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Changes in Postharvest Qualities of Stored Fresh Maize (*Zea Mays* L.) at Tropical Ambient Condition

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Abstract: *The effect of passive modified atmosphere packaging on some postharvest qualities of stored fresh maize was investigated at tropical ambient temperature (28±2 °C) and 80% RH. Changes in the appearances of husk, silk and kernel, kernel firmness, weight and microbial growth were monitored. Freshly harvested yellow maize (FHYM) served as control. Results showed that packaging film greatly affected the appearances of the husk, silk, kernel and kernel firmness compare to the control sample. The highest weight loss was observed in dehusked maize while the maize samples in packaging film had the least weight loss. Lactobacillus sp., Micrococcus liteus, Streptococcus sp., Serratia marcescens, Bacillus sp. and Saccharomyces cerevisiae were the bacteria isolated from the stored fresh maize while the suspected fungal include Rhizopus stolonifer, Penicillium notatum and Fusarium sp. Higher bacteria counts were observed in samples packaged with 25 and 30 µm LDPE while the least was found in unpackaged undehusked maize. The current packaging conditions had no impact on the shelf life of fresh maize.*

Keywords*: Appearances, Fresh maize, Microorganisms, Modified atmosphere packaging, Weight loss*

I. Introduction

Quality is generally defined as all those characteristics of a food that lead a consumer to be satisfied with the product and it is the main objective of postharvest technology [1]. Assessment of postharvest shelf-life of fresh-cut or minimally processed packaged fruit and vegetables is often based on changes or stability in physical attributes such as colour, firmness and absence of decay. These attributes reflect visual acceptance associated with produce quality. The modified atmosphere packaging technique consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration, reduce moisture loss and decay and/or extend the shelf life of the products [2]

Maize also known as corn (*Zea mays*) is a cereal crop which ranks among the most essential crops in the world agricultural economy [3]. It is agronomically versatile and become one of important staple food crops for most part of the population of Africa [4]. Fresh maize kernels are rich source of vitamin C, E, K and B-group. Potassium is a major mineral present which has a good significance in human diet [5]. It is a relatively poor cereal when it comes to the quality of its protein, because it has limiting amounts of two essential amino acids, lysine and tryptophan [6]. Although hundred of maize cultivars exist only limited varieties are commercially grown for human consumption and they include dent corn, flint corn, popcorn, waxy corn and sweet maize [7]. Agricultural commodity is a perishable food crop due to the presence of high moisture content [8]. Fresh maize is prone to fast post-harvest deterioration leading to kernel desiccation, loss of sweetness and moisture, husk discoloration and development of pathogens as a result of metabolic reactions [9]. Due to its perishable nature, it has to be consumed immediately after harvest by boiling or roasting. [10] reported that wrapping or sealing a fresh produce with a suitable plastic film reduce moisture loss by creating modified atmosphere around the fruit thereby retarding respiration. The present work was undertaken to test the effectiveness of passive modified atmosphere packaging on the extension of shelf life of fresh maize at tropical ambient temperature.

II. Materials and Methods

Ears of fresh yellow maize on the cob (SUWAN 1-SR) was obtained from the Teaching and Research farm of the Federal University of Technology Akure (FUTA). The two different packaging materials used were 25 and 30 µm gauges of low density polyethylene (LDPE) with 34 cm × 14.5 cm in area (TUBI Investment Ltd, Akure, Nigeria). Fresh maize were grouped into six lots: undehusked maize (T1), dehusked maize (T2), undehusked maize packaged with 25 µm LDPE (T3), dehusked maize packaged with 25 µm LDPE (T4), undehusked maize packaged with 30 µm LDPE (T5) and dehusked maize packaged with 30 µm LDPE (T6). Freshly harvested yellow maize (FHYM) was harvested daily for comparison purpose and was used as the control sample. The fresh maize was placed singly in LDPE and sealed properly using an impulse sealer (MEC, China). Samples were then transferred into a chamber set at temperature of 28±2 ^{o}C and 80% RH maintained for 8 days.

2.1 Physical attributes and weight loss

Twenty (20) member panelists selected among postgraduate students of FUTA were used to assess the quality of packaged and unpackaged fresh maize under storage. The quantitative descriptive analysis (QDA) method of [11] was used by the panelists where 8-9, 6-7, 4-5, 2-3 and 0-1 represent field fresh, good, fair, non marketable and unusable, respectively. The appearances of kernel, husk, silk and kernel firmness were visually evaluated.Weight losses were determined by measuring the initial and final weight of each packaged and unpackaged maize sample every two days using an electronic weighing balance (ML3002.E, Mettler Toledo, Switzerland). Weight loss was calculated according to the (1):

$$\%\ Weight\ Loss = \frac{W_o - W_f}{W_o} \times 100 \quad (1)$$

Where W_o is the initial weight (g) and W_f is the final weight (g) prior to package analysis.

2.2 Microbiological analysis

2.2.1 Isolation and cultivation of microorganisms

The samples were evaluated for microbiological analysis as described by [12]. Packaged and unpackaged stored maize samples were examined for viable count of bacteria and fungi using Nutrient Agar (NA) and Potato Dextrose Agar (PDA), respectively. The pour plate method was used for the enumeration of viable microorganisms. The preparation of each media was carried out according to manufacturer's instructions. Sample was thoroughly homogenized and serially diluted with 0.1% peptone water up to 10^4. Aliquot of 1 ml portion from the diluents was transferred aseptically into sterile Petri dishes. Melted and cooled NA was added to each plate. The inocula was evenly mixed with media by rotating the plates and allowed to solidify. The inverted plate was incubated at 37 ^oC for 1 day and after which the resultant microbial colonies were counted (cfu/g) using a Gallenkamp colony counter. For the enumeration of fungi, aliquot of 1 ml from the diluents was transferred aseptically into solidify PDA plates. Samples were carefully spread all over the surface of the plates using sterile bent glass rod. The plates were then incubated for 5 days at room temperature and the resultant microbial colonies were counted (cfu/g) using colony counter.

2.2.2 Biochemical characterization of the isolated bacterial cells

Gram's staining: Gram's staining technique was carried out using Christian Gram method. A heat-fixed smear from 24 h old culture was made. A loopful of sterile distilled water was placed on the centre of a clean slide. Aseptically, a very small amount of the culture was transferred into the loopful of water on the slide and emulsified. The slide was allowed to air dry and fixed by passing the slide over flame for 5 times. The smear was stained with crystal violet solution for 1 min and rinsed with lugol's iodine. The iodine was allowed to react for 1 min. The smear was washed with 95% alcohol for 30 sec and rinsed gently with water. The smear was counter stained with safranin for 1 min and washed in water, blot dried and examined under the microscope.

Oxidase: A drop of 1% aqueous solution of tetramethyl-p-phenylenediamine hydrogen chloride was dropped on a filter paper (No 1 Whatman). The impregnated filter paper was smeared with the bacteria culture with the aid of platinum loop. A purple colouration was produced within 10 s by oxidase positive culture.

Spore: A heat-fixed smear was prepared. Under steam condition a malachite green solution was added for 10 min. The preparation was carefully washed in cold water. The preparation was counterstained with safranin solution for 15 s, washed with water, blot dried and examined under microscope.

Sugar fermentation: A medium containing 1.0% peptone, 0.1% NaCl and 1.0% fermentable sugar was prepared. 0.01% phenol red was added as an indicator including an inverted Durham tube. The medium was sterilized at 121 ^oC for 15 min. After sterilization, the tubes were inoculated and incubated 121 ^oC for 15 min. Acid production was shown by a change in the colour of the indicator used. Gas production was also indicated by a space in the Durham tube. Sugars tested were glucose, galactose, lactose, sucrose, maltose and manitol.

2.3 Statistical Analysis

The statistical significance of the observed differences among the means of triplicates reading of experimental results were evaluated using one way analysis of variance (ANOVA), while means were separated by using Duncan's New Multiple Range Test. These analyses were done with SPSS (20) software.

III. Results and discussion

Figure 1 shows changes in physical attributes (husk appearance (A), silk appearance (B), kernel appearance (C) and kernel firmness (D)) of fresh and stored maize under different storage treatments at day 1, 2, 3, 4, 6 and 8. Results showed that the control sample had the highest scores for husk appearance, silk appearance, kernel appearance and kernel firmness while the least was observed in packaged samples.

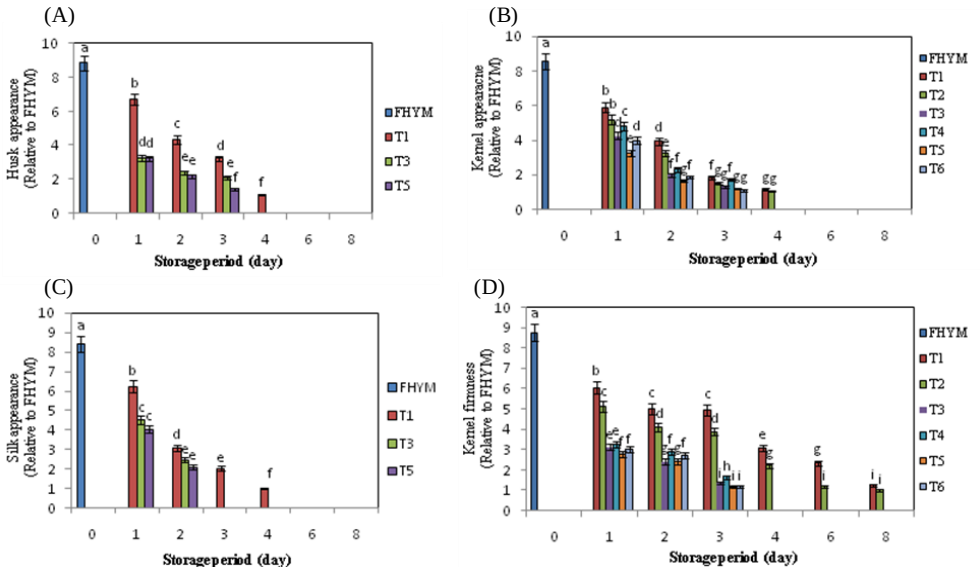

Figure 1: Changes in physical attributes (husk appearance (A), kernel appearance (B), silk appearance (C) and kernel firmness (D) of packaged and unpackaged fresh maize stored at 28±2 °C. Different letters denote significant differences ($p<0.05$). T1= Undehusked maize, T2= Dehusked maize, T3= Undehusked maize packaged with 25 µm LDPE, T4= Dehusked maize packaged with 25 µm LDPE, T5= Undehusked maize packaged with 30 µm LDPE, T6= Dehusked maize packaged with 30 µm LDPE. FHYM (Freshly Harvested Yellow Maize) was harvested daily for comparison purposes. Values are mean±SD of three determinations.

The qualities of the parameter assessed decreased gradually as the storage day progressed. Significant ($p<0.05$) differences existed among the treatments. Neither of the film packaging gauges nor the presence of husk preserved the qualities of fresh maize till the last day of storage. At day 3 of storage for T1 (undehusked maize), the husk showed yellowish colour and silk showed brownish colour and both showed dryness. The complete dryness was observed at day 6 and 8 of storage. Undehusked maize samples packaged with 25 µm (T3) and with 30 µm (T5) were completely water soaked. This could be as a result of the maize respiration which released water as one of the end products. Kernel appearance and kernel firmness followed the same trend of losing its qualities gradually at storage by showing dull kernel appearance with denting for dehusked maize (T2) and to some extent with undehusked maize samples (T1) while packaged samples were water soaked.

Figure 2 shows changes in weight of unpackaged and packaged maize samples. Significant ($p<0.05$) differences were observed among the treatments. The result showed highest weight loss in T2 (dehusked maize) while the least was observed in packaged samples; undehusked maize packaged with 25 µm LDPE (T3), dehusked maize packaged with 25 µm LDPE (T4), Undehusked maize packaged with 30 µm LDPE (T5) and dehusked maize packaged with 30 µm LDPE (T6) followed by T2. The least value observed in packaged samples was indirectly affecting the qualities of the fresh maize.With storage period the amount of water held by a fresh commodity decreases with time so does subsequent water loss and hence weight loss. Water loss in vegetables is determined by many factors, the most important of which is the resistance exerted by the outer periderm or cuticle to movement of water vapour due to transpiration [13]. [14] considered transpiration as the major cause of postharvest losses and poor quality in fresh produce. Weight loss adversely affects the appearance, texture, flavour and all factors that determine the quality of the fruits and vegetables. Weight loss induces wilting, shrinkage and loss of firmness. The observation in this study is in agreement with [15] who reported the highest weight loss for the green mealies stored at room temperature. [16] also reported that there was an interaction that existed between storage condition and weight loss.

The results of microbiological evaluation of unpackaged and packaged maize samples stored at day 2, 4, 6 and 8 are presented in TABLE 1. The total aerobic bacterial counts of stored samples at day 2 ranged from 8.17-15.26 $x10^4$cfu/g. The use of polymeric films in MAP is intended to serves as a mechanical barrier to the movement of water vapour and reduce produce weight loss as reported by [17] was not effective at ambient temperature. Significant ($p<0.05$) increase in bacterial counts was observed in all the treatments as storage days progressed. Packaged samples had the highest microbial counts while least count was recorded for undehusked sample (T1). Proliferation in bacterial counts was observed on day 8 of storage in which all the samples had significantly higher bacterial counts.

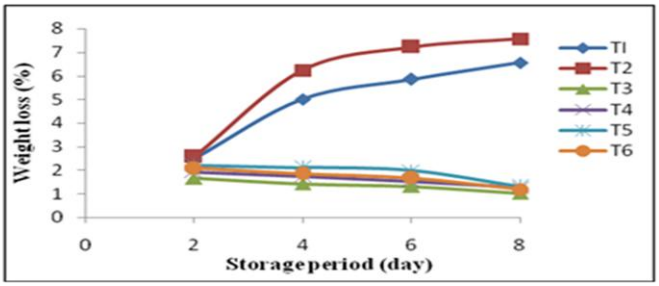

Figure 2: Weight loss of packaged and unpackaged fresh maize stored at 28±2 °C. T1= Undehusked maize, T2= Dehusked maize, T3= Undehusked maize packaged with 25 µm LDPE, T4= Dehusked maize packaged with 25 µm LDPE, T5= Undehusked maize packaged with 30 µm LDPE, T6= Dehusked maize packaged with 30 µm LDPE. FHYM (Freshly Harvested Yellow Maize) was harvested daily for comparison purposes. Values are means of three determinations.

Table 1: Total aerobic bacteria and fungi (10^4cfu/g) of packaged and unpackaged fresh maize at storage temperature 28±2 °C

Microbes	SP	Storage treatments					
	(day)	TI	T2	T3	T4	T5	T6
Bacteria	2	8.53 ± 0.51^{dA}	15.26 ± 1.51^{aA}	8.17 ± 1.26^{dA}	8.41 ± 1.55^{dA}	9.01 ± 1.55^{cA}	10.67 ± 1.81^{bA}
	4	16.34 ± 1.22^{eB}	18.41 ± 1.87^{dB}	27.57 ± 2.54^{cB}	28.13 ± 1.87^{bB}	32.00 ± 2.41^{aB}	29.58 ± 2.35^{bB}
	6	17.67 ± 1.53^{dC}	24.13 ± 2.16^{cC}	32.71 ± 2.41^{bC}	30.25 ± 2.58^{bC}	40.67 ± 2.62^{aC}	33.10 ± 2.46^{bC}
	8	21.71 ± 2.24^{dD}	26.88 ± 2.32^{dD}	39.22 ± 2.63^{cD}	34.10 ± 1.79^{cD}	48.11 ± 2.81^{aD}	41.10 ± 2.78^{bD}
Fungi	2	2.32 ± 0.71^{dA}	4.21 ± 1.22^{aA}	3.87 ± 1.05^{bA}	3.15 ± 0.22^{cA}	4.26 ± 0.81^{aA}	2.46 ± 0.56^{dA}
	4	5.12 ± 0.48^{dB}	6.01 ± 1.05^{cB}	7.41 ± 0.85^{aB}	6.24 ± 0.65^{bB}	7.82 ± 1.42^{aB}	6.58 ± 0.85^{bB}
	6	9.13 ± 0.58^{dC}	11.21 ± 1.42^{bC}	14.22 ± 2.34^{aC}	9.10 ± 1.21^{dC}	11.45 ± 1.76^{bC}	10.22 ± 2.04^{cC}
	8	11.81 ± 1.42^{dD}	12.76 ± 1.66^{bD}	16.11 ± 2.57^{aD}	11.22 ± 1.65^{aD}	15.33 ± 2.13^{aD}	12.11 ± 1.87^{cD}

Different letters denote significant difference ($p<0.05$) within each column (capital letters) and row (small letters). SP=Storage period, 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 are means±SD of three determinations.

Bacteriological characterization showed six different bacteria (*Lactobacillus sp., Micrococcus liteus, Streptococcus sp., Serratia marcescens, Bacillus sp*. and *Saccharomyces cerevisiae)* isolated from the stored samples (TABLE 2).Gradual increase in fungal count was noticed from day 2 to 8 of storage. Three suspected fungal isolated during the course of storage were *Rhizopus stolonifer, Penicillium notatum* and *Fusarium sp*. (TABLE 3). Highest count was found in all packaged samples while undehusked samples (T1) had the least count. In all the samples evaluated from day 2 to 8, it was observed that the counts of fungi (yeasts and moulds) were lowered than the bacteria. This may be attributed to the fact that yeasts and moulds could not thrive well at high pH (non acidic foods) comparison with aerobic mesophilic bacteria [18, 19].

Table 2: Biochemical characterization of bacterial isolates from stored maize samples

	Number of isolates					
	1	2	3	4	5	6
Gram's staining	+	+	+	–	+	+
Shape of cells	R	S	S	R	R	S
Oxidase	–	–	–	–	–	–
Spores	–	–	–	–	+	–
Fructose	–	A	–	AG	AG	–
Manitol	–	A	A	A	–	–
Sucrose	A	A	A	A	A	

1 = Lactobacillus sp., 2 = Micrococcus luteus, 3 = Streptococcus sp., 4 = Serratia marcescens, 5= Bacillus sp., 6 = Sachharomyces cerevisiae, – = Negative, + = Positive, R = Rod, S = Sphere, A = Acid, G = Gas

Table 3: Cultural characteristics and microscopic observation of the fungal isolates

Cultural characteristics	Microscopic observation	Suspected organisms
Cotton-like mycelia at 12 h	Non-septate hyphae, thin sporagiosphore with	*Rhizopus stolonifer*
turning dirty with development	a sporangium in umbrella-like form	
of black spores on mycelium		
Blue mould growth	Septate mycelium bearing single conidiophores	*Penicillium notatum*
	which are branched near the apex, ending in	
	phialides that carries conidia	
The thallus showing pink	Mycelium extensive in a cotton wool-like form.	*Fusarium sp.*
pigmentation fluffy in texture	Having phialides that is bearing a bean podlike	
	microconiia borne singly or in chain	

IV. Conclusion

The used of passive modified atmosphere in this study was not effective in keeping the qualities of freshly harvested maize as it was greatly affected the husk appearance, silk appearance, kernel appearance, kernel firmness, increased weight loss and encouraged the proliferation of microorganisms during storage. However, the presence of husk provided a better quality in terms of physical attributes, weight loss reduction and low microbial counts when compared to fresh maize without husk.

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