

1 IN CHEMICAL COMPOSITION AND NUTRITIVE VALUE DURING GRAIN 2 DEVELOPMENT OF THREE VARIETIES OF MAIZE

3

4

5 ABSTRACT

6 Two improved varieties of maize (OBA SUPER II and SWAN) and one local variety were
7 grown in the University of Ado Ekiti during the early cropping season of year 2016 to study
8 the changes in their chemical and nutritional quality as the maize kernel develops.

9 The chemical composition of the three varieties shows a decrease in carbohydrate content and
10 an increase in protein and fat content as the kernel matures while the concentration of Ash
11 and fibre in the three varieties varies and does not follow a consistent pattern as the kernel
12 matures.

13 The most abundant mineral elements are phosphorus, calcium, magnesium and zinc. Maize
14 grains are low in trace elements.

15

16 INTRODUCTION

17 The word “maize” is from the Spanish connotation “maiz” which is the best way of
18 describing the plant. Various other synonyms like zea, silk maize, makka, barajovar, etc. are
19 used to recognize the plant (Kumar & Jhariya, 2013).

20 Maize (*Zea mays* L.), monoceous plant belongs to the family Poaceae and is commonly
21 cultivated in tropical areas and grown as summer crop in temperate regions (Skerman and
22 Riveros, 1989). On the other hand, maize is grown in limited area because it is not a common
23 animal feed, except in case of shortage of other cereal forage (Ayesa et al, 2017).

24 Maize (*Zea mays* L.) is the third most important cereal grain in the world, the majority of
25 which is produced in developing countries for human consumption. In the developed world it
26 is mainly used for industrial purposes and animal feed (FAO, 1992). Maize is GRAS
27 (generally recognized as safe), nontoxic, and biodegradable protein. It possesses great
28 potential to provide important health benefits to human beings (Tajamul et al 2016). It acts as
29 a nanoscale biomaterial that has unique solubility and film-forming properties. It has novel
30 applications in pharmaceutical and nutraceutical areas to coat nanoparticles, develop
31 promising nanocomposite antimicrobial agents, produce novel food packaging, encapsulate
32 nutrients, and provide target delivery with controlled release (Fernandez et al., 2009; Jin et

33 al., 2009; Lai & Guo, 2011; Luo et al., 2010; Luo et al., 2011; Sanchez-Garcia et al., 2010;
34 Zhang et al., 2010).

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

39 Physically, the yellow flint maize has a high content of proteins and β -carotene. Field maize
40 contains approximately 4% of sucrose up to immature milky stage. Standard sweet maize
41 with the *sugary1(su1)* mutant at the same stage contains approximately 10% sucrose.
42 Following harvest or if left on the stalk too long, sucrose in *su1* standard sweet maize is
43 rapidly converted to starch. Grains can lose as much as 50% of their sucrose at room
44 temperature 24 hours after harvest (Amir *et al.*, 1971). Waxy maize is a starch variant of
45 normal maize which contains 100% amylopectin whereas normal maize contains 75%
46 amylopectin and 25% of amylose. Waxy maize is used by wet-maize millers to produce waxy
47 starch which is utilised by the food industry as a stabiliser and in the paper industry as an
48 adhesive (Ptaszek *et al.*, 2009). Popping maize has a hard, flinty endosperm that surrounds a
49 small amount of soft moist starch in the centre. Heating the grain turns this moisture into
50 steam which expands, splits the pericarp and causes the endosperm to explode, turning the
51 grain inside out. Most commercial varieties expand 30-40 times their volume. Among the
52 most important types of maize are high lysine maize, namely *opaque 2* and quality protein
53 maize (QPM) and high-oil content genotypes with more than 6% of oil high in
54 polyunsaturated essential fatty acids (Graham *et al.*, 1990).

55 In Nigeria, specifically in the Northern part of the country, cereal provides a major food
56 resource for man. They are the major source of energy and protein in the diet of many people.
57 Maize is the second most important cereal crop in Nigeria ranking behind sorghum in the
58 number of people it feeds. Estimated annual production of maize is about 5.6 million tones.
59 (Central Bank of Nigeria report, 1992). Maize is a multipurpose crop, providing food and fuel
60 for human being and feed for animals (poultry and livestock). Its grain has great nutritional
61 value and can be used as a raw material for manufacturing many industrial products. (Afzal et
62 al., 2009). Due to nutritional composition of maize, it serves as a good substrate for fungi
63 development many of which cause nutritional losses and production of toxic substances
64 known as mycotoxins (Lancey, 1998).

65 In view of all this, global food security and environmental preservation as well as farmer's
66 livelihood should be the main goals of a sustainable farming system in today's world of
67 maize plantation which can be plagued by degraded soils as a result of unsustainable crop
68 management practices (Montgomery, 2008) and also as result of biotic factors: such as
69 indiscriminate effluent discharge, smelting of iron, refuse disposal etc. (Ayesa et al 2017)

70

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

73

74 **MATERIALS AND METHODS**

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

77

78 **Seed materials**

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

82 The description of the features of the three cultivars used is shown in the table below.

83

84 **Table 1**

85 **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

86

87 **Land preparation**

88 The land preparation was done by clearing the bush with cutlass and filled on 8th of April,
89 2016. The experimental design was a Complete Randomized Block Design (CRBD) with
90 four replicates. The plot used was divided into twelve sub plots measuring 1.2m by 4.5m per
91 sub plot. Seeds were sown on April 10, 2016 at the rate of two seeds per hill and at a spacing
92 of 0.3m within rows and 0.9m across rows. Weeding was done to reduce competition for the
93 available soil nutrients, water and light.

94

95 **Data collection**

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

100

101 **Determination of Proximate**

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

104 (i) Determination of moisture content

105 Drying method was the common method used in estimating the moisture content of foods in
106 which the percentage weight loss of water was estimated; usually after removal by heating by
107 oven drying at 105°C (the oven used was DHG-9023A model, made by B. BRAN Scientific
108 and Instrument Company England). This method is considered to be reliable, provided that
109 there is no chemical decomposition of the sample (A.O.A.C., 2006).

110 Cleaned and dried Petri dishes were weighed by using OHUS Adventure analytical balance
111 and respective weight was recorded (W1). 3.0 g of the sample was weighed into the dishes
112 spreading as much as possible. The Petri dish and sample were weighed and recorded as W2.
113 The Petri dishes with the samples were transferred into the thermosetting oven maintained at
114 105°C, and dried for about three hours. It was later transferred to the desiccator for effective
115 cooling and then reweighed. This process was performed repeatedly until a constant weight
116 (W3) was obtained (A.O.A.C., 2006). The loss in weight during drying in percentage was
117 taken to be the percentage of moisture content.

118 % Moisture content = (Loss in weight)/(Weight of sample) × 100

119 % Moisture content = $(W_2 - W_3)/W_1 \times 100$

120

121 Where W_1 represent weight of sample

122 W_2 = Weight of empty evaporating dish

123 W_3 = Weight of empty evaporating dish + sample

124 W_4 = Constant weight, evaporating dish and dried sample.

125 (ii) Determination of crude fat

126 The crude fat was determined by Soxhlet extraction system. A previously dried filter paper
127 was weighed as (W_1). 2.5 g of the sample was added in the filter paper, weighed as (W_2).
128 This was tightened very well with white thread and transferred into a thimble. A 500 ml
129 round bottom flask was filled up to two-third of its capacity with n-hexane. The Soxhlet
130 extractor was then fitted with a reflux condenser and the heat source of the extractor was
131 adjusted so that the solvent boils gently and it was left to siphon for 8 hours, after which the
132 paper was removed. The filter paper and defatted samples were dried in the oven at 50°C for
133 about 30 minutes. The sample was allowed to cool down in desiccators and weighed as (W_3).
134 The percentage of fat content was thus calculated:-

135 % Crude fat = $(W_2 - W_3)/(W_2 - W_1) \times 100$

136 Where,

137 W_1 = weight of the filter paper

138 W_2 = weight of the filter paper and the sample

139 W_3 = weight of the defatted sample and the filter paper

140 (iii) Determination of total ash

141 Clean flat bottom crucibles were placed in muffle furnace for about 15 minutes at 350°C, the
142 crucibles were removed, allowed to cool in desiccators, properly labelled with lead pencil and
143 each was weighed as (W_1). 1g of the sample was added to each labelled crucibles and
144 samples were then transferred into the muffle furnace to ash at 550°C for 4 hours. After
145 complete ashing i.e when the samples become whitish in colour, the crucibles were allowed
146 to cool in a desiccator and reweighed as (W_3). Percentage ash was calculated and the ash
147 used for mineral analysis.

148 % Ash Content = (weight of ash)/ (weight of sample) × 100

149 % Ash Content = $(W_3 - W_1)/(W_2 - W_1) \times 100$

150

151 Where,

152 W_1 = weight of empty crucible,

153 W2 = weight of the crucible and sample,
154 W3 = weight of the crucible and ash sample

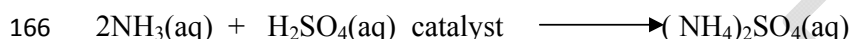
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156 (iv) Determination of Crude Protein (Using Kjeldhal Method)

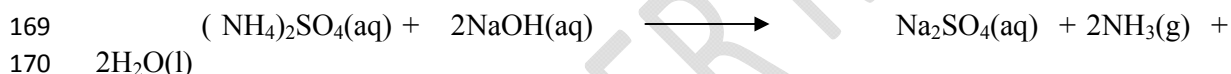
157 The stages involved are:

158 Digestion Stage

159 In this stage, 1 g of the sample was weighed into a Kjeldhal flask and 10 ml of H₂SO₄ with
160 Kjeldhal catalyst was added. The weight is taken to be W1. This was then heated on a heater
161 until it was digested. The flask was rotated at intervals until the digest was clear (light green)
162 and the heating was continued after that to ascertain complete digestion. This was allowed to
163 cool and the digested sample was made to 50 ml (V1). The sulphuric acid action result in
164 complete digestion of organic matter and the conversion of nitrogen into ammonium salt
165 (ammonium sulphate).



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

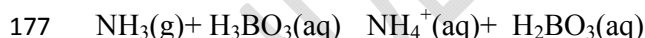


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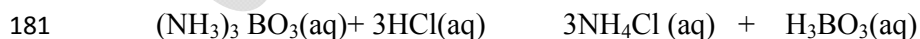
173 Distillation Stage

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



178 (3) Titration Stage

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



182 $\% \text{ Nitrogen} = ((T-B) \times 14 \times 0.01 \times V1) / (\text{Weight of sample} \times V2) \times 100$

183 where T = the titre value

184 B = blank

185 V1 = volume of digest

186 V2 = volume of digest used

225 W2 = weight of the crucible and sample,
226 W3 = weight of the crucible and ash sample

227 Mineral analysis

228 Determination of soluble carbohydrate (Nitrogen free extractive)

229 Carbohydrate is the most abundant constituent of plants and animals. The most common
230 approach for determination of carbohydrate content of food is the difference between the total
231 predominant content in percentages (ash, crude protein, fat, crude fibre, moisture) and one
232 hundred (A.O.A.C., 1990). % Carbohydrate = 100 – (% ash + % crude protein + % fat + %
233 crude fibre + % moisture).

234

235 RESULTS AND DISCUSSION

236 Table 2

237 Mean values of different growth and developmental characteristics of the three varieties
238 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

239

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

242 Plant growth and development is the primary source of energy for stability and functionality
243 for plants which is photosynthesis (Ayesa et al., 2018).

244 The germination percentage of a seed may be influenced by the living environment (Ayesa et
245 al., 2018).

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

248

249

250 **Table 3**

251 **Mean values of different grain yield components and total grain yield of the three maize**
252 **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

253

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

256

257 Table 3 shows the mean values of different grain yield compound and the total grain yield of
258 the three maize varieties. From the table, there were significant differences in the cob length,
259 row number and 250 kernel weight at $P \leq 0.05$ for the three cultivars. Local variety recorded
260 the highest cob length and 250 kernel weight while OBA SUPER II and SWAN are not
261 significantly different from each other. SWAN recorded the highest row number per cob
262 (17.00) while local variety recorded the lowest row number per cob.

263 **Table 4**

264 **Proximate composition (%Dry weight) of OBA SUPER II grains at 4,5,6,7 and 8 weeks**
265 **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

266

267

268

269 **Table 5**

270 **Proximate composition (%Dry weight) of SWAN grains at 4,5,6,7 and 8 weeks after**
271 **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

272

273 **Table 6**

274 **Proximate composition (%Dry weight) of LOCAL VARIETY (WHITE) grains at**
275 **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

276 **Table 7**

277 **Mineral elements of OBA SUPER II grains on dry weight basis in mg/kg at 4,5,6,7 and 8**
278 **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

279

280 **Table 8**

281 **Mineral elements of SWAN grains on dry weight basis in mg/kg at 4,5,6,7 and 8 weeks**
 282 **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

283

284 **Table 9**

285 **Mineral elements of LOCAL VARIETY (WHITE) grains on dry weight basis in mg/kg**
 286 **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

287

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

290 The carbohydrate content in the cultivars ranged between 69.92% at 8 week after tasselling in
291 the local variety to 11.29% at 8 weeks after tasselling in OBA SUPER II. The protein content
292 appears to be inversely correlated to the carbohydrate content and increases as the kernel
293 matures. The fat content ranged between 2.65 in the local variety at 4 weeks after tasselling to
294 4.30% in SWAN at 8 weeks after tasselling and like protein increased as the kernel matured.
295 The ash and fiber percentages did not follow a consistent trend as the kernel matured.

296 The mineral element of the three varieties of maize grain on dry weight basis in mg/kg at
297 4,5,6,7 and 8 weeks after tasselling is shown in Tables 7, 8 and 9.

298 The highest mineral elements in the three varieties are phosphorous which ranged between
299 2385.51mg/kg at 8 weeks after tasselling so it increases as the kernel matures.

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

306

307 **DISCUSSION**

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

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

313 Changes in the crude protein content can be attributed to the fact that with advancing
314 maturity plant fractions with structural role increases while at the same time soluble
315 components of protein are transferred to more growing points (Gonske and Keeney 1969,
316 Fleischer 1986, 1987). Protein was very low in maize grain which constitute about 8-11%.

317 Consequently, it can be expected that intake and utilization of maize would be low unless
318 supplemented with a Nitrogen rich source. The major chemical component in maize kernel is
319 the carbohydrate which provided up to 69.12-75.05% and this corroborates the findings of
320 Morrison (1956) that an average of 66.80% carbohydrate based on the dry weight of maize
321 grain is achievable. The concentration of carbohydrate decreased as the kernel matured.

322 The percentage of crude fibre and ash which are the lowest chemical content in maize kernel
323 decreased as the kernel matured which corroborates with (Ingle et al., 1965). Fat which
324 constitute of about 5% in maize kernel increases as the kernel matures.

325 **Conclusion and Recommendation**

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

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

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

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

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