IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 8, Issue 2 Ver. I. (Feb. 2015), PP 55-63
www.iosrjournals.org

Varietal and harvesting time effects on physical characteristics and sensory properties of roasted fresh yellow maize hybrids

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Abstract: *The present study evaluated the effects of physical characteristics and harvesting time on the overall likeness of roasted fresh yellow maize hybrids. Freshly harvested cobs from eight biofortified yellow maize hybrids, at three harvesting time (20, 27 and 34 days after pollination (DAP)), were used for this study. The harvested fresh yellow maize cobs were roasted with and without intact husk on hot-charcoal burning on wire gauze until the seeds were cooked and turned brown. Sensory evaluation was carried out on the roasted fresh yellow maize samples within 24 hours after harvesting. The physical characteristics of the fresh maize grains were also determined. Variety and harvesting time had significant effects (P≤0.001) on most of the physical properties, except porosity. Harvesting time and husk had effects on the overall likeness of roasted maize hybrids with husk or without husk. The optimum harvesting time to consume roasted maize hybrids was found to be 20DAP, but the overall likeness rating for roasted fresh yellow maize hybrid without husk was higher than that of roasted fresh yellow maize hybrid with husk. There was negative but significant correlation between the physical characteristics and the sensory properties except colour that showed positive correlation. Differences in kernel characteristics caused by genetic inheritance and harvesting time can influence the processing, utilization and consumer overall likeness of maize.*

I. Introduction:

In recent times, hybrid maize production has been given widespread support among farmers in Nigeria (Ayinde et al. 2011). Nigeria produces over 700,000 metric tonnes of green maize per annum (FAOSTAT, 2011) which is mainly consumed fresh by either boiled or roasted (Akinwumi, 1970; Fajemisin, 1983). Yellow maize is produced in at least one major maize production zone in the various countries in West Africa (CIMMYT, 1988) and its grain is converted into well-accepted local food products including gruels, porridges, pastes and infant weaning food. Yellow maize is preferred as green maize and consumed boiled or roasted on the cob to bridge the hunger gap after a long dry season. Whether boiled or roasted, you can find it virtually everywhere in Nigeria. It is cheap, affordable and can be combined with other things like pear and coconut to make tasty snack. Kernel hardness, moisture and sugar/starch ratio were the quality attributes of raw green maize, which determined the overall likeness of the product in either boiled or roasted form (Osanyintola, 1995). Corn with low-test weight (bulk density) contained lower percentages of hard endosperm, and produced lower yields of prime grits when milled dry (Rutledge, 1979). Mestres et al. (1991) found that chemical composition (ash and protein contents) and physical properties (sphericity or dent kernel percentage) could be used to predict dry–milling characteristics of different yellow dent corn hybrids. Kirleis and Stroshine (1990) and Mistry and Eckhoff (1992) found that white corn had significantly higher values of 100-kernel weight, density, and starch content. White corn also had lower test weight and protein and oil contents when compared with yellow dent corn.

Differences in kernel characteristics caused by genetic inheritance, environment, or handling can influence the processing and utilization of crop (Peplinski et al. 1992). Oluwatola et al. (1995) reported that husks provided limited protection and textural quality in green field maize. Desiccation of kernels appeared to be dominant in causing loss of physical (weight and shrinkage volume) and textural quality (hardness) of green field maize. Maize kernel hardness is an important economic trait. Sufficient hardness is necessary to maintain kernel integrity throughout mechanical harvesting, while being handled during marketing (Anderson and Hall, 1991) and in storage. There is also a loose relationship between density and grain hardness. The most common measure of density is bulk density, also referred to as test weight, which is the weight of a given volume of grain including the surrounding air (Pomeranz et al. 1986; Cauvain and Young, 2009). The other measure of density is true density that is actual density of the kernels themselves. Breeding efforts to enhance physical or compositional end-use characteristics of maize require effective and expedient assessments of phenotypic traits and may be optimized when genetic control of the traits is understood (Pratt et al. 1995). However, information on the physical characteristics and utilization of fresh yellow maize hybrids are scanty. The present study evaluated the effect of physical characteristics and harvest time on the overall likeness of roasted fresh yellow maize hybrids. The information from this study could used by the Maize breeders to further improve the physical characteristics of the maize hybrids and by the maize consumers to know the best harvest time to consume roasted maize hybrids.

II. Materials and experimental methods:

Genetic material and planting

Freshly harvested cobs from eight biofortified yellow maize hybrids with varying endosperm texture were used for this study. They were obtained from the research farms of International Institute of Tropical Agriculture (IITA). The eight selected yellow maize hybrids were planted in two separate trials at Ibadan (7^o22' N, 3^o 58'E, altitude 150m) and Ikenne (10^o40' N, 8^o 77'E, altitude 730m) locations in 2010 and 2011 seasons. The hybrids were arranged in a randomized complete block design (RCBD) with replications. Self pollination was done to minimize contamination from other sources. The harvesting times were 20, 27 and 34 days after pollination (DAP).

Field Sampling

Plants were randomly pre-labelled on the field for the three harvesting time of 20, 27 and 34 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 physical properties measurements, 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 yellow 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 samples for sensory evaluation were kept warm in a cooler equipped with Styrofoam and kept in a Cooler box equipped with Styrofoam to keep the samples warm.

Evaluation of Sensory properties:

Sensory evaluation was carried out on the roasted fresh orange maize samples within 24 hours after harvesting. The serving and experiment were performed under standard sensory test conditions (Larmond, 1977). The samples were evaluated by 10 trained panels and degree of liking and attributes ratings were determined on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely for colour, aroma, chewiness, appearance, taste, and overall likeness. The overall likeness ratings are means of duplicate averages of 10 panellists' hedonic scores. The selected panellists were screened for 'normal' sensory acuity through taste, aroma and texture/chewiness identification tests. Basic taste recognition assessment was conducted using solution of sucrose, sodium chloride, citric acid and quinine sulphate. Aroma and texture recognition tests were done following the method recommended by Watts et al. (1989). Panellists started with the selection of important quality attributes of boiled fresh maizes following by technique of evaluation and the use of standard rating scale. Panellists selected colour, aroma, chewiness, appearance and taste as the most important quality attributes of roasted maize. They were served with the roasted samples in duplicates while they were still warm to touch.

Physical characteristics determinations:

Test weight or bulk density of grain:

The test weight or bulk density was determined using method described by Paulsen and Hill (1985). This involves filling a 200ml measuring cylinder or a suitable calibrated beaker of known weight (W_1) to the mark or level full with grains the weight was recorded (W_2) and the weight of the grain is obtained by difference. The bulk density was calculated as weight per unit volume.

Kernel weight volume and true density:

Method described by Arnold et al. (1977) and Adeyemi et al. (1987) was used. This involved weighing 25 randomly selected whole seeds, and transferred into a graduated measuring cylinder containing a known volume of 50% absolute ethanol (maximum volume of 20ml). The volume of the kernel was recorded. The data were used for the computation of density and 1000 kernel weight.

Porosity:

Porosity of the grain reflects the fraction of void space in a bulk of grain and was determined by the method described by Bhattacharya et al. (1972). The bulk density (db) and kernel true density (d) were determined as described above and from the data, the porosity was calculated.

Kernel size (dimensions):

Kernel size was evaluated by randomly selecting 20 kernels and measuring the three major axes namely length (mm) breadth (mm) and thickness or depth (mm) with a vernier calliper (Martinez – Herrera and LaChance, 1979).

Kernel shape factor (sphericity):

The kernel shape factor (sphericity) was determined using the method described by Pomeranz et al. (1985). The kernel length (a), width (b) and thickness (c) were determined as described by Pomeranz et al. (1985) above and computed the data for sphericity.

Hardness test:

A hardness tester, Kiya M. 174856 of the Kiya Seisakutcho Limited, Japan was used to measure rigidity or hardness of grains. It measures the peak compression force which corresponds to the bioyield point in kilogram force units of the kernel. It delivers a uniaxial compression force on the kernel units' cell; hence if the grain is placed uniformly as described by Martinez–Herrera and LaChance (1979) it would give results similar to the Instron instrument. The peak force in the deformation of the kernel was used as a measure of hardness.

III. Results and Discussions

Effect of harvesting time on Physical characteristics of fresh yellow maize hybrids

The combined analysis of variance (ANOVA) for the physical characteristics of fresh yellow hybrid maize is presented in Table 1. For fresh yellow maize hybrid, hybrids and maturity had significant effects ($P \leq 0.001$) on most of the physical characteristics, except porosity. Kernel weight, kernel volume, bulk density and kernel size index (KSI) were significantly ($P \leq 0.05$) affected by location. There was significant location by maturity interaction mean squares (MS) for all characteristics except porosity and shape factor. Only kernel weight, kernel volume, true density and bulk density showed significant ($P \leq 0.05$) hybrid by maturity interaction mean squares.

The mean results for physical characteristics of unprocessed hybrid fresh yellow maize are presented in Tables 2a and 2b showed the summary of descriptive statistics for all physical parameters of fresh yellow maize hybrids. There was general increase of mean values of all physical characteristics as the maize matured. The mean values of true density, for all hybrids across the two locations, for 20DAP, 24DAP and 34DAP were found to be 1.09, 1.12, and 1.15g/ml respectively for maize hybrids. This could be attributed to the lower moisture content that reduces weight and decreases density (Arnold et al. 1977). Endosperm texture may be responsible for the density differences of maize kernel. The 1000 kernel weight was highly influenced by hybrid and maturity and the results found in these studies are in agreement with the findings of Moenteno (1985), Weller et al. (1988) and Osanyintola (1995) and are similar to values reported for sweet and field corn by Birchler and Hart (1985), Kang and Zuber (1989) and Osanyintola (1995). They are attributable to differential rate of accumulation of dry matter (Ingle et al. 1965). It has been observed that kernel weight peaks at 28DAP (Ingle et al. 1965) and 30DAP (Osanyintola, 1995). Kernel hardness increased with maturity and significant difference in kernel hardness was observed for the maize hybrids. This must be due to difference in corneous endosperm. Szaniel et al. (1984) indicated that the cell sizes, cell wall thickness, apart from the compactness of the cellular components, create differences observed in kernel hardness. The data presented in this study suggest that kernel growth in maize occurs along the length and breadth axes of the kernels but not much in depth, as inferred from the steady increase in length and breadth with maturity, while depth more or less remained constant. Kernel dimensions could become simple physical characteristics enabling the identification and providing some numeric descriptors for green maize. Kernel size was reported to be an important factor of quality in sweet corn independent of succulence or solid content (Kramer, 1952). Ilori (1989) also reported some correlation of kernel size index with bulk density, 1000 kernel weight and germination in sorghum. The results of kernel dimension from the present study are important, therefore, because they can be used as maturity indicator for developing maize.

Effect of physical characteristics and harvesting time on sensory properties of roasted fresh maize hybrids

Table 3 presents the ANOVA analysis for the sensory characteristics (colour, aroma, chewiness, taste, appearance and overall likeness) of fresh yellow maize hybrid. The analysis of variance for fresh yellow maize hybrid showed highly significant effects ($P \leq 0.001$) of location, hybrid, maturity and method in all sensory characteristics, except colour that showed no significant effect ($P \leq 0.05$) on location and maturity. There were also pronounced location by maturity and location by method interactions mean squares for all sensory characteristics but there were no strong hybrid by maturity interactions on hybrids of all sensory parameters except for colour, taste and appearance. This observation was not in close agreement with Osanyintola (1995) that reported strong hybrid by maturity interactions for selected white maize. From the present results, it could be observed that maturity, method and hybrid showed significant effects on ratings of overall likeness of the fresh yellow maize hybrid. Location and maturity were not showing significant effects on the colour ratings. Husk and maturity were found to be very important factors in rating of sensory characteristics of roasted fresh yellow maize hybrid. However, there were little effects of location and hybrid

Tables 4a and 4b showed the summary of descriptive statistics and mean results for sensory properties of roasted fresh yellow maize hybrid without husk. There was gradual increase in the rating of colour and aroma at 20DAP and 27DAP before a decrease was observed at 34DAP. However, colour showed no statistical mean difference across the three maturity stages. Aroma only showed no statistical difference at 20DAP and 27DAP but showed significant difference at 34DAP. It was observed that the chewiness, taste and appearance showed a decrease across the maturity stages. There were significant mean differences for chewiness and taste, while overall likeness ratings showed no significant mean differences across the three maturity stages. The overall likeness showed optimum rating at 20DAP (6.52) for roasted yellow maize hybrid. From the data on roasted fresh yellow maize hybrid without husk, it was also observed that:

(i) at 20DAP, hybrids 1, 3 and 6 had higher overall likeness ratings than the grand mean of 6.52 but hybrid 6 was with the highest rating of 6.80 ± 1.28.
(ii) at 27DAP, hybrids 2, 3, 4, 6 and 7 had higher overall likeness ratings than the grand mean of 6.13 but hybrid 7 was with the highest rating of 6.85 ± 0.99.
(iii) at 34DAP, hybrids 1 and 7 had higher overall likeness ratings than the grand mean of 6.14 but hybrid 1 was with the highest rating of 8.40 ± 16.21.

It could be concluded that hybrid 1 showed higher overall likeness rating than their respective grand mean across the three maturity stages. However, hybrids 3 and 6 had higher overall likeness rating than the grand mean at 20DAP and 27DAP while hybrid 7 had higher overall likeness rating at 27DAP and 34DAP. This observation suggested that maturity and hybrid played a major role in the overall likeness of roasted maize hybrid without husk.

The data on sensory properties for roasted fresh yellow maize hybrid with husk are presented in Tables 5a and 5b.There was general decrease in the mean ratings for all sensory properties. Aroma, chewiness, taste, appearance and overall likeness showed significant differences across the maturity stages but colour showed no significant difference across the maturity stages. This observation suggested that maturity had effect on the ratings for all sensory properties except colour that showed no effect. The colour, chewiness and taste ratings showed similar pattern when compared with those data on roasted fresh yellow maize hybrid without husk. The overall overall likeness rating was not similar to that of roasted fresh yellow maize hybrid without husk. This observation suggested maturity and husk had effect on the overall likeness of roasted maize with husk or without husk. However, the optimum overall likeness rating was observed at 20DAP which is the same for fresh yellow maize hybrid roasted without husk, but the overall likeness rating for roasted fresh yellow maize hybrid without husk was higher than that of roasted fresh yellow maize hybrid with husk. It was observed from the data on roasted fresh yellow maize hybrid with husk presented in Tables 7a and 7b that:

(i) at 20DAP,hybrids 1, 2, 3, 4, 5 and 6 had higher overall likeness rating than the grand mean rating of 6.44 but hybrid 1 had the highest rating value of 6.80 ± 1.24.
(ii) at 27DAP, hybrids 1, 2 and 7 had higher overall likeness rating than the grand mean rating of 5.61 but hybrid 2 had the highest rating value of 6.70 ± 1.13.
(iii) at 34DAP, hybrids 2, 5 and 7 showed higher overall likeness than the grand mean of 5.24 but hybrid 2 had the highest rating of 5.60 ± 1.19.

It could be observed that hybrid 2 had higher overall likeness rating than the grand mean at the three maturity stages. However, hybrid 1 showed higher overall overall likeness rating than the grand mean at 20DAP and 27DAP, while hybrid 7 showed higher overall likeness rating at 27DAP and 34DAP. This observation suggested that maturity and hybrid played a major role in the overall likeness of roasted fresh yellow maize hybrid with husk. Hybrids 1, 2 and 7 were found to be acceptable for roasted fresh yellow maize hybrid with husk.

Pearson correlation results between Physical characteristics and Sensory properties:

Table 7 showed the Pearson correlation coefficient between the physical characteristics and sensory properties of roasted fresh yellow maize hybrids. There was negative correlation between the physical characteristics and the sensory properties except colour that showed positive correlation. There was no significant ($P \leq 0.05$) correlation ($P \leq 0.05$) between the physical characteristics, colour and appearance. This result suggested that physical characteristics did not affect the sensory ratings of colour and appearance but affected the ratings of aroma, chewiness, taste and overall overall likeness. Kernel TD showed highly significant ($P \leq 0.001$) and positive correlation with aroma (r= -0.56), chewiness (r = -0.675), taste (r= -0.691) and overall likeness(r =-0.628). Kernel size index (KSI) which is an index of length, breadth and depth showed highly significant ($P<0.001$) and negative correlation with aroma (r= -0.496), chewiness (r= -0.678), taste (r=-0.715) and overall likeness(r= -0.644).The highest negative correlation between KSI and taste suggested that as the length, breadth and depth increase the taste of the roasted fresh maize hybrids decreases. Breadth was the key kernel dimension that mostly affected the sensory ratings of chewiness, taste and hence overall likeness of roasted fresh cobs of yellow maize hybrids. Hardness test also showed highly significant ($P \leq 0.001$) but negative correlation with aroma(r= -0.520), chewiness (r= -0.692), taste(r= -0.736) and overall likeness (r= -0.645).This observation suggested that as hardness increases the sensory ratings of aroma, chewiness, taste and overall likeness decrease.

IV. Conclusion:

The kernel size index (KSI) and Kernel hardness increased as the maize matured for maturity for fresh yellow maize hybrid. The endosperm texture and composition contributed more significantly to kernel hardness and density differences in maize kernels. Kernel growth in maize occurs along the length and breadth axes of the kernels, but not much in depth as inferred from the steady increase in these dimensions with maturity. The best harvesting time (maturity stage) to roast fresh yellow maize hybrid was found to be 20DAP and roasted maize without husk was more acceptable than roasted maize with husk. The key sensory properties that affected by the physical characteristics were aroma, chewiness and taste. These three identified sensory properties played key role on overall likeness of roasted fresh yellow maize hybrids.

Table 1: Mean squares from the analysis of variance for the physical characteristics of fresh yellow maize hybrid evaluated at two locations and two years

		kernel wt	Kernel vol	kernel TD	bulk density	porosity	length	breadth	depth	shape	KSI	hardness test
	DF	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
Location	1	5212*	2.09*	0.000	0.004**	29.5	7.68***	2.28**	0.291	0.002	23.2***	5.33
Hybrid	7	3851***	1.17**	0.011***	0.002**	38.7	1.35***	1.09**	0.684**	0.007***	3.48*	6.06***
Maturity	2	42792***	12.6***	0.029***	0.019***	32.3	16.2***	9.23***	1.27**	0.012***	57.9***	128***
Location * hybrid	7	531	0.157	0.002	0.003***	42.2	0.100	0.484	0.246	0.002	0.779	2.35
Location * maturity	2	9377***	2.27**	0.010**	0.007***	31.0	0.548	2.46***	0.189	0.003	5.34*	11.8***
hybrid *maturity	14	2218*	1.47***	0.007***	0.002**	24.6	0.143	0.252	0.322	0.001	1.07	1.66
Location * hybrid *maturity	14	517	0.266	0.001	0.003***	23.3	0.234	0.334	0.2111	0.001	1.13	1.16
Error		912	0.355	0.002	0.001	12.0	0.320	0.307	0.223	0.001	1.28	1.44

*** * *, * *, * - Significant at P<=0.001, P<=0.01 and P<=0.05, respectively**
ns -Not significant P>0.05, MS =Mean Square, DF = Degree of Freedom
Kernel TD =kernel true density
KSI = kernel size index
Kernel wt = Kernel weight
Kernel vol = Kernel Volume

Table 2a: Descriptive statistics of physical characteristics of unprocessed fresh yellow maize hybrid at different harvest maturity stages across two locations and two years

Maturity		kernel wt g	kernel vol ml	kernel TD g/ml	bulk density g/ml	porosity	length mm	breadth mm	depth mm	shape	KSI	hardness test kg/f
20DAP	**Mean**	278c	6.40c	1.09c	0.540b	50.5a	9.21c	8.25c	4.35b	0.750a	21.8	5.28c
	Min	240	5.33	1.03	0.510	46.5	8.63	7.76	4.11	0.710	4.01	240
	Max	309	7.47	1.22	0.560	57.7	9.64	8.76	4.58	0.780	6.38	309
	LSD(0.05)	25.0	0.529	0.040	0.027	3.16	0.415	0.438	0.362	0.028	0.930	0.970
	SE	2.93	0.074	0.008	0.002	0.431	0.045	0.038	0.022	0.003	0.076	0.098
	CV (%)	1.05	1.15	0.707	0.373	0.852	0.490	0.459	0.515	0.397	0.349	1.85
27DAP	**Mean**	325b	7.26b	1.12b	0.580a	48.5b	9.77b	8.76b	4.75a	0.760a	23.3	6.95b
	Min	294	6.40	1.05	0.530	45.6	9.10	8.40	4.18	0.710	5.83	294
	Max	356	8.00	1.16	0.630	52.0	10.4	9.28	5.19	0.810	8.44	356
	LSD(0.05)	25.0	0.529	0.040	0.027	3.16	0.415	0.438	0.362	0.028	0.930	0.970
	SE	2.80	0.060	0.005	0.004	0.315	0.048	0.044	0.044	0.004	0.087	0.120
	CV (%)	0.862	0.829	0.412	0.690	0.648	0.487	0.506	0.937	0.486	0.372	1.73
34DAP	**Mean**	350a	7.62a	1.15a	0.580a	49.5ab	10.6a	9.32a	4.55ab	0.720b	24.5	9.26a
	Min	305	6.72	1.11	0.560	45.4	10.1	8.75	4.05	0.680	8.13	305
	Max	401	8.46	1.21	0.60	51.4	11.2	9.85	5.41	0.780	11.3	401
	LSD(0.05)	25.0	0.529	0.040	0.027	3.16	0.415	0.438	0.362	0.028	0.930	0.970
	SE	3.99	0.083	0.004	0.002	0.242	0.046	0.053	0.052	0.004	0.093	0.113
	CV (%)	1.14	1.09	0.362	0.339	0.489	0.430	0.572	1.14	0.508	0.380	1.22

Values with similar letters in column do not differ significantly ($p < 0.05$).
Kernel TD =kernel true density
KSI= kernel size index

Table 2b: Means table of the physical characteristics of unprocessed fresh yellow maize hybrid at different harvest maturity stages at two locations

hybrid	maturity	kernel wt	kernel vol	kernel TD	bulk density	porosity	length	breadth	depth	shape	KSI	hardness test
1	20DAP	276±15.8	6.35±0.700	1.09±0.066	0.561±0.030	48.6±4.91	9.56±0.334	8.57±0.595	4.17±0.425	0.730±0.425	22.3±0.967	6.38±0.922
2	20DAP	309±0.000	7.47±0.000	1.04±0.000	0.555±0.001	46.5±0.143	9.64±0.872	8.11±1.27	4.11±0.479	0.709±0.479	21.9±2.53	4.43±2.00
3	20DAP	287±26.2	6.51±0.564	1.10±0.030	0.535±0.027	51.5±2.39	9.11±0.573	8.25±0.783	4.45±0.167	0.763±0.167	21.8±1.00	5.83±2.31
4	20DAP	263±22.6	6.27±0.231	1.05±0.051	0.531±0.057	49.2±6.86	8.87±0.570	8.22±0.534	4.54±0.095	0.781±0.095	21.6±1.12	5.12±1.01
5	20DAP	286±0.000	6.73±0.000	1.06±0.000	0.536±0.002	49.6±0.178	9.15±0.530	8.08±0.203	4.25±0.362	0.743±0.362	21.5±0.915	5.17±0.918
6	20DAP	305±54.0	6.26±0.924	1.22±0.096	0.510±0.056	57.7±8.02	9.57±0.457	8.76±0.584	4.58±0.333	0.759±0.333	22.9±0.947	5.47±1.34
7	20DAP	261±34.7	6.30±0.467	1.03±0.056	0.525±0.012	48.7±3.93	9.14±0.891	8.24±0.246	4.23±0.070	0.766±0.070	21.6±0.921	5.87±1.91
8	27DAP	240±0.000	5.33±0.000	1.13±0.000	0.535±0.001	52.7±0.122	8.63±1.06	7.76±1.30	4.44±0.601	0.772±0.601	20.8±2.92	4.01±1.06
1	27DAP	300±31.6	7.10±0.333	1.05±0.060	0.561±0.006	46.7±2.67	9.92±0.212	8.40±0.315	4.18±0.120	0.710±0.120	22.5±0.161	7.91±0.754
2	27DAP	325±0.000	7.23±0.000	1.13±0.000	0.595±0.088	47.2±7.84	10.4±0.458	9.01±0.674	5.12±1.17	0.746±1.17	24.5±2.15	7.48±1.51
3	27DAP	311±25.4	7.15±0.346	1.09±0.062	0.575±0.056	46.9±7.74	9.10±0.423	8.50±0.099	5.19±0.611	0.810±0.611	22.8±0.852	6.78±1.23
4	27DAP	333±16.6	7.43±0.308	1.12±0.010	0.553±0.036	50.5±3.34	9.66±0.181	9.28±0.336	4.62±0.146	0.772±0.146	23.6±0.398	8.44±1.97
5	27DAP	294±0.000	6.40±0.000	1.15±0.000	0.626±0.064	45.6±5.59	9.67±0.347	8.48±0.126	4.42±0.153	0.738±0.153	22.6±0.449	5.99±0.695
6	27DAP	356±12.7	7.73±0.271	1.15±0.008	0.605±0.057	47.4±4.77	9.83±0.650	8.93±1.161	4.76±0.159	0.759±0.159	23.5±1.59	7.10±1.93
7	27DAP	328±45.3	7.05±0.712	1.16±0.042	0.558±0.012	51.9±2.25	10.0±0.536	9.11±0.614	4.63±0.328	0.750±0.328	23.7±1.12	5.83±0.591
8	27DAP	351±0.000	8.00±0.000	1.10±0.000	0.528±0.066	51.9±6.03	9.55±0.498	8.40±0.704	5.05±0.480	0.773±0.480	23.0±1.26	6.06±0.105
1	34DAP	354±21.4	8.02±0.599	1.11±0.018	0.603±0.031	45.4±3.56	11.2±0.651	9.51±0.337	4.05±0.162	0.677±0.162	24.7±0.509	11.3±1.32
2	34DAP	345±66.2	7.62±1.26	1.13±0.035	0.559±0.013	50.5±1.94	10.9±0.861	9.71±0.414	4.50±0.303	0.717±0.303	25.1±0.898	9.22±0.667
3	34DAP	309±59.3	6.72±1.45	1.16±0.054	0.562±0.039	51.4±3.52	10.1±1.11	8.92±0.353	4.34±0.225	0.727±0.225	23.4±1.19	8.81±0.673
4	34DAP	373±46.1	8.12±0.917	1.15±0.049	0.579±0.035	49.6±1.33	10.3±0.509	9.53±0.322	5.41±1.33	0.777±1.33	25.3±0.832	9.29±1.47
5	34DAP	305±66.7	6.72±1.14	1.13±0.052	0.589±0.021	48.1±0.542	10.5±0.498	8.75±0.939	4.34±0.052	0.701±0.052	23.6±1.19	8.98±1.05
6	34DAP	401±13.3	8.46±0.166	1.19±0.036	0.589±0.020	50.4±1.03	10.9±0.756	9.85±0.301	4.45±0.109	0.720±0.109	25.2±0.845	9.22±1.17
7	34DAP	350±29.1	7.23±0.514	1.21±0.024	0.593±0.020	51.0±0.900	10.8±0.394	9.49±0.512	4.41±0.059	0.711±0.059	24.7±0.877	9.16±0.659
8	34DAP	367±9.08	8.10±0.038	1.13±0.023	0.569±0.032	49.9±1.82	10.3±0.364	8.82±0.404	4.87±0.234	0.740±0.234	24.0±0.557	8.13±1.88

[a] Parameter mean value± SD

Table 3a: Descriptive statistics of sensory properties of roasted yellow maize hybrid without husk at different harvest maturity stages across tow locations and two years

MATURITY		colour	aroma	chewiness	taste	appearance	overall likeness
20DAP	**Mean**	6.17a	6.04a	6.13a	6.39a	6.46a	6.52a
	Min	5.45	5.75	5.55	5.85	6.15	6.30
	Max	6.45	6.50	6.55	6.90	6.75	6.80
	LSD(0.05)	0.318	0.290	0.401	0.369	0.275	0.794
	SE	0.040	0.029	0.041	0.043	0.030	0.021
	CV (%)	0.641	0.482	0.664	0.668	0.470	0.320
27DAP	**Mean**	6.40a	6.09a	5.13b	5.84b	6.35a	6.13a
	Min	5.85	5.70	4.65	5.20	5.90	5.65
	Max	6.70	6.85	5.90	6.70	6.75	6.85
	LSD(0.05)	0.318	0.290	0.401	0.369	0.275	0.794
	SE	0.039	0.046	0.060	0.056	0.030	0.046
	CV (%)	0.613	0.752	1.17	0.964	0.473	0.748
34DAP	**Mean**	6.12a	5.51b	4.29c	5.28c	6.03b	6.14a
	Min	5.50	5.15	3.65	4.15	5.85	5.50
	Max	6.40	5.75	4.85	5.80	6.50	8.40
	LSD(0.05)	0.318	0.290	0.401	0.369	0.275	0.794
	SE	0.036	0.028	0.044	0.068	0.028	0.116
	CV (%)	0.590	0.509	1.03	1.29	0.467	1.88

Values with similar letters in column do not differ significantly ($p < 0.05$).

Table 3b: Means table of the sensory properties of roasted yellow maize hybrid without husk at different harvest maturity stages across tow locations and two years

hybrid	maturity	colour	aroma	chewiness	taste	appearance	overall likeness
1	20DAP	6.45±1.85	6.15±1.63	6.25±1.25	6.55±2.04	6.60±1.27	6.70±1.49
2	20DAP	5.45±1.50	5.90±1.55	6.40±1.35	6.40±1.70	6.15±1.39	6.45±1.43
3	20DAP	6.10±1.97	6.10±1.48	5.95±1.50	6.50±1.64	6.70±1.53	6.60±1.47
4	20DAP	6.30±1.78	5.75±1.77	5.55±1.79	5.85±2.18	6.20±1.64	6.30±1.56
5	20DAP	6.40±1.70	6.10±1.77	6.05±1.57	6.30±1.95	6.50±1.73	6.40±1.31
6	20DAP	6.25±1.62	6.50±1.15	6.55±1.19	6.90±1.45	6.60±1.39	6.80±1.28
7	20DAP	6.10±1.83	5.85±2.01	6.35±1.57	6.65±1.87	6.20±1.70	6.45±1.88
8	20DAP	6.30±1.30	5.95±1.32	5.90±1.68	6.00±1.69	6.75±0.910	6.45±1.19
1	27DAP	6.70±1.22	5.70±0.865	4.80±1.88	5.80±1.70	6.25±1.41	6.00±1.62
2	27DAP	6.15±1.69	6.10±1.21	5.70±1.42	6.25±1.55	5.90±0.718	6.15±1.35
3	27DAP	6.70±0.923	5.95±1.19	4.65±1.98	5.65±1.81	6.75±0.967	6.30±1.22
4	27DAP	6.35±1.42	6.15±1.09	5.40±2.21	5.75±1.52	6.25±1.12	6.15±1.57
5	27DAP	6.60±1.19	5.80±1.20	4.90±1.65	5.60±1.57	6.45±1.10	5.75±1.33
6	27DAP	6.65±0.988	6.30±1.22	5.05±2.33	5.80±1.94	6.40±1.10	6.15±1.50
7	27DAP	6.20±1.28	6.85±1.31	5.90±1.21	6.70±1.08	6.45±0.945	6.85±0.99
8	27DAP	5.85±1.63	5.85±0.988	4.65±2.43	5.20±2.17	6.35±1.46	5.65±2.06
1	34DAP	6.25±1.41	5.35±0.988	3.65±2.16	4.15±2.11	5.95±1.50	8.40±16.21
2	34DAP	5.50±1.64	5.60±1.31	4.35±1.98	5.80±1.47	5.85±0.875	6.00±1.21
3	34DAP	6.40±0.883	5.25±1.48	4.00±2.15	5.75±1.16	5.90±0.912	5.80±1.15
4	34DAP	6.20±1.32	5.65±1.27	4.40±1.90	5.40±1.35	5.95±1.10	5.85±1.46
5	34DAP	6.05±1.64	5.15±1.53	4.25±2.22	4.90±1.92	5.90±1.62	5.50±1.47
6	34DAP	5.95±1.50	5.60±1.57	4.85±1.53	5.15±1.95	5.95±1.15	5.80±1.32
7	34DAP	6.30±1.13	5.70±0.865	4.50±2.01	5.55±1.28	6.25±1.41	6.60±1.30
8	34DAP	6.30±1.38	5.75±1.52	4.30±1.98	5.55±1.73	6.50±1.10	5.80±1.85

[a] Parameter mean value± SD

Table 4: Mean squares from the analyses of variance for the sensory properties of yellow maize hybrid evaluated at two locations

Sensory properties	DF	colour MS	aroma MS	chewiness MS	taste MS	appearance MS	overall likeness MS
Location	1	1.58	27.1***	15.8*	28.3***	19.2***	51.8***
Hybrid	7	38.5***	9.36***	26.4***	31.2***	5.63***	15.3**
Maturity	2	0.630	79.9***	443***	348***	26.6***	134***
Method	1	53.7***	76.8***	261***	38.2***	56.7***	24.4*
Location x hybrid	7	2.65	2.49	5.06	7.31**	0.390	6.44
Location x maturity	2	9.63**	16.5***	1.95	11.2*	26.2***	8.36
Location x method	1	27.3***	15.1**	5.00	16.3*	17.3***	9.13
Hybrid x maturity	14	4.87***	2.57	2.64	4.89*	2.98*	4.04
Hybrid x method	7	1.61	2.93	1.44	2.08	1.23	0.790
Location x hybrid x method x maturity	39	2.21	1.81	3.53	2.67	1.96	4.31
Error		1.81	1.82	2.77	2.76	1.49	4.80

***, **, *** - Significant at P<=0.05, P<=0.01 and P<=0.001 respectively**
ns -Not significant P>0.05

Table 5a: Descriptive statistics of sensory properties of roasted yellow maize hybrid with husk at different harvest maturity stages across tow locations and two years

MATURITY		colour	aroma	chewiness	taste	appearance	overall likeness
20DAP	**Mean**	6.21a	6.21a	5.87a	6.31a	6.51a	6.44a
	Min	5.15	5.50	5.00	5.55	5.95	5.90
	Max	6.85	6.60	6.70	7.00	7.00	6.80
	LSD(0.05)	0.314	0.323	0.384	0.379	0.278	0.347
	SE	0.081	0.043	0.060	0.052	0.047	0.034
	CV (%)	1.30	0.690	1.03	0.816	0.721	0.531
27DAP	**Mean**	6.11a	5.54b	4.76b	5.39b	6.21b	5.61b
	Min	5.25	4.95	3.95	4.35	6.00	4.85
	Max	6.60	6.50	6.60	6.95	6.60	6.70
	LSD(0.05)	0.314	0.323	0.384	0.379	0.278	0.347
	SE	0.062	0.058	0.103	0.093	0.026	0.068
	CV (%)	1.01	1.05	2.17	1.72	0.412	1.22
34DAP	**Mean**	5.89a	5.21c	3.89c	4.74c	5.82c	5.24c
	Min	4.95	4.90	3.35	4.10	5.55	4.75
	Max	6.25	5.60	4.30	5.55	6.05	5.60
	LSD(0.05)	0.314	0.323	0.384	0.379	0.278	0.347
	SE	0.055	0.026	0.042	0.051	0.022	0.035
	CV (%)	0.934	0.503	1.07	1.08	0.372	0.673

Values with similar letters in column do not differ significantly (p < 0.05).

Table 5b: Means table of the sensory properties of roasted yellow maize hybrid with husk at different harvest maturity stages across tow locations and two years

hybrid	maturity	colour	aroma	chewiness	taste	appearance	overall likeness
1	20DAP	6.70±1.49	6.60±1.19	5.95±1.36	6.55±1.36	7.00±0.918	6.80±1.24
2	20DAP	5.15±1.57	6.30±1.42	6.70±0.923	7.00±0.918	6.20±1.47	6.60±1.47
3	20DAP	6.85±1.14	6.55±1.10	6.05±1.00	6.20±1.28	6.80±1.11	6.60±0.94
4	20DAP	6.40±1.31	6.10±1.25	5.85±1.39	6.15±1.39	6.70±1.13	6.30±1.13
5	20DAP	6.70±1.03	6.20±1.06	5.95±1.64	6.20±1.40	6.80±1.32	6.55±1.28
6	20DAP	6.65±1.04	6.35±1.09	5.00±1.45	6.40±0.940	6.45±0.887	6.45±1.00
7	20DAP	5.55±1.73	6.10±1.02	5.95±1.61	6.45±1.47	6.15±1.50	6.30±1.34
8	20DAP	5.70±1.13	5.50±1.43	5.50±1.32	5.55±1.70	5.95±1.28	5.90±1.33
1	27DAP	6.60±1.27	5.75±1.07	4.95±1.85	5.75±1.71	6.20±1.47	5.85±1.46
2	27DAP	5.25±1.77	6.50±1.40	6.60±1.39	6.95±1.05	6.35±1.23	6.70±1.13
3	27DAP	6.60±1.39	5.70±1.30	4.10±1.94	5.20±2.04	6.60±1.31	5.55±1.67
4	27DAP	6.40±1.79	5.30±1.87	3.95±1.99	4.35±2.37	6.00±1.69	4.85±2.30
5	27DAP	5.85±1.57	4.95±1.88	4.45±1.99	5.10±2.02	6.00±1.52	5.15±2.06
6	27DAP	5.60±1.88	5.20±1.82	4.90±2.20	5.20±2.07	6.05±1.39	5.40±1.93
7	27DAP	6.20±1.54	5.55±1.64	4.40±1.88	5.40±2.09	6.30±0.923	5.65±1.98
8	27DAP	6.35±1.31	5.40±1.79	4.70±1.95	5.20±2.12	6.20±1.54	5.70±2.27
1	34DAP	6.25±1.80	4.90±1.83	3.50±1.99	4.70±2.00	5.90±1.52	5.05±1.82
2	34DAP	4.95±1.64	5.60±1.57	4.25±1.97	5.55±1.47	5.60±1.39	5.60±1.19
3	34DAP	6.00±1.21	5.30±1.56	3.80±2.07	4.55±1.96	5.90±1.12	5.10±1.41
4	34DAP	5.70±1.45	5.10±0.968	3.35±1.73	4.10±1.71	5.55±1.28	4.75±1.65
5	34DAP	5.70±1.45	5.30±1.13	3.95±1.73	4.70±1.56	5.95±1.32	5.50±1.40
6	34DAP	6.15±1.14	5.25±1.94	3.95±1.67	4.60±1.70	5.85±1.14	5.15±1.84
7	34DAP	6.20±1.32	5.15±1.50	4.30±2.08	4.95±1.70	6.05±1.23	5.45±1.76
8	34DAP	6.20±1.47	5.05±1.96	4.05±2.09	4.80±2.21	5.75±1.29	5.35±1.66

[a] Parameter mean value± SD

Table 6: Pearson correlation coefficients between physical characteristics and sensory properties of boiled fresh yellow maize hybrids

	Colour	Aroma	Cheweness	Taste	Appearance	Overall Likeness
KernelTD	0.303	-0.567***	-0.675***	-0.691***	-0.138	-0.628***
Bulk density	0.355	-0.532***	-0.601***	-0.673***	-0.035	-0.557***
Length	0.134	-0.439**	-0.597***	-0.662***	-0.222	-0.594***
Breadth	0.255	-0.515**	-0.705***	-0.732	-0.153	-0.654***
Depth	0.258	-0.484**	-0.671***	-0.629***	-0.098	-0.592***
KSI	0.206	-0.496**	-0.678***	-0.715***	-0.186	-0.644***
Hardness test	0.252	-0.520**	-0.692***	-0.736***	-0.176	-0.643***

***, * *, * - Significant at P<=0.001, P<=0.01 and P<=0.05, respectively**

ns -not significant P>0.05,

Kernel TD =kernel true density

KSI = kernel size index

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