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RESEARCH ARTICLE :

Quality characteristics of fresh-cut banana pseudo stem stored in both active and passive modified atmosphere

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SUMMARY : The fresh-cut produce has largely driven by increasing consumer demand for healthy, freshly prepared convenient vegetables. Fresh-cut banana pseudostem shelf life is increased by the modified atmospheric packaging. The cut-vegetable was pre-treated with anti-browning agent (Potassium meta-bisulphite 0.1% for 1 hour). Pre-treated samples were packaged under two atmosphere *z* active (O2-3%, CO_2-5% and N_2- 92%) and passive (atmospheric air) with two packaging material i.low density polyethylene (LDPE) and ii.poly propylene (PP). The study revealed that the quality characteristic such as colour value (L-16.2%, a-32%, b-20%) showed minimum change with no change in fibre content during its storage in passive modified atmospheric packaging. The bacterial and fungal population of 4.96×10^5cfu/g, 7.31×10^3cfu/g were noriced at maximum storage days which were within the safe level of consumption. Modified atmospheric packaging condition extended the shelf-life of fresh-cut banana pseudostem to 30 days at 8±2°C in both active and passive atmosphere.

KEY WORDS :
Active MAP, Fresh-cut banana pseudostem, Modified atmosphere packaging, Passive map

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BACKGROUND AND OBJECTIVES

Banana (*Musa* spp.), the second largest fruit crop of tropical and subtropical regions, is a major source of carbohydrates and contains high levels of potassium and vitamins B and C. In India it is recognized as the 4th major food source for our country and also in terms of gross value of production it ranks fourth after rice, wheat and maize (Kotecha and Desai, 1998). After the harvest of banana, a large amount of pseudo-stem residue is left behind in soil as waste. It has been estimated that a few tonesof banana pseudo-stem per hectare are produced annually (Cordeiro *et al.*, 2004). The banana pseudo-stem is rich in minerals and fibre content. There is a registered patent that describes to use the heart of banana tree for human consumption (Cardoso *et al.*, 2007). The fibre content of banana pseudostem helps to cure constipation, aids in detoxification of body and improves the functional efficiency of kidney and liver. It also acts as a diuretic agent helping to eliminate waste fluids from the body. It helps

in the treatment for the removal of stones in kidney, gall bladder and prostate. Banana pseudo stems are alsoused in the manufacture of blades, veneer, plywood (Correa, 2006), Cloth for lampshades, boxes, cases (Oliveira, 2004), biogas (Souza *et al.*, 2007) cellulose pulp and paper (Chertman and Simoes-Moreira, 2008). In agriculture, it is used as a good source of nitrogen and phosphorus for growing ferns (Pacheco *et al.*, 2010).

Changes in lifestyle patterns have lead to increased demand for cut vegetables as people do not have time to prepare vegetables at home as well as in hotels. Because of these factors consumption of minimally processed products has significantly increased (Allende *et al.*, 2006). The shelf-life of fresh-cut produce in ambient conditions is very limited which can be extended by many preservation techniques like low temperature storage, controlled atmosphere, hypobaric and modified atmosphere packaging methods.

Modified atmosphere packaging technology is one among them, which is largely used for minimally processed fruits and vegetables including fresh, ''ready-to-use'' vegetables (Sandhya, 2010). Active and passive modified atmospheric packaging's are the two systems generally recognized for packaging of fresh-cut produce. Active modification occurs by the displacement of gases in the package, which are then replaced by a desired mixture of gases, while passive modification occurs when the product is packaged using a selected film type, and a desired atmosphere develops naturally as a consequences of products respiration and the diffusion of gases through the film. (Kitinoja and Gorny, 1998).

Though many vegetables are part of our dietary habit, the technology of ready to eat or ready to cook form of minimal processing is available only for few vegetables in India. Thus, it is necessary to develop techniques to preserve banana pseudostem. Keeping in view the above prospective, the present investigation on preservation of fresh-cut banana pseudostemusing modified atmosphere packaging with different packaging material has been taken to conduct studies under passive and active modified atmosphere packaging for enhancing the shelf life.

RESOURCES AND METHODS

Raw material :

The Poovan variety of banana pseudo stem were procured from the university orchard of TAU, Coimbatore. After harvesting (within ½ hour) the vegetables were stored at 8±2°C and for 2 hours before processing. Packaging materials such as low density polyethylene (LDPE) and poly propylene (PP) of 100 µ thickness both were chosen based on the previous study by Mangaraj *et al.* (2009). The packaging films were procured from the local market, Coimbatore.

Preparation and packaging of fresh-cut banana pseudo stem :

Fresh good quality and uniformly matured banana pseudo stems (var. poovan) were cut in to small cubes of approximately 5 mm length and immediately pretreated for 1 hour with anti-browning agent 0.1 per cent potassium meta-bisulphite (KMS) (Kadam *et al.*, 2006). The treated cubes were shade dried for 15 min. at room temperature to remove surface moisture and approximately 100g samples were packaged in LDPE and PP films. Passive and active modified atmospheric packaging's are the two systems used for packaging of fresh-cut banana pseudostem. Passive modification (atmospheric condition – 21%O_2, 0.01%CO_2, 79%N_2) was done by placing the fresh-cut vegetables in the package film (LDPE and PP) and then sealed using heat sealer. A desired atmosphere develops naturally inside the package as a consequence of respiration of products and the diffusion of gases through the film. The gas was analyzed using gas analyzer at room temperature (MAKE: PBI Dansensor). Active modification was done by placing the fresh-cut vegetables in pouch and then air inside the pouch (LDPE and PP) were replaced by a desired mixture of gases using gas mixing unit (MAP mix 8000 EL, PBI Dansensor). The fresh-cut banana pseudostem were flushed with 3%, O_2, 5% CO_2 and 92% N_2. The treated and control samples (without packaging) were stored under refrigeration condition 8±2°C.

Head space gas analysis :

The selected polymeric films (LDPE and PP) were made in to pouch of size 20.5 cm length and 15.5 cm breadth. The silicon septum was pasted on the surface of the pouch for drawing the gas samples. The fresh-cut vegetables of approximately 100g were taken in the pouch and it is sealed for passive atmosphere where as for active atmosphere, the desired mixture of gases are filled and sealed. At particular interval the gas was measured in the package using gas analyser (PBI Dansensor).

Quality characteristics such as colour value (Make: Hunter Lab, Model: 45°/0°), crude fibre (Maynard, 1970) and MAP Packaged fresh-cut banana pseudo stem were analysed for total plate count and yeast and mold growth using (Allen, 1953). Sensory evaluation of the vegetables was done by the panel of untrained judges (10 members) for appearance, colour, flavour, texture, taste and overall acceptability using 9-point Hedonic scale varying from like extremely (rated as 9) to dislike extremely (rated as 1).

Statistical analysis:

All the analysis was carried out in three replications. Statistical analysis was carried out to study the effect of different parameters on all the dependent variables. Analysis of variance (ANOVA) was conducted with Factorial Completely Randomized Block Design (FCRD) using the software AGRES version 7.01.

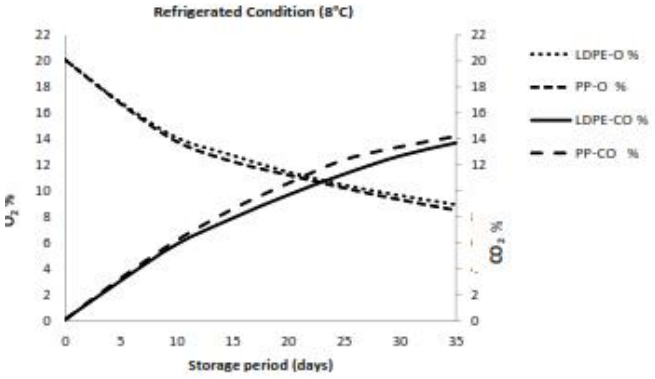
OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Head space gas analysis :

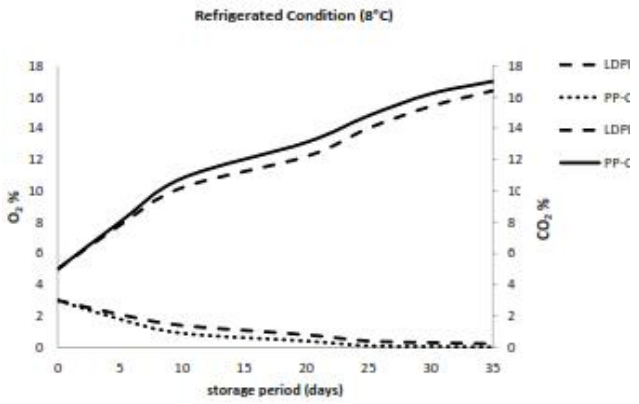
The effect of gas concentration on the head space of the pouches (LDPE and PP) containing fresh-cut banana pseudostem in both active and passive MAP stored at 8±2°C are shown in the Fig. 1 and Fig. 2. Meyer *et al*. (1973) reported that the plant materials during respiration takes oxygen and break the organic reserves to simpler molecules of CO_2 and water with release of energy. The initial concentration of passive MAP were 21% O_2 and 0.01% $CO_2$and at active MAP were 3% O_2, 5% CO_2 and 92% N_2. It is evident from the figure that as the time progressed, the concentration of O_2 was decreasing whereas the concentration of CO_2 was increasing. These results are in agreement with Lee *et al*. (1995).

The gas concentration of fresh-cut banana pseudostem at refrigerated condition packaged in a LDPE pouch in passive atmosphere (Fig.1) showed reduction of O_2 concentration from 20.1 to 8.95 per cent and increase of CO_2 from 0.1 to 13.7 per cent. In PP pouches, the O_2 concentration reduced to 8.52 per cent and CO_2 production was increased to 14.2 per cent till after 30 days of storage.This may be due to the more metabolic



LDPE- Low density polyethylene packaged sample,
PP- Poly propylene sample O_2%- Oxygen concentration,
CO_2%- Carbon dioxide concentration

Fig. 1: The effect of storage environment on gas concentration in fresh-cut banana pseudostem under passive MAP



LDPE- Low density polyethylene packaged sample,
PP- Poly propylene sample O_2%- Oxygen concentration,
CO_2%- Carbon dioxide concentration

Fig. 2: Effect of storage environment on gas concentration in fresh-cut banana pseudostemunder active MAP

activity of the samples at higher temperature. Baur *et al*. (2005) also reported that concentration of oxygen and carbon dioxide inside the headspace is related to the metabolic state of the samples. The result clearly shows that the temperature is the most important external factor influencing the respiration. Biological reactions generally increase by two or three-fold for every 10°C rise in temperature within the range of temperatures normally encountered in the distribution and marketing chain (Burzo, 1980 and Zagory and Kader, 1988). Similar trend of results were reported by Sandhu and Parhawak (2002).

The fresh-cut banana pseudostem was packaged in LDPE and PP pouches and flushed with O_2 (3%) and CO_2 (5%) and stored under refrigerated condition. The effects of storage environment on gas composition of fresh-cut banana pseudostem under active MAP are presented in the Fig. 2.

In LDPE under active MAP, the O_2 concentration was ranging between 3 and 0.22 per cent and the CO_2 concentration was in the range of 5 to 16.4 per cent whereas in PP and the O_2 concentration was 3 to 0.013 per cent and CO_2 concentration was 5 to 17 per cent at end of 35 days. Iqbal *et al*. (2004) also had similar trend of O_2 consumption and CO_2 production rates for sliced mushrooms.

Changes in colour value for MAP of fresh-cut banana pseudostem :

Change in 'L' value of fresh-cut banana pseudostem:

The effect of storage period on 'L' value of MAP fresh-cut banana pseudostem is presented in the Table 1. There was significant effect of treatment (packaging material × active and passive MAP) at P≤ 0.01 on colour value of 'L. It was observed that as the storage period increased; darkening of the fresh-cut banana pseudostem also increased which was reflected in terms of 'L' value. The initial 'L' value of the fresh-cut banana pseudostem was recorded as 72.57 and gradual decrease of 'L' value was observed and minimum 'L' value was in T_2 (16.2%) in 30 days of storage at refrigerated condition (8±2°C). Alez *et al*. (1993) also reported that the lightness ('L' value) of 'Red Delicious' apple rings decreased with increase of storage period. Caner *et al*. (2008) reported that the 'L' value decreased from 30.87 to 28.65 in 10 days of storage for MAP of strawberries packaged in LDPE pouch. 'L' value had maximum change of about 45 per cent in control after 30 days of storage.

Change in 'a' value for fresh-cut banana pseudostem:

The effect of storage period on 'a' value of MAP fresh-cut banana pseudostem is presented in the Table 1. There was significant effect of treatment (packaging material × active and passive MAP) at P≤ 0.01 on colour value of 'a'. The initial 'a' value of fresh-cut banana pseudostem was recorded as 1.56. The 'a' value increased with storage period.Gonzalez *et al.* (1993) reported that a decrease in 'L' value and an increase in 'a' value are indicatives of browning. From the table, it is evident that increase was minimum change in passive MAP of about 32.7 per cent 30 days of storage under refrigerated condition. Maximum increase of 'a' value was seen in T_1 (70 %) on 30th day of storage. Sothornvit and Kiatchanapaibul (2009) reported that colour change

Table 1 : Effect of storage period on colour value for MAP of fresh-cut banana pseudostem

Reatment	Colour value											
	8±2°C storage days											
	L				a				b			
	0	10	20	30	0	10	20	30	0	10	20	30
Control (T_1)	72.6	50.24^{d}	46.14d	39.48d	1.56	3.06d	4.12e	4.77d	22.2	17.24c	16.11d	14.06c
Passive atmosphere (LDPE)- T_2	72.6	70.18^{a}	66.42a	60.81a	1.56	1.62a	1.86a	2.32a	22.2	21.96a	19.32a	17.74a
Passive atmosphere (PP)- T_3	72.6	66.62^{ab}	59.24b	52.23b	1.56	1.78a	2.04b	2.68b	22.2	21.14a	18.17b	16.06b
Active atmosphere (LDPE)-T_4	72.6	64.42^{b}	56.11b	50.21b	1.56	2.02b	2.96c	3.34c	22.2	20.62ab	18.42b	16.68ab
Active atmosphere (PP)-T_5	72.6	55.51^{c}	49.12c	44.42c	1.56	2.84c	3.41d	3.82c	22.2	19.48b	17.76c	15.53b

Means are the average of 3 determination and means in a column followed by same letter are not significantly different at p ≤ 0.05 among treatments.

Table 2 : Effect of storage period on bacterial and fungal growth for MAP of fresh cut banana pseudostem

Treatments	Bacteria (10^5 CFU/g)				Fungi (10^3 CFU/g)			
	8±2°C (Storage days)							
	0	10	20	30	0	10	20	30
Control (T_1)	2.24	4.96^{d}	6.62^{e}	8.48^{e}	4.23	6.81^{c}	8.42^{d}	10.68^{e}
Passive atmosphere (LDPE)- T_2	2.24	2.58^{a}	3.92^{a}	4.96^{a}	4.23	4.96^{a}	5.92^{a}	7.31^{a}
Passive atmosphere (PP)- T_3	2.24	3.14^{b}	4.36^{b}	5.62^{b}	4.23	5.82^{b}	6.77^{b}	8.56^{c}
Active atmosphere (LDPE)-T_4	2.24	3.06^{b}	4.84^{c}	6.11^{c}	4.23	5.52^{b}	6.22^{a}	8.01^{b}
Active atmosphere (PP)-T_5	2.24	4.12^{c}	5.42^{d}	6.92^{d}	4.23	6.46^{c}	7.46^{c}	9.12^{d}

Means are the average of 3 determinations and means in a column followed by same letter are not significantly different at p ≤ 0.05 among treatments

of fresh-cut asparagus dependent on storage period

It is seen that irrespective of storage environment, the refrigerated condition was more suitable for fresh-cut banana pseudostem in order to retain the 'a' value. The packaging materials and active MAP did not affect the 'a' value upto 30 days of storage.

Changes in 'b' value for MAP of fresh-cut banana pseudostem:

The effect of storage period, active and passive atmosphere and storage conditions at both ambient and refrigeration on 'b' value of fresh-cut banana pseudostem are shown in the Table 1. There was significant effect of treatment (packaging material × active and passive MAP) at $P \leq 0.01$ on colour value of 'b'. The initial 'b' value of fresh-cut banana pseudostem was recorded as 22.23. From the table, it can be seen that decrease was minimum in T_2 (20%) at 30th day of storage under refrigerated condition. The maximum loss of 'b' value was recorded in T_1 (54%).

The refrigerated condition was more suitable for fresh-cut banana pseudo stem in order to retain the 'b' value. From the results of colour value, it was observed that the pre-treated samples of banana pseudostem had minimum decrease in 'L' and 'b' value whereas in 'a' value there was a minimum increase under passive MAP at 8±2°C.Apintanapong *et al.* (2007) reported that for pre-treated banana slices had the lowest change of L* and b* that representedless browning and blueness.

Change in fibre content for MAP fresh-cut banana pseudostem:

Fibre is a indigestible cell wall component of plant materials which plays an important role in human health. The initial fibre content of fresh-cut banana pseudostem was 0.8 g/100g. The fibre content at both ambient and refrigerated condition does not change during the storage period and it remained as such upto its storage days. This may be due to the fact that the fibre is relatively inert and not sensitive to degradation during storage.

Microbial growth for MAP fresh-cut banana pseudostem:

The effect of storage period on the microbial growth of fresh-cut banana pseudostem are presented in the Table 2 (bacteria and fungi). There was significant effect on treatment (packaging material × active and passive MAP) of fresh-cut banana pseudostem at ($P \leq 0.01$) on the bacterial and fungal growth. The initial bacterial and fungal population of the fresh-cut banana pseudostem was 2.24×10^5cfu/g and 4.23×10^3cfu/g, respectively. As the storage period increased, the microbial growth also increased due to oxidative reactions. The KMS act as antimicrobial agents which is freely soluble in water forming sulphurous acid, bisulphate and sulphite ions. Sulphurous acid blocks enzymes of the micro -organism by reducing essential disulphide (-S-S-) linkage.

The bacterial and fungal growth was less in T_2 (4.96×10^5cfu/g,7.31×10^3cfu/g) after 30 days of storage in passive MAP. Active MAP had more water loss resulting in higher relative humidity inside the pouch which would have facilitated the growth of microbial population. Srinivasa *et al*. (2002) reported that microbial growth increased inside the package due to more condensation of water from the vegetables. Steen *et al*. (2002) reported that for fresh cut produce the atmospheric air packaging inhibits the growth of micro-organism, prevent undesired anaerobic respiration and maintain the quality.Willocx, (1995) reported that refrigerated condition is the most suitable or fresh-cut vegetables. The LDPE packaged fresh-cut banana pseudostem showed less growth of micro-organism than PP film and this could be due to less water vapour transmission rate in LDPE. Matche and Baldev, (2006) reported that PP (7-9 % g/m^2/day) had more water vapour transmission rate than LDPE (14-18 % g/m^2/day). From the results, it was concluded that the pre-treated fresh-cut banana pseudostem packaged in LDPE under passive atmosphere had lesser

Table 3: Sensory evaluation of fresh-cut banana pseudostem stored under MAP condition

Treatments	Appearance	Colour	Texture	Flavour	Taste	Overall acceptability
Fresh sample	8.2	8.4^{a}	8.2^{a}	8.3^{a}	8.1^{a}	8.21^{a}
Active MAP- LDPE (T_2)	8.1	8.1^{b}	7.6^{b}	8^{a}	7.6^{ab}	7.88^{ab}
Active MAP- PP (T_3)	7.8	7.7^{bc}	7.2^{bc}	7.4^{b}	7.2^{bc}	7.46^{bc}
Passive MAP-LDPE (T_4)	7.6	7.5^{dc}	6.8^{c}	7^{b}	6.8^{cd}	7.14^{cd}
Passive MAP-PP (T_5)	7.1	7.1^{d}	6.2^{d}	6.4^{c}	6.4^{d}	6.64^{d}

Means are the average of 3 determination and means in a column followed by same letter are not significantly different at $p \leq 0.05$ among treatments

microbial growth.

Sensory evaluation for MAP of fresh-cut banana pseudostem:

The microbial quality is the main parameter in determining the product shelf-life. From the results obtained for the microbial analysis, it was observed that the samples (T_2, T_3, and T_4 and T_5) were within the safe. Hence, the above samples were taken for conducting the sensory evaluation. Curry was prepared from selected samples and were evaluated based on the nine -point hedonic scale.

From the Table 3, it is observed that, the fresh sample scored overall acceptability of 8.21. Among all the samples, the passive MAP of fresh-cut banana pseudostem scored maximum overall acceptability of 7.88 (T_2) followed by T_4, T_3 and T_5. The passive MAP of fresh-cut banana pseudostem had 30days of shelf-life with good colour and texture.Gomez and Arte (2005) also reported that MAP packaged cerely sticks scored maximum in sensory attributes. There was significant effect on treatment (packaging material × active and passive MAP) of fresh-cut banana pseudostem at $P \leq 0.01$ on sensory evaluation.

Conclusion:

The fresh-cut banana pseudostem has minimum loss in quality during its storage period so MAP is a suitable technology to extend its shelf-life. In both active and passive MAP, the shelf-life of fresh-cut banana pseudostem can be stored upto 30 days. The passive MAP technology is more economical compared to active MAP for fresh-cut banana pseudostem.

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