CHANGES IN CHEMICAL COMPOSITION AND NUTRITIVE VALUE DURING GRAIN DEVELOPMENT OF THREE VARIETIES OF MAIZE

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 compositon 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.

INTRODUCTION

Maize (*Zea mays* L.) IS the third most important cereal grain in the world, the majority of this product in developing countries is for human consumption, in the developed world it is mainly used for industrial purposes and animal feed (FAO,1992). 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 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 loose as much as 50% of their sucrose at room temperature 24 hours after harvest (Amir *et al.*,1971). 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 (Ptaszek *et al.,* 2009). 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 (Graham *et al.,*1990).

In Nigeria, specifically in the Northern part of the country, cereal provides a major food resource for man. It is 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. (Central Bank of Nigeria report 1992).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 raw material for manufacturing many industrial products. (Afzal et al.,2009).Due to nutritional composition of maize, it serves as a good.

Substrate for fungi development that many cause nutritional losses and production of toxic substances known as mycotoxin (Lancy, 1998).

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

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.

Seed materials

Two improved varieties (OBA SUPER II and SWAN) were 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 feature of the three cultivars used is shown in the table below.

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

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 1.2m by 4.5m per sub plot. Seeds were sown on 10th April, 2016 at the rate of two seeds per hill and at a spacing of 0.3m within rows and 0.9m across rows, weeding was done to reduce competition for the available soil nutrients, water and light.

Data collection

Agronomic characters such as Days to Tasselling, Days to anthesis, Days to silking, plant height, cob height, kernel row per cob, 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.

Determination of Proximate

The proximate parameters such as moisture, ash, crude fiber, protein and carbohydrate contents of the samples were carried out as follows; 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 is the main 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 105oC (the oven used was DHG-9023A model, made by B. BRAN Scientific and Instrument Company England). This method is considered to be a reliable method provided that there is no chemical decomposition of the sample (A.O.A.C., 2006).

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 105oC, and dried for about three hours. It was later transferred to the desiccator for effective

cooling and then reweighed. This process was performed repeatedly until a constant weight (W3) was obtained (A.O.A.C., 2006). The loss in weight during drying in percentage was taken to be the percentage moisture content.

% Moisture content = (Loss in weight)/(Weight of sample) × 100

% Moisture content =(W2 –W3)/3 × 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). 2.5g 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 500ml 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 filtre paper and defatted samples were dried in the oven at 50^{o}C for about 30 minutes. The sample was allowed to cool down in dessicators and weighed as (W3). The percentage fat content was calculated thus:-

% 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^{o}C, the crucibles were removed, allowed to cool in desiccators, properly labelled with lead pencil and each was weighed as (W1). 1g of the sample was added to each labelled crucibles and samples were then transferred into the muffle furnace to ash at 550^{o}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, 1g of the sample was weighed into a Kjedhal flask and 10ml of H2SO4 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 50ml (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 25ml 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 5ml 2% boric acid that is contained in a receiving flask in which 4 drops of mixed indicator (0.198g bromocresol green plus 0.132g methyl red in 200ml alcohol) has been added.

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

(3) Titration Stage

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

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

$$\% \text{ Nitrogen} = ((T-B) \times 14 \times 0.01 \times V1) / (\text{Weight of sample} \times V2) \times 100$$

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.

(v)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 (Pearson, 1976). 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 6.25ml of concentrated H2SO4 with the aid of measuring cylinder, and pour in 500ml 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, 200ml of 1.25% of H_2SO_4 was added to the sample in the conical flask, 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 200ml of 1.25% NaOH was added then allowed to boil for few minutes and 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 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 ovenat 105^0C, ashed at 550^0C 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

Mineral analysis

Determination of soluble carbohydrate (Nitrogen free extractive)

Carbohydrate is the most abundant constituent of plants and animals. The most common approach for the 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 (A.O.A.C., 1990). % Carbohydrate = 100 – (% ash + % crude protein + % fat + % crude fibre + % moisture).

RESULTS AND DISCUSSION

The mean values of different growth and developmental characters of the three varieties of maize grown during the experiment are shown in Table 2. From the table, days to tasselling, anthesis and silking were significantly different (P=0.05) in the three cultivars.

The hybrid yellow variety (OBA SUPER II) at P≤0.05 was recorded for both plant and ear height among the three cultivars investigated but on the average, the open pollinated variety (local white) recorded the highest plant height and ear height while SWAN recorded the least in plant and ear height respectively.

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	191.10a	151.50a
2	SWAN	55.30b	57.33b	59.33b	180.73b	132.87b
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	14.33a	87.90a
2	SWAN	18.53a	17.00b	87.30a
3	LOCAL VARIETY	34.37b	13.00c	84.50b

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

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 also like protein increases as the kernel matures. The ash and fiber percentages do not follow a consistent trend as the kernel matures.

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

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

Other elements such as iron, copper and manganese shows an increase as the maize kernel matures. The concentration of sodium and potassium for the three varieties increases form 4 weeks to 6 weeks after tasselling and decreases at 7 weeks and later increases at 8 weeks after

tasselling while the concentration of zinc in the three varieties increases form 4-7 weeks after tasselling and later decreases at 8 weeks after tasselling. The concentration of potassium magnesium and cobalt are generally unstable in the maize grain.

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

DISCUSSION

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

This is against the findings of Gomez-Brenes, Elias and Bressani (1968) which reported that protein quality decreases as kernel matures.

Changes in the crude protein content can be attributed to the fact that with advancing maturiey plant fractions with structural role increases while at the same time soluble

components of protein are transferred to more growing points (Gonske, Keeney 1969, Fleischer 1986, 1987). Protein is 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 Morrison (1956) that an average of 66.80% carbohydrate based on the dry weight of maize grain is achievable. The concentration of carbohydrate decreases as the kernel matures.

The percentage of crude fibre and ash which are the lowest chemical content in maize kernel decreases as the kernel matures which corroborates with (Ingle, Bietz and Hageman 1965). Fat which constitute of about 5% in maize kernel increases as the kernel matures.

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

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

Maize also provides significant amount of protein, fat and high amount of phosphorous, calcium. Thus maize should be promoted in infant feeding.

REFERENCES

Afzal M, Nasir Z, Bashir MH, Khan BS (2009). Analysis of List Plant resistance in some genotypes of maize against Chilo Partellus (Swinhoe) (Pyralidae: Lepidoptera). *Pakistan J. Botany*. 41:421-428

Amir J., Wright R.D., Cherry J.H., 1971. Chemical control of sucrose conversion to polysaccharides in sweet corn after harvest. *J Agric Food Chem* 19, 954-957.

AOAC (2006) Official Methods of Analysis. 18th Edition, Association of Official Analytical Chemists, Gaithersburgs, MD.

Central Bank of Nigeria (1992). Annual Report and Statement of Account Central Bank of Nigeria, Lagos. pp 78.

FAO, 1992. Maize in human nutrition. Report series 25. Food and Agricultural Organization, Rome, Italy.

Fleischer. J.E. 1986. Harnessing Ghana's renewal energy resources for increased protein production In; proc Ghana National Conference on population and National Reconstruction, Legon 7-10 April 1986.

Fleischer, J.E. 1987. A study of the growth and nutritive value of green panicum (*Panicum maximum*) vatrichoglume (v petrie) & Rhodes grass (chloris gayana kunth) OAU (STRC BULL) *Animal Health and Prod*. 35(3):229-237

Gomez-Brenes R.A., Elias L.G. and Bressan, R. 1968. Effectodel Procesode maduracion del

maiz sobre su valor nutritive Arch. *Latinoam. Nutr*., 18:6579

Gonske, R.G & Keeney D.R. 1969. Effect of fertilization Nitrogen variety and maturity on dry
matter yield of corn grown for sillage *Agron. J*. 61:72-75

Graham G.G., Lembcke J., Morales E., 1990. Quality-protein maize as the sole source of dietary
protein and fat for rapidly growing young children. Pediatrics 85, 85-91.

Lancey J (1998). Prevention of Mould Growth and Mycotoxin Production through control of
Environmental Sector. *Mycotoxin and Phycotoxin.* Elisever. Amsterdam P. 161-189.

Morrison F.B. (1956). Feeds and feeding 22nd edition. Morrison Pub. Co. New York.

Pearson, D., 1976. Chemical Analysis of Foods. 7th Edn., Church Hill Livingstone, London,
UK., pp: 72-73,138-143, 488-496.

Ptaszek A., Berski W., Ptaszek P., Witczak T., Repelewicz U., Grzesik M., 2009. Viscoelastic
properties of waxy maize starch and selected non-starch hydrocolloids gels. *Carbohydr Polymers* 76, 567-577.