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Full Length Research Paper

Effect of Maturity Stages and Roasting Method on the Proximate Composition of orange Maize Hybrids

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This study evaluated the effect of harvesting time and methods of roasting on the proximate composition of orange maize hybrids. The maturity stages were 20 days, 27 days and 34 days after pollination (20 DAP, 27 DAD and 34 DAP, respectively), while the roasting was done with and without husk. Across the maturity stages, the dry matter (DM), ash, protein, fat, total carbohydrate, starch and sugar, amylose, and amylopectin levels of the unprocessed maize peaked at 34 DAP, 20 DAP, 27 DAP, 27 DAP, 34 DAP, 20 DAP, 34 DAP, and 27 DAP, respectively. Roasting with and without husk resulted in increase in the DM and sugar contents of the maize across the various maturity stages, relative to the unprocessed maize. Ash and starch contents decreased at the 27 DAP and 34 DAP, but increased at the 20 DAP due to roasting with and without husk, in relation to the unprocessed maize. Crude protein, fat, amylose and amylopectin contents were affected differently at the various maturity stages, due to roasting method. Therefore, the proximate composition of orange maize hybrid is modulated by the maturity stage at which it is harvested; and method of roasting also affects the amount retained.

Keywords: Orange maize, hybrid, maturity stage; roasting; husk; proximate;

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's three most important cereal crops (the other two being wheat and rice), and it is an important source of food, feed, fuel and fibers (Tenailon and Charcosset, 2011). It has the widest distribution of all the cereals, and it is primarily grown for its grain as food human consumption (Tolera *et al.*, 1998). Maize and other cereals are the major source of calories and protein to the diets of humans and livestock, and this is

largely due to their adaptability, high yields, ease of harvest and storage, as well as their processing and eating properties (Lafiandra *et al.*, 2014). Typically, maize kernel is composed of 8–10 % protein, 4–5 % lipid, 70–75 % starch, 1–3 % sugar, and 1–4 % ash; and supplies approximately 365 kcal/100 g of energy (USDA/ARS, 2012). Maize contains a proportion of all of the important vitamins with the exception of vitamin B12. These vitamins, especially the fat-soluble vitamins A and E, are generally concentrated in the embryo (Loy and Wright, 2003).

Maize plant development can be divided into distinct vegetative and reproductive stages, as described in applied guides for plant management (OMFRA, 2009). Plant development and maturation are known to influence

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the DM yield and affect the DM contributions of different plant fractions to the whole plant biomass yield (Phipps and Weller, 1979). This, in turn, may affect the nutritive value because of variations in rumen availability of starch and fiber (Jensen *et al.*, 2005). Studies have shown that plant development and maturation can be manipulated by hybrid choice (Marton *et al.*, 2007; Argillier *et al.*, 2000) and time of harvest (Wilkinson and Phipps, 1979). Consumption of maize requires pre-treatments such as heat processing, which could confer some nutritional benefits, as well as alter the physicochemical contents and properties of its components (Deosthale, 1982; Siljestrom *et al.*, 1986). Roasting is regarded as a key procedure in the preparation of the maize beverage, due to the characteristic flavor produced during the roasting process. In the food industry, roasting is an important processing method used to improve food quality, to extend the shelf-life of foods, and to improve the processing efficiency of subsequent treatment (Youn and Chung, 2012). Roasting with and without husk might have effect on these beneficial effects of roasting.

This study was therefore designed to evaluate the effect of maturity stage and method of roasting on the proximate composition of orange maize hybrid.

MATERIALS AND METHODS

Source of genetic materials

Freshly harvested biofortified orange maize hybrids cobs obtained from the research farms of International Institute of tropical Agriculture (IITA) were used for this research work. The orange maize hybrids were planted in a trial at Ibadan (7°22' N, 3° 58'E, altitude 150m) in 2010 and 2011 seasons. They were harvested at three different maturity stages, namely, 20 days, 27 days and 34 days after pollination (20 DAP, 27 DAD and 34 DAP, respectively).

Field Sampling

Plants were randomly prelabelled on the field for the three harvesting time of 20, 27 and 34 days after pollination (DAP) (The day after pollination started from 50% anthesis or 50% silk emergence which was 57 days after planting) for each hybrid. They were harvested at 08.00hrs on the appropriate and marked dates. A total of 20 selected cobs of each hybrid were harvested from each plot and these were pooled to give 60 cobs per hybrid per harvest. They were packed in mailing sacks and conveyed to the laboratory as soon as possible. In the laboratory, each hybrid was divided into 3 sets for chemical assays, roasting with intact husk (undehusked cobs) and roasting without husk (dehusked cobs) respectively. All the selections and divisions were strictly randomised.

Processing of freshly harvested orange maize

The 20 selected harvested cobs of each hybrid with intact husk (undehusked) and 20 selected cobs without husk (dehusked) were roasted on hot-charcoal burning on wire gauze until the seeds were cooked and turned brown according to the local practice as described in other studies (Osanyintola *et al.* 1992). The roasting time varied with harvest times for both forms of roasting. Dehusked cobs from 20, 27 and 34DAP harvests roasted at 15, 12 and 10 mins respectively, while undehusked cobs from 20, 27 and 34DAP harvests roasted at 20, 15 and 12 mins respectively. All the harvested cobs were processed within 12 hours after harvesting. The fresh and processed orange maize samples were carefully shelled, freeze-dried using Labconco Freezone 4.5L (at temperature of minus 54 °C and vacuum pressure of 0.45mbar.). The freeze-dried samples were milled using Laboratory mill 310 from PERTEN using sieve size 0.5mm and packed in the polythene whirl- pack before they were stored at 4°C until they were analyzed

All the chemicals used for analysis were of analytical grade.

Determination of proximate composition

The proximate composition of the samples was determined according to methods of AOAC (2005). Moisture content was determined by oven-drying at 100°C - 105°C for 18-24 h. Total Nitrogen content (N) was determined by Kjeldahl method, and the protein content was calculated as N x 6.25. Ash content was determined by incinerating 2 g of samples in a pre-weighed porcelain crucible in a muffle furnace at 600°C for 6 hours. Crude fat (ether extract) content of the samples was determined using a Soxtec extraction machine.

Determination of Amylose and amylopectin content

Amylose level of samples was determined following the iodine method reported by Juliano *et al.* (1981). 0.1 g of sample was mixed with 1 mL of 95 % ethanol and 9.2 mL of 1 N NaOH, and heated at 100 °C in a water bath for 10 min. After cooling, 0.5mL of diluted extract was mixed with 0.1mL of 1 N acetic acid solution and 0.2 mL of iodine solution (0.2 % I₂ in 2 % KI). The test mixture was made up to 10 mL with 9.2 mL of distilled water, mixed and left for 20 min for color development. Thereafter the absorbance was read at 620nm, and amylose content of sample was calculated using standard amylose.

Amylopectin was calculated by difference (Juan *et al.*, 2006) using the following formula:

$$\text{Amylopectin (\%)} = 100\% - \text{amylose (\%)}$$

Determination of starch and total free sugar

Starch and sugar content of flour samples were quantified following the phenol-sulphuric acid method as reported by (Onitilo *et al.*, 2007). Starch and sugar were extracted from 0.02 g of sample using 80% hot ethanol. The mixture was then centrifuged at 2000 rpm for 10 min., after which the supernatant was decanted and used for free sugar analysis, while the residue was used for starch analysis. For free sugar analysis, 0.2 mL of the diluted supernatant was mixed with 0.5 mL of phenol solution (5%) and 2.5 mL of conc. H₂SO₄. The mixture was allowed to cool to room temperature, and the absorbance was read at 490nm.

The residue was hydrolyzed with 7.5 mL of perchloric acid for 1 h, diluted to 25 mL with distilled water and filtered through What man filter paper (No. 2). Then 0.05 mL of the filtrate was mixed with 0.5 mL of phenol solution (5 %) and 2.5 mL of conc. H₂SO₄. The mixture was allowed to cool to room temperature and the absorbance was read at 490 nm. Starch and total free sugar contents of sample were calculated from a D-glucose standard curve prepared at a concentration of 0.1 mg/mL.

The addition of sugar and starch gives the total digestible carbohydrate content (DCHO).

RESULTS

The proximate composition of fresh orange maize hybrid at three maturity stages of harvesting due to roasting method (with and without husk) is presented in Table 1. Ash content gradually decreased across the harvest maturity stages when fresh orange hybrid maize was roasted without husk. Ash content at 27 DAP was significantly ($P < 0.05$) different from that at 34 DAP. Amylose, sugar, protein and DCHO contents decreased at 20 DAP and 27 DAP and slightly increased at 34 DAP.

There was no significant ($P > 0.05$) difference at 20 DAP and 27 DAP for amylose, protein and DCHO. The difference at 20 DAP and 27 DAP was significant ($P < 0.05$) for sugar content. There was an increase in amylose, protein, and DCHO between 20 DAP and 34 DAP; but sugar level increased only at 20 DAP and 27 DAP, and remained constant at 34 DAP. Roasting with husk resulted in significant ($P < 0.05$) changes in ash, amylose, amylopectin, sugar, protein and fat contents across the maturity stages of harvesting. There were no significant ($P > 0.05$) differences in starch and DCHO contents at 20 DAP and 27 DAP, but those at 34 DAP were significant ($P < 0.05$).

The mean percentage changes in the proximate composition of the orange hybrid maize at the different maturity stages due to roasting method are presented in Table 2. There was 9.82 % loss in ash content at 20 DAP; but a gain of 7.57% at 27 DAP and 6.82% at 34 DAP for roasted hybrid maize without husk. Whereas there was a loss in ash content by

10.5 % at 20 DAP, there was a gain of 7.57 % at 27 DAP, and 4.57 % at 34 DAP for roasted hybrid maize with husk. Amylose showed losses of 3.46% at 20 DAP; 1.87% at 27 DAP; and a gain of 2.39% at 34 DAP for roasted hybrid maize without husk. Roasted hybrid maize with husk showed a loss of 12.8% at 20 DAP, with gains of 7.02% and 10.30% at 27 DAP and 34 DAP, respectively.

The sugar content showed a gain of 104% at 20 DAP and 70.8% at 34 DAP but a loss of 0.71% at 27 DAP for roasted fresh orange hybrid maize without husk. Roasting with husk resulted in a gain of 91.2%, 7.33%, and 78.0% at 20 DAP, 27 DAP and 34 DAP, respectively, in the sugar content. Roasting with and without husk increased sugar content at both 20 DAP and 34 DAP. The starch content showed a loss of 14.9% at 20 DAP, but gains of 4.53% and 99.8% at 27 DAP and 34 DAP, respectively, for roasted hybrid maize with husk; while roasted hybrid maize without husk showed a loss of 9.32% at 20 DAP, and gains of 6.9% at 27 DAP and 55.9% at 34 DAP.

There were 9.71% and 26.0% gains in crude protein content of the orange maize hybrid at 20 DAP and 34 DAP, respectively; but a loss of 4.51% at 27 DAP due to roasting without husk. Roasting with husk led to losses of 15.5% and 6.61% in crude protein at 20 DAP and 27 DAP respectively; but gains of 3.54% at 34 DAP. These results suggested that husk had an effect on the protein content of roasted fresh orange maize. The fat content showed gains of 19.4% at 20 DAP and 19.5% at 34 DAP; but losses of 8.21% at 27 DAP for roasted hybrid maize without husk. At 20 DAP, roasting with husk resulted in a gain of 21.3% in fat content; but losses of 10.30% at 27 DAP and 13.60% at 34 DAP.

DISCUSSION

The choice of a hybrid of a crop for an area has influence on the relative maturities and the nutritive quality of the plant (Argillier *et al.*, 2000). Orange maize, in addition to being an important dietary source of energy, lipids, protein, minerals and vitamins, is a readily available and affordable source of beta-carotene and other carotenoids (Menkir *et al.*, 2008). Beta-carotene is a precursor for vitamin A, making orange maize a veritable tool for alleviating vitamin A deficiency. Orange maize is preferably eaten as green maize and is consumed boiled, or roasted on the cob after a long dry season to bridge the "hunger gap" (Menkir *et al.*, 2008). The maturity stage at which harvesting is done and method of roasting (whether with husk or without husk), are two important factors that can affect the nutrient composition of maize.

Jensen *et al.*, (2005) demonstrated that DM concentration is a more consistent and continuous descriptor of plant maturity; and this has been used in many hybrid evaluation programs to rank the relative hybrid maturity (Schwab *et al.*, 2003; Marton *et al.*, 2007). In this study, the

Table 1: Proximate composition of fresh orange hybrid maize due to method of roasting at different maturity stages

Maturity/ Processing	%MC	%DM	%Ash	%Protein	%Fat	%DCHO	%Sugar	%Starch	%Amylose	%Amylopectin
20 DAP Unprocessed	8.70 ± 0.43 ^a	91.31 ± 0.43 ^e	2.12 ± 0.29 ^a	9.61 ± 1.31 ^{ab}	5.94 ± 0.28 ^d	56.96 ± 3.23 ^b	3.83 ± 1.34 ^b	53.14 ± 2.41 ^b	21.63 ± 1.52 ^{cd}	78.38 ± 1.52 ^{cd}
Roasted with husk	6.47 ± 0.19 ^e	93.54 ± 0.19 ^a	1.88 ± 0.15 ^b	7.71 ± 1.50 ^c	7.17 ± 0.24 ^c	48.59 ± 4.36 ^{de}	6.51 ± 1.05 ^a	42.06 ± 4.66 ^e	18.48 ± 2.41 ^f	81.53 ± 2.41 ^a
Roasted without Husk	6.79 ± 0.64 ^{cde}	93.21 ± 0.64 ^{abc}	1.89 ± 0.18 ^b	10.08 ± 0.85 ^a	7.04 ± 0.9 ^c	50.68 ± 4.58 ^{cd}	6.91 ± 1.89 ^a	43.74 ± 4.23 ^{de}	20.78 ± 1.26 ^{de}	79.23 ± 1.26 ^{bc}
27 DAP Unprocessed	7.57 ± 1.15 ^b	92.43 ± 1.16 ^d	1.52 ± 0.11 ^{cd}	10.48 ± 0.72 ^a	9.49 ± 1.32 ^a	46.51 ± 3.39 ^e	3.31 ± 0.61 ^{bc}	43.2 ± 3.16 ^{de}	21.51 ± 0.69 ^{cd}	78.49 ± 0.69 ^{cd}
Roasted with husk	7.32 ± 0.40 ^{bcd}	92.69 ± 0.40 ^{bcd}	1.62 ± 0.04 ^c	9.71 ± 0.36 ^{ab}	7.54 ± 0.29 ^c	47.36 ± 3.06 ^{de}	3.7 ± 1.14 ^b	43.64 ± 2.79 ^{de}	21.80 ± 1.07 ^{cd}	78.20 ± 1.07 ^{cd}
Roasted without Husk	6.99 ± 0.31 ^{bce}	93 ± 0.30 ^{abcd}	1.60 ± 0.11 ^c	9.28 ± 1.83 ^{ab}	7.68 ± 0.29 ^c	49.66 ± 2.90 ^{cde}	3.49 ± 0.68 ^{bc}	46.19 ± 3.37 ^{cd}	19.89 ± 1.60 ^e	80.11 ± 1.60 ^b
34 DAP Unprocessed	7.45 ± 0.29 ^{bc}	92.55 ± 0.28 ^{cd}	1.43 ± 0.07 ^d	8.53 ± 0.54 ^{bc}	7.24 ± 0.20 ^c	34.59 ± 2.49 ^f	2.50 ± 0.52 ^c	32.10 ± 2.75 ^f	22.79 ± 0.86 ^{bc}	77.21 ± 0.86 ^{de}
Roasted with husk	7.30 ± 0.70 ^{bcd}	92.71 ± 0.70 ^{bcd}	1.48 ± 0.09 ^{cd}	8.745 ± 1.06 ^{bc}	6.26 ± 0.63 ^d	65.35 ± 1.78 ^b	4.39 ± 0.81 ^b	60.98 ± 1.79 ^a	25.05 ± 0.64 ^a	74.95 ± 0.64 ^f
Roasted without Husk	6.67 ± 1.15 ^{de}	93.33 ± 1.16 ^{ab}	1.52 ± 0.06 ^{cd}	10.38 ± 0.85 ^a	8.63 ± 0.35 ^b	52.6 ± 4.83 ^c	4.18 ± 0.54 ^b	48.40 ± 5.09 ^c	23.30 ± 1.13 ^b	76.70 ± 1.13 ^e

Data represent the mean ± standard error of replicate readings (n = 96). Values with the same lowercase superscript letter along the same column are not significantly different (P > 0.05).

MC = moisture content; DM = dry matter; DCHO = digestible carbohydrate

DM of unprocessed maize increased progressively with the maturity stages (from 91.31% at 20 DAP to 92.55% at 34 DAP), with a concomitant decrease in MC (from 8.7% at 20 DAP to 7.45% at 34 DAP) as maturity increased. This is in agreement with the report of Tolera *et al.* (1998) who observed that DM increased as maturity stage increased. Phipps and Weller (1979) also reported that DM yield is affected by plant development and maturation. This, in turn, may have influence on the nutritive value as a result of variations in rumen availability of starch and fiber (Jensen *et al.*, 2005).

Total carbohydrate (TCHO) also increased progressively as the maturity stage increased,

peaking at 34 DAP. However, starch and total free sugar decreased with increasing maturity of the orange maize hybrid. This is contrary to the positive linear correlation between starch concentration and increased maturity due to remobilization of available carbohydrates from the vegetative organs of the plants reported by Argillier *et al.* (2000). It is possible that as maturity progressed, there was increase in hydrolysis of starch due to higher activity of hydrolytic enzymes such as α -amylase, β -amylase and starch phosphorylase (Stanley, 1998), thereby leading to reduced starch level in the orange maize hybrid. Carbohydrates (starch and sugars) primarily provide energy to body

cells, particularly the brain, which is entirely carbohydrate-dependent. Sugars are also prominent for their involvement in controlling blood glucose and insulin metabolism, intestinal microflora activity, and food fermentation. Monosaccharides (such as glucose) bound to protein and lipid molecules (glycoproteins and glycolipids) participate in cell signaling (Hounsborne *et al.*, 2008).

Table 2. Mean percentage changes in proximate composition of orange hybrid maize at different maturity stages due to roasting with and without husk

Maturity/ Processing	MC	DM	Ash	Protein	Fat	DCHO	Sugar	Starch	Amylose	Amylopectin
20 DAP Roasted with husk	-24.6	2.45	-10.5	-15.5	21.3	-9.19	91.2	-14.9	-12.8	4.18
Roasted without Husk	-20.3	2.11	-9.82	9.71	19.4	-3.48	104	-9.32	-3.46	1.17
27 DAP Roasted with husk	-0.119	0.287	9.08	-6.61	-10.3	5.40	13.9	4.53	7.02	0.04
Roasted without Husk	-2.86	0.66	7.57	-4.51	-8.21	6.5	-0.71	6.9	-1.87	2.56
34 DAP Roasted with husk	1.08	0.19	4.57	3.54	-13.6	97.2	78.0	99.8	10.3	-2.91
Roasted without Husk	-8.03	0.86	6.82	26.0	19.5	56.4	70.8	55.9	2.39	-0.65

MC = moisture content

DM = dry matter

DCHO = digestible carbohydrate

+ve = gain

-ve = loss

At the three different maturity stages of harvesting, amylopectin was consistently greater than amylose, irrespective of method of roasting. This is in consonant with the reports of some previous studies that amylopectin is the major component in most plant starch (Yotsawimonwat *et al.*, 2008; Irondi *et al.*, 2013). The carbohydrates that are absorbed relatively quickly from the small intestine such as starch and free sugars have the greatest impact on postprandial blood glucose. The type of starch is crucial in this respect, with amylose being slowly digested by α -amylase present in the human duodenum and amylopectin being very rapidly digested because the branched structure provides multiple sites for enzymatic hydrolysis (Lafiandra *et al.*, 2014). Moreover, amylose is structurally organized in the form of the double helixes, with the inner part of the helix

accommodating the hydrophobic ends of polar lipids which form molecular complexes and reduce the accessibility of the molecule to α -amylase (Birt *et al.*, 2013). These properties of amylose, in addition to its propensity to retrogradation, call for identification of the maturity stage of orange maize hybrid at which amylose content peaks, so that it could be harvested at such stage and used for the preparation of cereal foods with a low glycaemic index (Rahman *et al.*, 2007). This is particularly important for people that are either suffering from or are susceptible to nutrition-related diseases such as obesity and diabetes. Interestingly, according to the results of this present study, amylose content peaked at 34 DAP.

Crude protein and fat peaked at 27 DAP, suggesting that beyond this maturity stage (27 DAP), there was degradation of these two

important nutrients. Proteins provide structural material for the human body and function as antibodies, enzymes and hormones. Dietary proteins are regarded as the main source of the essential amino acids for humans (Hounsome *et al.*, 2008). Fats, in addition to providing fuel for metabolism, are major components of cell membranes. Vrablík *et al.* (2009) reported that some plant lipids contain bioactive polyunsaturated fatty acids (omega 3 and omega 6) that are beneficial in preventing cardiovascular diseases, and decreasing the incorporation of cholesterol in the membranes of arteries.

Studies have shown that roasting generally confers desirable nutritional and functional qualities on cereal grains when roasting time and temperature are properly selected. It can improve the digestibility of cereals protein (Srivastav *et al.*, 1990, Nout, 1993); it also improves the sensory qualities and inactivates destructive enzymes, thereby improving the storage and nutritional quality of the product (Coulibaly *et al.*, 2011). However, during thermal processing such as roasting, nutrients such as proteins may undergo chemical changes resulting in a reduction of their nutritional value and biologically available amino acids. This may be brought about by Maillard reactions which take place between reducing sugars and the lysine residue present in the protein (Sarwar Gilani *et al.*, 2012).

As expected, roasting with and without husk resulted in increase in the DM of orange maize hybrid. This could be attributed to dehydration associated with the roasting process, and this is important as it could increase the nutrient density of the maize.

Contrary to the expectation that roasting (with and without husk) would lead to a decrease in the total free sugar content of the maize due to caramelization and hydrolytic decomposition, there was an increase in total free sugar content, relative to the unprocessed maize. This observation may be accounted for by the roasting temperature and time. In a study aimed at optimizing the roasting temperature and time for preparation of coffee-like maize beverage using the response surface methodology, Youn and Chung (2012) observed that the content of free sugar generally decreased with increasing roasting temperature and time. During roasting oligosaccharides can decompose hydrolytically or caramelize. Sugars form Amadori compounds on reacting with amino acids as precursors of the Maillard reaction (Özdemir *et al.*, 2001), thereby leading to reduction in the amount of total free sugars.

CONCLUSION

From the results of this study, it could be concluded that maturity and method of roasting had significant effects on all the proximate components evaluated. The effects of maturity stage of harvesting and method of roasting (with or without husk) varied among the proximate components of the orange maize hybrid.

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