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Combined Effects of Packaging Film and Temperatures on the Nutritional Composition of Stored Fresh Maize (*Zea mays*) on the Cob

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Abstract This study investigated the effects of passive modified atmosphere packaging (PMAP), storage temperature (5 and 10°C) and duration of 8 days on the sugar, proximate and mineral compositions of fresh maize (*Zea mays*) on the cob. Freshly harvested maize (control) was analysed immediately after harvesting while the remaining maize were grouped into unpackaged undehusked, unpackaged dehusked and PMAP samples where the maize was placed singly in low density polyethylene (LDPE) film of 25 µm and 30 µm gauge, sealed and stored appropriately for 8 days. The results of proximate composition of fresh maize showed 61.82 mg/g total sugar, 61.13% moisture content, 3.93% ash, 13.12% crude protein, 4.78% crude fat, 5.43% crude fibre and 72.74% carbohydrate. K, P, Na and Mg were the minerals abundantly found in fresh maize and K had the highest content (801.98 mg/100g). The results of stored samples showed that as storage days progressed the nutrients decreased gradually. Nevertheless, the nutritional quality of fresh maize was still maintained at these low temperatures. It is therefore be concluded that the most suitable packaging gauge and storage conditions to preserve the nutritional compositions and extend the shelf life of fresh maize up to 8 days were found to be dehusked maize packaged with 25 µm LDPE at 5°C.

Keywords: *fresh maize, low temperature, moisture content, packaging film, Sugar*

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1. Introduction

Most studies on post-harvest technology in Africa, especially Nigeria, have so far concentrated on grains and other durable products which are stored dry and a substantial technology has been developed to deal with these problems. Less work has been undertaken on the perishable food crops, yet they are of great importance in many parts of the humid and sub-humid tropics. They contribute the staple carbohydrate portion of the diets of some 500 to 700 million people in the developing countries [1]. Maize or corn (*Zea mays*) is one of the most widely cultivated cereal crops in the world. It is an important cereal crop, serving as staple food to large population of Africa, Asia, and North and South America. Fresh maize is highly perishable with a short postharvest life which depends on harvest maturity and storage conditions. Their high perishability leads to high postharvest losses and reduces realization of the commercial potential of fresh maize in Nigeria. Loss of sweetness is the main quality degradation during storage. The rapid moisture loss and conversion of endosperm sugars to starch shortly after harvesting especially at room temperature has long been a major postharvest problem in maintaining the quality of fresh maize. Deterioration of freshly harvested maize is attributable to various biological factors (internal) such as respiration, compositional changes (associated with colour, texture, flavour and nutritive value), physiological disorder and pathological breakdown. The environmental factors (external) include temperature, relative humidity, atmospheric compositions (oxygen (O_2) and carbon dioxide (CO_2)), and air velocity [2].

To extend the shelf life of fresh-cut produce without compromising nutritional quality, many methods have been proposed including low temperature storage, low-pressure storage, controlled atmosphere storage, modified atmosphere storage, irradiation, hot water dip, antibrowning dip and edible coatings [3,4,5,6,7]. The selection and application of either of these strategies depends on the efficacy, versatility and relative value of the agricultural commodities [8]. Modified atmosphere packaging (MAP) is a simple postharvest technology. It involves packaging actively respiring produce in polymeric film to modify the O_2 and CO_2 levels within the package atmosphere [9]. Modified atmosphere have positive effect on the physicochemical and physiological processes of fresh produce and some of these beneficial effects include, reduced transpiration water loss, delayed ripening by inhibiting the production of ethylene, delayed biochemical activities and increased resistance to the attack of postharvest pathogens [3,9,10,11]. Polymeric films used in MAP reduce postharvest losses and wastes [12] by hindering water vapour diffusion and as a result, the internal atmosphere package becomes saturated with water vapour pressure thereby reducing transpiration of the tissues and the resultant weight loss. Use of MAP in extending the shelf life of sweetcorn had been thoroughly carried out by many researchers [13,14,15,16,17] but till date no work has addressed the storage of normal (field) maize. In view of this, the study investigated the changes in nutritional values of fresh yellow maize on the cob during storage under passive MAP at 5 and 10°C.

2. Materials and Methods

2.1. Sample Collection and Preparation

Fresh yellow maize on the cob (SUWAN 1-SR) was obtained from the Federal University of Technology Akure (FUTA) Research farm. The two different gauges of packaging material used were 25 and 30 µm Low Density Polyethylene (LDPE) with 34 cm × 14.5 cm in area (TUBI Investment Ltd, Akure, Nigeria). Freshly harvested maize (FHM) were dehusked and randomly selected for immediate analysis (control) while the remaining fresh maize were grouped into six lots: unpackaged undehusked maize (T_1), unpackaged dehusked maize (T_2) and passive modified atmosphere packaging (PMAP) samples which include undehusked maize packaged with 25 µm low LDPE (T_3), dehusked maize packaged with 25 µm LDPE (T_4), undehusked maize packaged with 30 µm LDPE (T_5) and dehusked maize packaged with 30 µm LDPE (T_6). All the PMAP samples were heat sealed using an impulse sealer (MEC, China). Samples were then stored at 5 and 10°C with 80% RH for 8 days.

2.2. Total Sugar Analysis of Packaged and Unpackaged Fresh Maize Samples

Phenol-sulphuric acid method as described by [18] was adopted. A 50 mg of grounded maize sample was mixed with 1 ml of 5% aqueous solution of phenol in a test tube. Subsequently, 5 ml of concentrated H_2SO_4 is added rapidly to the mixture. After allowing the test tubes to stand for 10 min, they are vortexed for 30 s and placed for 20 min in a water bath at room temperature for colour development. The blank solution also followed the same procedure except that distilled water was used instead of sample. Standard curve was also prepared using stock solution of glucose. After colour development, absorbance was measured at wavelengths 490 nm on a spectrophotometer.

2.3. Proximate Analyses of Packaged and Unpackaged Fresh Maize Samples

Maize samples were analysed chemically according to the Official Methods of Analysis described by the Association of Official Analytical Chemists [19].

2.3.1. Moisture Content Determination

Sample (2 g) was weighed into previously weighed Petri dish. The Petri dish and sample taken was then transferred into the oven and set at 105°C to dry to a constant weight for 3 hr. At the end, the Petri dish and sample was removed from the oven and transfer to desiccator, cooled for ten minutes and weighed.
Calculation:

$$\%\ Moisture\ content = \frac{W_1 - W_3}{W_1 - W_o} \times 100 \qquad (1)$$

where weight of the empty Petri dish is Wo, Weight of Petri dish and sample is W_1 and Weight of Petri dish and oven dried sample is W_3.

2.3.2. Determination of Ash Content

Two (2) gram of sample was weighed into a porcelain crucible. This was transferred into the muffle furnace (Buck Scientific 2000A UK) set at 550°C and left for about 4 h. About this time it had turned to white ash. The crucible and its contents were cooled to about 100°C in air oven, then room temperature in a desiccator and weighed. This was done in triplicate. The percentage ash was calculated from the formula:

$$\%\ Ash\ content = \frac{Weight\ of\ ash}{Original\ weight\ of\ sample}. \qquad (2)$$

2.3.3. Determination of Crude Protein Content

The total crude protein content in maize was determined using the micro Kjeldahl technique of analysis (Digestion, Distillation and Titration). One (1) g of each grounded maize sample was weighed carefully into the Kjeldahl digestion tubes. One Kjeldahl catalyst tablet (selenium) and 10 ml of conc. H_2SO_4 were added. These were set in appropriate hole of the digestion block heaters in a fume cupboard. The digestion was left on for 4 h, after which a clear solution was left in the tube. The digest was cooled and carefully transferred into 100 ml volumetric flask, thoroughly rinsing the digestion tube with distilled water and the flask was made up to mark with distilled water. The distillation was done with Markham Distillation Apparatus which allows volatile substance (ammonia) to be steam distilled with complete collection of the distillate. Five (5) ml portion of the digest was pipetted into the body of the apparatus via the small funnel aperture and 5 ml of 40% (w/v) NaOH was added through the same opening. The mixture was steam distilled for 2 min into a 50 ml conical flask containing 10 ml of 2% boric acid mixed indicator solution placed at the receiving tip of the condenser. The boric acid and indicator solution changes colour from red to green showing that all the ammonium liberated have been trapped. The green colour solution obtained was then titrated against 0.01N HCl contained in a 50 ml burette. At the end point, the green colour turns to wine colour which indicates that all the nitrogen trapped as ammonium borate $(NH_4)_2BO_3$ have been removed.

The percentage nitrogen in this analysis was calculated using the formula:

$$\%\ N = \frac{\begin{pmatrix} Titre\ value \times Normality\ of\ acid\ used \times \\ Atomic\ mass\ of\ N \\ \times Vol.of\ flask\ containing\ the\ digest \end{pmatrix}}{\begin{pmatrix} Weight\ of\ sample\ digested\ in\ mg \times \\ Vol.of\ digest\ for\ steam\ distillation \end{pmatrix}}. \qquad (3)$$

The crude protein content is determined by multiplying percentage Nitrogen by a constant factor of 6.25 i.e. % Crude Protein = % N x 6.25.

2.3.4. Determination of Crude Fat Content

Crude fat was determined by using Soxhlet apparatus. One (1) g of grounded maize sample was weighed into fat free extraction thimble and plug tightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 ml Soxhlet flask which was been previously dried in the oven, cooled and weighed. The Soxhlet flask is then filled to three-quarter of its volume with petroleum ether (40^{o}-60°C b.pt) and the Soxhlet flask, extractor and condenser set was placed on the heater. The heater was put on for 6 h with constant running water from the tap for condensation of ether vapour. The set was constantly watched for ether leaks and the heat source was adjusted appropriately for the ether to boil gently. The ether was left to siphon over several hours times at least 10-12 times until it was short of siphoning. The thimble containing sample was then removed and dry on a clock glass on the bench top. The extractor, flask and condenser were replaced and the distillation continued until the flask was practically dried. The flask which now contains the oil was detached, its exterior cleaned and dried to a constant weight in the oven. % crude fat is obtained by the formula:

$$\%\ Crude\ Fat = \frac{W_1 - W_o}{Weight\ of\ sample} \times 100 \qquad (4)$$

where the initial weight of dry Soxhlet flask is W_o and the final weight of oven dried flask and fat is W_1.

2.3.5. Determination of Crude Fibre Content

Sample (2 g) was accurately measured into the fibre flask and 100 ml of 0.255 N H_2SO_4 was added. The mixture was heated under reflux for 1 h with the heating mantle. The hot mixture was filtered through a fibre sieve cloth. The filtrate obtained was thrown off and residue was returned to the fibre flask to which 100 ml of 0.313 N NaOH was added and heated under reflux for another 1 h. The mixture was filtered through a fibre sieve cloth and 10 ml of acetone added to dissolve any organic constituent. The residue was washed with about 50 ml hot water twice on the sieve cloth before it was finally transferred into the crucible. The crucible and residue was oven dried at 105°C overnight to drive off moisture. The oven dried crucible containing the residue was cooled in a desiccator and later weighed to obtain the weight W_1. The crucible with weight W_1 was transferred into the muffle furnace at 550°C for 4 h. The crucible containing white or grey ash (free of carbonaceous material) was cooled in the desiccator and weighed to obtain W_2. i.e.

$$\%\ Crude\ Fibre = \frac{W_1 - W_2}{Weight\ of\ sample} \times 100. \qquad (5)$$

2.3.6. Determination of Total Carbohydrate Content

Carbohydrate content was determined by difference method. This was done by subtracting the total sum of the percentage moisture, crude fat, ash, crude fibre and crudeprotein content from one hundred (100).

2.4. Mineral Analysis of Packaged and Unpackaged Maize Samples

The maize samples were ashed at 550°C. The ash was boiled with 10 ml of 20% HCl in a beaker and then filtered into a 100 ml standard flask. This was made up to the mark with deionized water and the minerals were determined from the resulting solution using the method of [20]. Sodium (Na) and Potassium (K) were determined using the standard flame emission photometer. NaCl and KCl were used as the standards. Phosphorus was determined calorimetrically by vanado-molybdate method using the spectronic 20 (Gallenkamp, UK) with KH_2PO_4 as the standard. Calcium (Ca), Magnesium (Mg) and Iron (Fe) were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). All values were expressed in mg/100 g.

2.5. Statistical Analysis

All data were subjected to one way analysis of variance (ANOVA). The statistical significance ($p<0.05$) of the observed differences among the means of three determinations were separated with Duncan's New Multiple Range Test in SPSS (20) software.

3. Results and Discussion

3.1. Total Sugar Content of Packaged and Unpackaged Fresh Maize Samples

The result of total sugar content of packaged and unpackaged maize samples stored at 5 and 10°C from day 1 to 8 is presented in Table 1. The freshly harvested maize (control) sample had higher value (61.82 mg/g) than the stored samples at all the temperatures studied. The result is similar to the finding of [21], but lower than the result (8% equivalent to 80 mg/g) of [22] that studied sugar content of cv. 7210, this may be as a result of environmental factors or genetic variation. Total sugar decreased from 60.24-14.35 mg/g and 57.83-10.75 mg/g for 5 and 10°C, respectively. Dehusked maize packaged with 25 µm gauge (T_4) consistently had the highest value at both 5°C and 10°C throughout the storage days while unpackaged dehusked maize (T_2) had the lowest value at both low temperatures irrespective of the storage days. However, the value for the control was not significantly ($p>0.05$) different from that of T_4 at 5°C on day 1 of storage but different significantly ($p<0.05$) from remaining treatments (T_1, T_2, T_3, T_5 and T_6) throughout the storage duration at both temperatures.

A general decrease was observed in all the treatment samples irrespective of undehusked, dehusked, thickness of polyethylene bag and storage temperatures. This denotes that sugar content decreased as the storage duration progressed. This supports the finding of [23,24]. All PMAP treatments (T_3, T_4, T_5 and T_6) had significantly higher levels of sugar than the unpackaged samples (T_1 and T_2). Sugar (sweetness) is the main quality parameter for fresh maize [25].

It declines rapidly at room temperature and decreases less rapidly at low temperature storage [24]. This decrease is as a result of the reduction in metabolic rates at lower temperatures causing reduction in the respiration rate.

Moreover, the low metabolic rate reduces the sugars conversion into starch thus helping to retain high sugar content after harvesting and especially at storage. Also, low temperatures reduce water loss and subsequently reducing denting and husk drying of cobs. Besides, the low temperatures also prevent the proliferation of microorganisms and thereby prolong the shelf life of freshly harvested maize. The reduction rate in total sugar content was relatively slow in dehusked maize packaged with 25 µm gauge (T_4) at 5°C.

Table 1. Total sugar content (mg/g) of packaged and unpackaged maize samples stored at 5 and 10°C

SD	ST	Sample code					
(day)	(°C)	T_1	T_2	T_3	T_4	T_5	T_6
0		(61.82±0.56^{a})	(61.82±0.56^{a})	(61.82±0.56^{a})	(61.82±0.56^{a})	(61.82±0.56^{a})	(61.82±0.56^{a})
1	5	54.73±1.43^{b}	38.61±0.21^{b}	56.02±0.63^{b}	60.24±4.10^{a}	41.53±0.35^{b}	52.60±0.67^{b}
	10	51.81±1.37^{c}	35.57±0.43^{c}	52.43±0.55^{c}	57.83±0.56^{b}	37.22±0.55^{c}	45.75±1.36^{cd}
2	5	39.65±1.48^{d}	34.58±1.60^{c}	54.54±1.91^{c}	58.74±0.48^{b}	41.53±0.66^{b}	49.56±0.63^{c}
	10	34.22±0.93^{e}	31.70±0.91^{d}	51.69±1.00^{c}	55.23±2.23^{c}	36.74±0.62^{c}	48.50±0.87^{c}
3	5	32.53±0.53^{ef}	31.76±1.48^{d}	46.93±1.61^{d}	55.68±1.18^{c}	35.72±0.40^{c}	44.25±0.65^{cd}
	10	30.55±1.95^{f}	30.21±0.90^{d}	42.91±2.32^{e}	51.47±0.40^{c}	31.20±1.10^{d}	42.63±0.99^{d}
4	5	25.86±0.94^{g}	22.61±0.92^{e}	43.30±0.59^{e}	54.08±1.50^{c}	32.65±0.51^{d}	34.81±0.50^{e}
	10	22.74±0.35^{h}	20.87±1.34^{f}	41.28±1.33^{e}	46.86±1.62^{d}	31.92±1.25^{e}	32.63±1.35^{ef}
6	5	21.35±0.88^{h}	20.28±0.85^{f}	35.59±0.58^{f}	53.25±0.32^{c}	31.67±0.44^{e}	32.18±0.21^{ef}
	10	15.60±0.57^{i}	12.11±0.55^{g}	32.05±0.52^{fg}	44.72±1.28^{e}	28.50±0.59^{f}	31.12±0.64^{f}
8	5	19.54±0.20^{h}	14.35±0.28^{g}	28.63±0.58^{g}	51.23±0.63^{c}	25.44±0.52^{g}	26.40±0.64^{g}
	10	11.29±0.71^{j}	10.75±0.26^{h}	24.18±0.39^{h}	38.69±0.56^{f}	22.08±0.64^{gh}	25.53±0.52^{g}

Different letters denote significant difference (p<0.05) within each column. SD=Storage Duration, ST=Storage Temperature, T1= Undehusked maize, T2= Dehusked maize, T3= Undehusked maize packaged with 25 µm gauge LPDE, T4= Dehusked maize packaged with 25 µm gauge LDPE, T5= Undehusked maize packaged with 30 µm gauge LDPE, T6= Dehusked maize package with 30 µm gauge LDPE. Values in parenthesis are for day 0 (Freshly harvested maize) only. Values are means±standard deviation of three determinations.

Table 2a. Proximate composition of packaged and unpackaged fresh maize stored at 5°C

SD (day)	Sample code	Moisture content (%)*	Ash (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Carbohydrate(%)
0	FHYM	61.13±0.32^{j}	3.93±0.02^{a}	13.12±0.59^{a}	4.78±0.13^{a}	5.43±0.34^{a}	72.74±1.75^{g}
2	T_1	62.05±0.48^{h}	3.52±0.09^{c}	12.55±0.46^{c}	4.92±0.29^{a}	5.31±0.35^{a}	73.70±0.36^{e}
	T_2	63.12±0.21^{d}	3.45±0.47^{d}	12.32±0.56^{d}	4.94±0.17^{a}	5.27±0.39^{b}	74.02±0.71^{d}
	T_3	61.51±0.53^{i}	3.88±0.24^{b}	12.95±0.15^{b}	4.74±0.41^{b}	5.36±0.41^{a}	73.07±0.35^{f}
	T_4	61.19±0.48^{j}	3.91±0.25^{a}	13.05±0.66^{a}	4.83±0.15^{b}	5.38±0.34^{a}	72.83±0.63^{g}
	T_5	61.53±0.36^{i}	3.86±0.41^{b}	12.82±0.73^{b}	4.68±0.34^{c}	5.34±0.70^{a}	73.28±0.73^{f}
	T_6	61.48±0.32^{i}	3.87±0.28^{b}	12.70±0.21^{b}	4.61±0.34^{c}	5.37±0.55^{a}	73.45±1.44^{e}
4	T_1	62.24±0.51^{g}	3.47±0.35^{d}	12.47±0.41^{d}	4.71±0.84^{b}	5.29±0.29^{a}	74.06±0.59^{d}
	T_2	63.33±0.65^{c}	3.32±0.30^{e}	11.57±0.53^{e}	4.89±0.61^{b}	5.21±0.38^{b}	75.01±0.56^{d}
	T_3	61.62±0.47^{i}	3.83±0.29^{b}	12.64±0.71^{c}	4.72±0.47^{b}	5.32±0.30^{a}	73.49±0.75^{f}
	T_4	61.26±0.28^{j}	3.85±0.29^{b}	12.98±0.34^{b}	4.81±0.51^{b}	5.35±0.28^{a}	73.01±0.16^{g}
	T_5	61.98±0.41^{h}	3.85±0.20^{b}	12.66±0.74^{c}	4.42±0.31^{d}	5.32±0.40^{a}	73.75±0.38^{e}
	T_6	61.65±0.83^{i}	3.84±0.15^{b}	12.68±0.82^{c}	4.56±0.39^{d}	5.35±0.28^{a}	73.57±0.69^{e}
6	T_1	62.89±0.83^{e}	3.35±0.22^{e}	11.71±0.75^{d}	4.66±0.64^{c}	5.18±0.59^{b}	75.10±0.36^{cd}
	T_2	63.88±1.10^{b}	3.28±0.37^{f}	11.23±0.28^{f}	4.85±0.66^{b}	5.02±0.62^{c}	75.62±0.58^{c}
	T_3	62.14±0.50^{g}	3.79±0.29^{bc}	12.22±0.19^{d}	4.75±0.55^{b}	5.30±0.17^{a}	73.94±1.33^{e}
	T_4	61.31±0.06^{j}	3.84±0.06^{b}	12.95±0.70^{b}	4.78±0.46^{b}	5.33±0.52^{a}	73.12±0.24^{f}
	T_5	62.22±1.80^{g}	3.80±0.20^{b}	12.64±0.45^{c}	4.53±1.02^{d}	5.32±0.48^{a}	73.71±0.59^{e}
	T_6	62.16±0.58^{g}	3.82±0.26^{b}	12.60±0.60^{c}	4.41±0.70^{d}	5.31±0.29^{a}	73.86±0.75^{e}
8	T_1	63.17±0.44^{b}	3.32±0.20^{e}	11.27±0.67^{f}	4.54±0.57^{d}	5.04±0.49^{c}	75.83±0.67^{b}
	T_2	64.38±0.51^{a}	3.21±0.12^{f}	11.18±0.69^{g}	4.62±0.70^{c}	4.92±0.15^{c}	76.07±0.34^{a}
	T_3	62.06±0.85^{h}	3.75±0.27^{bc}	11.31±0.35^{f}	4.61±0.47^{c}	5.28±0.30^{b}	75.50±0.96^{c}
	T_4	61.35±0.26^{j}	3.78±0.30^{bc}	12.93±0.79^{b}	4.72±0.30^{b}	5.30±0.19^{a}	73.27±0.45^{f}
	T_5	62.41±0.34^{f}	3.62±0.19^{c}	12.57±0.93^{c}	4.40±0.47^{d}	5.26±0.19^{b}	74.15±0.58^{d}
	T_6	62.28±0.55^{g}	3.54±0.35^{c}	12.20±0.45^{d}	4.39±0.53^{d}	5.29±0.39^{a}	74.58±0.40^{d}

Different letters denote significant difference (p<0.05) within each column. % * = % wet basis, SD= Storage duration, FHYM = Freshly Harvested Yellow Maize, SD= Storage Duration, T1= Undehusked maize, T2= Dehusked maize, T3= Undehusked maize packaged with 25 µm gauge LPDE, T4= Dehusked maize packaged with 25 µm gauge LDPE, T5= Undehusked maize packaged with 30 µm gauge LDPE, T6=Dehusked maize packaged with 30 µm gauge LDPE. Values are means±standard deviation of three determinations.

Table 2b. Proximate composition of packaged and unpackaged fresh maize stored at 10°C

SD (day)	Sample code	Moisture content (%)*	Ash (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Carbohy drate (%)
0	FHYM	61.13±0.32^{g}	3.93±0.02^{a}	13.12±0.59^{a}	4.78±0.13^{a}	5.43±0.34^{a}	72.74±1.75^{f}
2	T1	63.25±0.42^{e}	3.70±0.09^{b}	12.21±0.46^{d}	4.61±0.29^{b}	5.28±0.35^{b}	74.20±0.36^{c}
	T2	63.82±0.76^{d}	3.65±0.47^{c}	12.13±0.56^{d}	4.56±0.17^{b}	5.23±0.39^{b}	74.43±0.71^{d}
	T3	62.46±0.52^{g}	3.82±0.24^{a}	12.75±0.15^{b}	4.72±0.41^{a}	5.32±0.41^{a}	73.39±0.35^{d}
	T4	62.30±0.82^{g}	3.86±0.25^{a}	12.84±0.66^{a}	4.81±0.15^{a}	5.35±0.34^{a}	73.14±0.63^{e}
	T5	62.38±0.59^{g}	3.82±0.41^{a}	12.31±0.73^{c}	4.73±0.34^{a}	5.30±0.70^{a}	73.84±0.73^{d}
	T6	62.79±0.60^{g}	3.84±0.28^{a}	12.33±0.21^{c}	4.74±0.34^{a}	5.31±0.55^{a}	73.78±1.44^{d}
4	T1	63.52±0.72^{d}	3.67±0.35^{c}	12.17±0.62^{c}	4.25±0.84^{d}	5.24±0.29^{b}	74.67±0.59^{b}
	T2	64.26±0.61^{c}	3.62±0.30^{c}	12.08±0.41^{c}	4.21±0.61^{d}	5.21±0.38^{ab}	74.88±0.56^{b}
	T3	63.24±0.61^{e}	3.78±0.29^{b}	12.65±0.53^{a}	4.64±0.47^{b}	5.28±0.30^{a}	73.65±0.75^{d}
	T4	63.12±0.59^{f}	3.84±0.29^{a}	12.72±0.71^{a}	4.68±0.51^{b}	5.32±0.28^{a}	73.44±0.16^{d}
	T5	63.41±0.59^{d}	3.82±0.20^{a}	12.22±0.34^{b}	4.62±0.31^{b}	5.28±0.40^{a}	74.06±0.38^{c}
	T6	63.30±0.48^{d}	3.80±0.15^{a}	12.30±0.74^{b}	4.64±0.39^{a}	5.30±0.28^{a}	73.96±0.69^{c}
6	T1	63.58±0.34^{d}	3.65±0.22^{c}	11.71±0.75^{d}	4.23±0.64^{d}	5.22±0.59^{b}	75.19±0.36^{a}
	T2	65.56±0.50^{b}	3.58±0.37^{cd}	11.56±0.28^{d}	4.19±0.66^{d}	5.15±0.62^{c}	75.52±0.58^{a}
	T3	63.40±0.30^{d}	3.76±0.29^{b}	12.51±0.19^{a}	4.62±0.55^{b}	5.19±0.17^{b}	73.91±1.33^{c}
	T4	63.30±0.33^{d}	3.79±0.06^{b}	12.66±0.70^{a}	4.65±0.46^{b}	5.28±0.52^{a}	73.62±0.24^{d}
	T5	63.50±0.14^{d}	3.75±0.20^{b}	12.19±0.45^{b}	4.59±1.02^{b}	5.20±0.48^{b}	74.27±0.59^{c}
	T6	63.35±0.82^{d}	3.72±0.26^{b}	12.18±0.60^{b}	4.61±0.70^{b}	5.27±0.29^{a}	74.22±0.75^{c}
8	T1	65.45±0.47^{b}	3.56±0.20^{cd}	11.60±0.67^{d}	4.18±0.47^{d}	5.15±0.49^{c}	75.55±0.67^{a}
	T2	66.42±0.34^{a}	3.52±0.12^{cd}	11.31±0.69^{d}	4.13±0.53^{d}	5.06±0.15^{d}	75.95±0.34^{a}
	T3	63.92±0.48^{d}	3.74±0.27^{b}	12.23±0.35^{b}	4.48±0.47^{a}	5.21±0.30^{b}	74.34±0.96^{b}
	T4	63.45±0.33^{d}	3.77±0.30^{b}	12.41±0.79^{a}	4.53±0.30^{b}	5.24±0.15^{b}	74.05±0.45^{c}
	T5	64.50±0.60^{c}	3.71±0.19^{b}	11.94±0.93^{cd}	4.35±0.57^{c}	5.17±0.22^{b}	74.83±0.58^{b}
	T6	64.10±0.42^{c}	3.69±0.35^{c}	11.81±0.45^{d}	4.40±0.70^{c}	5.23±0.36^{b}	74.87±0.40^{b}

Different letters denote significant difference ($p<0.05$) within each column. % * = % wet basis, FHYM = Freshly Harvested Yellow Maize, SD=Storage Duration, T1= Undehusked maize, T2= Dehusked maize, T3=Undehusked maize packaged with 25 µm gauge LPDE, T4= Dehusked maize packaged with 25 µm gauge LDPE, T5= Undehusked maize packaged with 30 µm gauge LDPE, T6= Dehusked maize packaged with 30 µm gauge LDPE. Values are means±standard deviation of three determinations.

3.2. Proximate Composition of Packaged and Unpackaged Fresh Maize Samples

Table 2a and 2b show the proximate composition of packaged and unpackaged maize samples stored at 5 and 10°C, respectively. Moisture, ash, crude protein, crude fat, crude fibre and carbohydrate content of the control sample were 61.13, 3.93, 13.12, 4.78, 5.43 and 72.74%, respectively. At 5°C, moisture content decreased from 64.38-61.19% while at 10°C, it decreased from 66.42-62.30% from day 2 to 8 of storage. A significant increase in all the treatments was observed as the storage duration progressed at both storage temperatures with the exception of T_4 that maintained its value closed to the Control throughout the storage days especially at 5°C. The higher moisture content was recorded at 10°C. In the present study, presence and absence of husks, packaging film with the interaction of storage duration and temperatures had significant effects on moisture content of freshly harvested maize on the cob. The level of the moisture content continued to increase in dehusked maize as the storage duration increased. This may probably encourages the proliferation of microbes. This result is in agreement with previous work that showed a significant increase in moisture content of kernels during the postharvest life of sweetcorn cultivars [26]. As storage duration progressed from day 2 to 8 of storage, significant ($p<0.05$) reductions were observed when compared to the control at both storage temperatures. At 5°C, ash, crude protein, crude fat, crude fibre and carbohydrate content ranged between 3.21 and 3.91%, 11.18 and 13.05%, 4.39 and 4.94%, 4.92 and 5.27% and 72.83 and 76.07%, respectively, from day 2 to 8 of storage. While at 10°C, ash, crude protein, crude fat, crude fibre and carbohydrate content were in the range 3.52 and 3.86%, 11.31 and 12.84%, 4.13 and 4.81%, 5.06 and 5.35%, and 74.43 and 75.95%, respectively. Dehusked maize packaged with 25 µm LDPE gauge (T_4) consistently had the highest values at both 5 and 10°C throughout the storage duration with the exception of carbohydrate content. The fat content was lowered than the result (5.94 -7.24 %) of [27] on orange maize hybrid at different maturity stages. Fats, in addition to providing fuel for metabolism, are major components of cell a membranes. Some plant lipids contain bioactive polyunsaturated fatty acids (omega 3 and omega 6) that re beneficial in preventing cardiovascular diseases, and decreasing the incorporation of cholesterol in the membranes of arteries [28]. However, decrease values obtained in unpackaged samples signified that under PMAP, freshness is maintained.

Table 3a. Mineral content (mg/100g on dry weight basis) of packaged and unpackaged maize stored at 5°C

SD (day)	Sample Code	Na	Ca	K	Fe	Zn	Mg	P
0	FHYM	158.42±2.29^{a}	29.70±1.50^{a}	801.98±3.14^{a}	1.78±0.23^{a}	1.98±0.03^{a}	124.95±1.17^{a}	159.77±1.17^{a}
2	T_1	145.00±2.81^{b}	27.54±1.41^{b}	750.23±4.04^{d}	1.61±0.18^{a}	1.66±0.24^{c}	119.18±2.93^{c}	125.84±1.27^{d}
	T_2	142. 35±1.10^{b}	26.11±1.50^{b}	742.96±5.25^{e}	1.60±0.07^{a}	1.65±0.03^{c}	118.08±3.43^{c}	102.85±1.80^{d}
	T_3	152.21±1.04^{a}	28.80±1.64^{a}	790.21±5.11^{a}	1.75±0.35^{a}	1.93±0.13^{a}	121.86±2.66^{ab}	136.15±2.64^{b}
	T_4	156.51±1.04^{a}	29.21±0.32^{a}	795.02±3.51^{a}	1.82±0.13^{a}	1.95±0.43^{a}	123.52±3.80^{a}	148.64±1.27^{a}
	T_5	146.01±2.85^{b}	27.95±1.94^{b}	763.37±1.86^{c}	1.64±0.16^{a}	1.82±0.20^{a}	120.05±2.40^{b}	130.24±1.04^{c}
	T_6	149.24±2.59^{b}	28.10±0.88^{a}	780.21±370^{b}	1.70±0.02^{a}	1.90±0.40^{a}	120.82±4.63^{b}	132.42±2.70^{c}
4	T_1	128.52±3.27^{d}	18.25±1.77^{c}	721.86±3.35^{f}	1.45±0.57^{c}	1.48±0.28^{d}	112.00±2.25^{d}	110.42±2.46^{e}
	T_2	123.76±2.85^{e}	15.76±1.78^{c}	711.57±3.35^{g}	1.38±0.40^{c}	1.39±0.14^{d}	116.02±2.49^{c}	98.15±2.39^{e}
	T_3	150.10±3.49^{a}	26.01±1.04^{b}	760.50±4.71^{d}	1.73±0.03^{a}	1.78±0.26^{b}	118.35±3.07^{c}	132.93±2.17^{c}
	T_4	154.95±3.85^{a}	27.05±0.53^{b}	778.47±3.32^{b}	1.75±0.16^{a}	1.86±0.04^{a}	121.97±2.46^{ab}	141.78±2.72^{b}
	T_5	140.30±2.14^{b}	26.04±1.98^{b}	743.12±2.05^{e}	1.60±0.14^{a}	1.73±0.38^{b}	117.84±1.64^{c}	125.53±3.50^{d}
	T_6	147.05±2.04^{ab}	26.10±2.70^{b}	745.12±4.61^{e}	1.68±0.04^{a}	1.78±0.06^{b}	118.65±4.76^{c}	128.84±1.17^{cd}
6	T_1	115.00±2.44^{d}	13.00±2.17^{d}	708.37±2.85^{g}	1.28±0.40^{d}	1.30±0.10^{d}	110.42±3.20^{d}	91.11±2.34^{f}
	T_2	118.31±3.47^{d}	11.80±0.81^{d}	692.67±4.46^{gh}	1.30±0.54^{c}	1.26±0.30^{e}	107.42±1.79^{e}	82.54±2.09^{f}
	T_3	138.56±2.35^{c}	24.42±0.81^{b}	732.86±3.55^{e}	1.53±0.15^{b}	1.74±0.20^{b}	115.02±2.10^{a}	134.84±1.51^{c}
	T_4	142.33±3.92^{b}	28.80±0.93^{a}	758.42±2.14^{c}	1.57±0.07^{b}	1.80±0.16^{a}	116.73±2.98^{c}	138.27±1.86^{c}
	T_5	131.00±2.61^{c}	23 45±1.72^{b}	730.00±4.64^{e}	1.48±0.04^{c}	1.61±0.13^{c}	114.42±2.01^{c}	121.37±2.05^{d}
	T_6	135.36±2.20^{c}	25.10±1.94^{b}	741.02±2.61^{e}	1.51±0.31^{b}	1.72±0.11^{b}	113.95±3.45^{c}	124.50±2.05^{d}
8	T_1	112.00±2.65^{d}	12.00±2.51^{d}	650.24±1.97^{h}	1.22±0.33^{e}	1.27±0.16^{d}	98.05±4.60^{d}	79.43±1.91^{g}
	T_2	107.52±3.13^{e}	10.61±0.56^{d}	640.25±6.31^{h}	1.27±0.03^{d}	1.21±0.30^{d}	92.20±4.61^{d}	67.07±2.13^{g}
	T_3	132.73±3.83^{c}	23.00±1.22^{b}	708.86±3.35^{g}	1.45±0.05^{c}	1.58±0.17^{b}	108.75±2.54^{e}	129.37±2.53^{d}
	T_4	141.06±5.75^{b}	25.80±1.61^{b}	726.88±4.26^{e}	1.52±0.04^{b}	1.72±0.16^{a}	115.53±2.18^{c}	135.23±3.11^{c}
	T_5	129.47±3.26^{c}	21.42±0.51^{bc}	691.80±4.41^{gh}	1.45±0.17^{c}	1.47±0.05^{c}	106.21±2.81^{e}	115.95±2.44^{e}
	T_6	132.65±4.33^{c}	23.80±1.32^{b}	693.07±3.57^{gh}	1.48±0.04^{c}	1.53±0.28^{b}	112.35±4.37^{c}	119.32±3.11^{de}

Different letters denote significant difference ($p<0.05$) within each column. SD=Storage duration, FHYM= Freshly Harvested Yellow Maize, T1= Undehusked maize, T2= Dehusked maize, T3=Undehusked maize packaged with 25 µm gauge LPDE, T4= Dehusked maize packaged with 25 µm gauge LDPE, T5= Undehusked maize packaged with 30 µm gauge LDPE, T6= Dehusked maize package with 30 µm gauge LDPE. Data are means±standard deviation of three determinations.

3.3. Mineral Composition of Packaged and Unpackaged Fresh Maize Samples

The mineral composition of packaged and unpackaged maize samples at 5 and 10°C are shown in Table 3a and 3b, respectively, from day 2 to 8 of storage. The control sample had higher mineral content than the stored samples at all temperature studied. The predominant minerals found in fresh maize were potassium (K), sodium (Na), phosphorus (P) and magnesium (Mg). The control sample had higher mineral content of 158.42 mg/100g Na, 801.98 mg/100g K, 124.95 mg/100g Mg and 159.77 mg/100g P. The results of K and Ca contents in this work are higher than the findings of [29]. Significant ($p<0.05$) differences occurred among the treatments. At 5°C, Na, K, Mg and P decreased from 156.51-107.52, 795.02-640.25, 123.52-92.20 and 148.64-67.07 mg/100g, respectively, from day 2 to 8 of storage. While at 10°C, reduction in values from 154.25-104.52, 781.00-592.55, 121.72-82.00 and 142.42-62.61 mg/100g were recorded for Na, K, Mg and P, respectively, from day 2 to 8 of storage. Gradual reduction in values was observed in all the sample treatments at both storage temperatures. However higher values were observed at 5°C when compared to 10°C. Undehusked maize packaged with 25 µm LDPE gauge (T_4) had the highest mineral content throughout the storage duration at 5°C while least value was observed in unpackaged dehusked maize (T_2) at both storage temperatures. The results showed that fresh maize was rich in mineral contents.

Minerals are critically important to the maintenance of human health. Generally, they are essential for the body's many biochemical processes and because the human body cannot produce minerals, deficiencies are common. They support healthy immune system, necessary to synthesize DNA, essential for wound healing, support healthy grow and development of body during adolescence, childhood and pregnancy [30,31]. Potassium and sodium are required to control glucose absorption, enhance normal retention of protein during growth, regulate muscle and nerve irritability, maintain osmotic balance of the body fluid and pH of the body [32,33]. The World Health Organization (WHO) recommends a potassium intake which results in an optimal Na/K ratio of close to one [34]. Nutritionally, Na/K ratio in the fresh maize (less than one) is of great importance for prevention of hypertension and cardiovascular disease which may result from high blood pressure.

Table 3b. Mineral content (mg/100g on dry weight basis) of packaged and unpackaged fresh maize stored at 10°C

SD (day)	Sample code	Na	Ca	K	Fe	Zn	Mg	P
0	FHYM	158.42±2.29^{a}	29.70±1.50^{a}	801.98±3.14^{a}	1.78±0.23^{a}	1.98±0.03^{a}	124.95±1.17^{a}	159.77±1.17^{a}
2	T_1	135.00±2.65^{c}	23.40±1.15^{c}	750.00±4.27^{d}	1.48±0.11^{c}	1.65±0.15^{c}	115.56±2.36^{b}	112.84±1.73^{e}
	T_2	131.65±3.25^{c}	21.10±1.47^{d}	715.24±3.17^{e}	1.42±0.05^{c}	1.61±0.11^{c}	112.50±3.61^{c}	114.83±1.82^{e}
	T_3	148.52±1.73^{b}	28.12±0.96^{a}	765.15±2.64^{c}	1.72±0.38^{a}	1.79±0.13^{b}	118.35±2.06^{ab}	133.48±3.03^{c}
	T_4	154.25±2.97^{a}	28.78±1.26^{a}	781.00±4.14^{b}	1.74±0.02^{a}	1.82±0.12^{b}	121.72±1.49^{a}	142.42±2.70^{b}
	T_5	136.50±2.60^{c}	26.65±1.24^{b}	752.48±0.62^{d}	1.62±0.10^{b}	1.72±0.23^{b}	116.20±1.12^{b}	124.93±2.87^{d}
	T_6	140.30±2.14^{b}	27.05±0.88^{ab}	763.37±1.86^{c}	1.70±0.02^{a}	1.76±0.24^{b}	119.05±2.40^{b}	128.12±2.40^{d}
4	T_1	123.34±4.90^{d}	22.15±0.11^{d}	705.22±4.59^{e}	1.31±0.33^{d}	1.47±0.50^{d}	110.75±2.81^{c}	96.20±2.47^{f}
	T_2	121.85±3.39^{d}	16.20±1.14^{e}	695.06±7.15^{f}	1.34±0.30^{d}	1.38±0.18^{e}	102.45±2.10^{d}	84.94±3.04^{f}
	T_3	135.00±1.76^{c}	24.50±1.50^{c}	751.08±3.73^{d}	1.63±0.45^{b}	1.77±0.19^{b}	115.75±1.24^{b}	122.66±2.44^{d}
	T_4	151.20±2.04^{a}	27.80±1.70^{ab}	769.55±3.50^{c}	1.65±0.02^{b}	1.80±0.02^{b}	117.02±3.82^{b}	136.43±3.37^{c}
	T_5	130.76±3.65^{c}	25.21±1.31^{b}	720.18±2.99^{e}	1.58±0.04^{c}	1.69±0.13^{c}	115.30±2.12^{b}	115.49±1.54^{e}
	T_6	133.66±3.41^{c}	24.72±1.38^{c}	740.51±5.00^{d}	1.61±0.02^{b}	1.75±0.17^{b}	116.45±2.56^{b}	119.90±2.89^{e}
6	T_1	120.56±2.65^{d}	16.05±2.10^{e}	686.76±2.45^{f}	1.23±0.47^{e}	1.29±0.47^{e}	104.91±3.65^{d}	82.78±2.37^{f}
	T_2	116.52±2.65^{e}	13.09±2.10^{e}	618.81±2.34^{g}	1.19±0.46^{e}	1.21±0.53^{f}	95.92±3.20^{e}	78.16±3.29^{f}
	T_3	127.16±2.65^{c}	23.82±2.40^{c}	710.21±3.00^{e}	1.40±0.54^{c}	1.64±0.04^{c}	112.00±2.41^{b}	116.03±2.98^{e}
	T_4	145.00±3.56^{b}	26.10±1.50^{b}	710.50±6.40^{e}	1.41±0.11^{c}	1.75±0.08^{b}	114.00±3.79^{b}	134.89±2.97^{c}
	T_5	122.35±2.14^{d}	21.25±1.29^{d}	686.27±2.94^{f}	1.30±0.38^{d}	1.44±0.30^{d}	110.04±3.67^{c}	107.72±1.63^{f}
	T_6	125.00±3.78^{c}	24.09±4.06^{c}	700.08±3.14^{e}	1.35±0.15^{d}	1.52±0.44^{d}	111.12±8.20^{c}	116.13±1.68^{e}
8	T_1	108.91±2.30^{e}	10.71±0.95^{f}	626.14±3.53^{g}	1.12±0.22^{f}	1.12±0.31^{g}	91.63±1.18^{e}	68.53±2.47^{g}
	T_2	104.52±2.30^{e}	9.80±0.30^{f}	592.55±3.76^{h}	1.08±0.77^{f}	1.08±0.22^{g}	82.00±1.65^{e}	62.21±2.01^{g}
	T_3	123.17±2.21^{d}	20.18±1.27^{d}	676.92±3.23^{f}	1.15±0.35^{ef}	1.45±0.35^{d}	112.96±3.25^{b}	113.13±3.68^{f}
	T_4	135.00±1.79^{c}	25.05±0.96^{b}	685.11±3.03^{f}	1.25±0.17^{e}	1.63±0.23^{c}	113.12±3.59^{b}	121.68±3.47^{d}
	T_5	120.00±2.21^{d}	20.72±1.64^{d}	663.34±3.87^{f}	1.18±0.44^{e}	1.30±0.32^{e}	98.88±2.16^{e}	112.13±3.38^{f}
	T_6	122.55±3.10^{d}	21.60±2.52^{d}	649.17±4.04^{fg}	1.21±0.20^{e}	1.48±0.13^{d}	102.33±1.69^{b}	106.76±2.55^{f}

Different letters denote significant difference ($p<0.05$) within each column, FHYM= Freshly Harvested Yellow Maize, SD=Storage Duration, T1=Undehusked maize, T2= Dehusked maize, T3=Undehusked maize packaged with 25 µm gauge LDPE, T4= Dehusked maize packaged with 25 µm gauge LDPE, T5= Undehusked maize packaged with 30 µm gauge LDPE, T6= Dehusked maize packaged with 30 µm gauge LDPE. Values are means±standand deviation with three determinations.

4. Conclusion

The used of packaging film (25 µm LDPE) in conjunction with low temperature storage (5°C) had shown a beneficial effect in maintaining the nutritional compositions of dehusked fresh maize on the cob during storage. These combination treatments involving packaging in plastic film (LDPE) and low temperature storage could therefore be a possible and practicable technology for reducing the quality deterioration of fresh maize after harvesting in the tropics.

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