	685.83	926.12	23.49	25.63	13.15	11.27	2866.91
8	102.53	71.20	443.33	686.35	521.17	24.83	26.98	15.19	13.30	3267.99

The highest mineral elements in the three varieties are phosphorous which ranged between 2385.51mg/kg at 8 weeks after tasselling so it increases as the kernel matures.

Other elements such as iron, copper and manganese showed an increase as the maize kernel matured. The concentration of sodium and potassium for the three varieties increases from 4 weeks to 6 weeks after tasselling and decreased at 7 weeks and further increased at 8 weeks after tasselling while the concentration of zinc in the three varieties increased form 4-7 weeks after tasselling and later decreases at 8 weeks after tasselling. The concentration of potassium magnesium and cobalt were generally unstable in the maize grain.

3.1 Discussion

The results of the proximate and nutritional value showed that the hybrid (OBA SUPER II) had the highest protein content which can be attributed to its improved genetic structure while local variety (WHITE) had the least protein content which increased as the kernel matures.

This is against the findings of [24] which reported that protein quality decreased as kernel matured.

Changes in the crude protein content can be attributed to the fact that with advancing maturity plant fractions with structural role increases while at the same time soluble components of protein are transferred to more growing points ([25], [26];[27]). Protein was very low in maize grain which constitute about 8-11%.

Consequently, it can be expected that intake and utilization of maize would be low unless supplemented with a Nitrogen rich source. The major chemical component in maize kernel is the carbohydrate which provided up to 69.12-75.05% and this corroborates the findings of [28] that an

average of 66.80% carbohydrate based on the dry weight of maize grain is achievable. The concentration of carbohydrate decreased as the kernel matured.

The percentage of crude fibre and ash which are the lowest chemical content in maize kernel decreased as the kernel matured which corroborates with [29] Fat which constitute of about 5% in maize kernel increases as the kernel matures.

The proximate composition as revealed in this study showed that the higher the number of weeks after tasselling the higher the percentage carbohydrate that is also observed is in line with the submission of [30] which says generally maize is a good source of industrial products such as starch.

According to this report, all the varieties of maize studied revealed great attributes which can help in the improvement of health, this is in line with the submission of [5].

4. CONCLUSION AND RECOMMENDATION

The abundant mineral form is the phosphorous which increases as the kernel matures.

In human nutrition, maize is good for consumption because it's able to meet up the recommended daily requirement (rDA) for carbohydrate which is about 72-75%.

From results above, maize also provides significant amount of protein, fat and high amount of phosphorous, calcium.

Among the varieties used in this study, OBA SUPER II is hereby recommended and should be promoted in infant feeding for their high protein content.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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