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Effects of moisture barrier and initial moisture content on the storage life of some horticultural produce in evaporative coolant

Iwuagwu, Christian C.[1]* and N. J. Okonkwo[2]

Department of Crop Science/Horticulture, Nnamdi Azikiwe University, Awka, Anambra State Nigeria.

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Shelf-life of five horticultural produce were studied. These include three leafy vegetables: *Telfairia occidentalis, Celosia argentea* and *Amaranthus cruentus* and two fruit vegetables: *Lycopersicum esculentum* and *Abelmuschus esculentus*. The layout plan of the experiment was a 3x2 factorial in a completely randomized design and each treatment replicated three times. The two factors examined were moisture barrier at three levels namely: thick lining, thin lining and non-lining. The other factor included initial moisture content of the produce, namely, turgid and partially wilted. Partial wilting of the produce was achieved by exposing freshly harvested materials at ambient temperature to dry for 45 min. During this period, about 20% of the moisture content was lost. Eighteen (18) vegetable baskets which work on the principle of evaporative cooling system were used. Each type of produce was stored at a time inside the vegetable basket. Some quantity of each produce were kept on the laboratory benches to serve as controls. Data recorded includes length of storage of produce, severity of disease infection, visual quality, disease incidence, ambient temperature and relative humidity of the storage baskets. The result indicates that there was a significantly higher relative humidity (P< 0.05) in the lined baskets than in the non-lined baskets. Consequently, the shelf-life of produce in lined basket was prolonged. Turgid produce had better quality retention and stored much longer than partially wilted produce. Generally, the evaporative coolant baskets provided an average temperature of 3°C lower than the ambient condition. The shelf-life of leaf vegetables *T. occidentalis, C. argentea* and *A. cruentus* was extended appreciably for 78 days compared to the controls.

Key words: Evaporative coolant, moisture barrier, shelf-life of horticultural produce.

INTRODUCTION

Post-harvest loss is the bane of agricultural production in Nigeria. Available data indicated that postharvest losses may be as high as 50% and above in Nigeria (Mbuk et al., 2011; Nwufo et al. 1990). This stemmed from the fact that fruits and vegetables are classified as highly perishables produce (Piet et al., 2011, Kay and Pallas, 1991). Once harvested, they tend to shrivel, wilt or rot at a very fast rate. This is due to their relatively high moisture content, soft texture and high respiration rate (Atanda et al., 2011).

Large quantities of fruits and vegetables may be produced during the growing season but due to lack of effective postharvest handling, much of the produce are wasted and millions of naira are spent in importing their concentrates. This then makes postharvest management of fruits and vegetables very important in any food sufficiency programme in Nigeria. Moreover, it will help to stabilize prices by carrying over produce period of high

*Corresponding author. E-mail: chrisiwuag@yahoo.com.

production to period of low production (Agoda et al., 2011). Therefore, adequate storage should help to solve the problems of excess supply during the fruiting season when supply exceeds demands with the consequent low prices (Idah et al., 2007).

To achieve adequate storage, therefore, appropriate technologies should be applied. These technologies should be available to farmers adequately, affordable and easily adoptable (Ife and Bas, 2003). Evaporative coolant system (ECS) is an example of such technology in which principles the vegetable basket works (Nwufo et al., 1990). The evaporative coolant system is adoptable to environment where most of the rural farmers live. Most poor resource farmers cannot afford storage by refrigeration, irradiation and use of chemical control which may be adequate but not affordable by most farmers. ECS is a process of producing a cooling effect as a result of evaporation of liquid; electricity is not needed. It is based on the principles of adiabatic cooling of unsaturated air when in contact with water (liquid) for a sufficiently long time. The evaporative coolant is capable of reducing the temperature and producing appropriate humidity suitable for tropical fruits and vegetables (Amrat et al., 2013).

The vegetable basket has room for further modification, such as lining with polyethylene materials to enhance its effectiveness. According to Shukla et al. (2010), another method of reducing water loss from horticultural crops is placing physical barrier around the produce which also reduces air movement across the surface. Liberty et al. (2013a, b) reported that the use of very thin plastic wraps and heat - shrink films for packaging individual fruits is practiced in postharvest handling of fruits.

Another factor that influences post-harvest life of perishable produce is the initial quality of the produce before storage. Leaves attached to their parent plant function primarily to the acquisition of carbon through photosynthesis. After harvest, all these functions are not as operative as before harvest, the leaf losses its potential as energy source after harvest. With detachment from the parent plant, leaves can no longer replenish water lost through trans-piration. Therefore, since water loss from the harvested leafy vegetables is inimical to the shelf life of the produce, their initial moisture content will determine their shelf life. The rate of water loss is modulated by the nature of the produce and the environmental condition in which it is stored. The objective of the study was to investigate factors that affect the effectiveness of vegetable basket in the preservation of horticultural produce.

MATERIALS AND METHODS

Five horticultural produce were used in this experiment. It was a 3x2 factorial experiment laid out in a completely randomized design and replicated three times. The two factors namely: Moisture barrier at three levels: thick lining, thin lining and non-lining. The second factor was moisture content of the produce at two levels - turgid and partially wilted. The freshly harvested vegetables were exposed to room drying for 45 min during which 20% of moisture content were lost. From preliminary test, produce exposed to drying for more than this period could not regain their turgidity after rewetting. Eighteen (18) vegetable baveets, which function on the principles of evaporative cooling, were used. The moisture barrier was made of polyethene materials of two different gauges; these materials were used to line inner surfaces of the rectangular shaped vegetable baskets. The vegetables basket were made of cane or wooden frame and covered with absorbent materials such as jute materials. The baskets were wetted with tap water on the outside surfaces, two times daily. Each of the horticultural produce was stored one at a time.

Data recorded included, temperature and humidity inside the vegetable baskets and the ambient, length of storage, disease incidence and severity and visual qualities. Temperature readings were measured with the use of laboratory thermometer while humility was measured with thermocouple. Disease severity was assessed on a five point score as suggested by Snedecor and Cochran (1967) for subjective evaluation. The grading score is as follows: 1, no disease; 2, trace; 3, slight; 4, moderate; 5, server disease. Similarly, the visual qualities were graded on a five - point score as follows: 5, very fresh and no trace of colour bleaching; 4, fresh and fairly green; 3, slightly fresh and slightly bleached; 2, poorly fresh and bleached; 1, on set of deterioration. Disease incidence was determined thus:

$$\text{Disease incidence} = \frac{\text{Number of spoilt fruits due to x}}{\text{Total number of fruit sampled}}$$

Where, x = type of disease symptom.

RESULTS

Effect of lining and initial moisture content of produce on produce quality

Produce quality

Colour: Lining with polyethylene and initial moisture content of produce had significant effect on the quality criteria during the storage of all the horticultural produce. Table 1 shows that lining, initial moisture content of produce and; lining x initial moisture content significantly affected the colour of the three leaf vegetables: *Telfairia, Amaranthus* and *Ceiosia*.

For *Telfairia,* thick lining had the highest colour grade (5.0) which was significantly higher than thin lining and non-lining (4.3 and 4.2, respectively) (Table 1). Thin lining and non-lining did not differ with each other. In *Amaranthus,* thick and thin lining had identical and higher colour grade (3.3) than non-lining (1.8). Also, in *Celosia,* thick and thin lining had significantly higher colour grade but only thin lining was significantly higher than non-lining. Initial moisture content of *Telfairia* did not affect colour quality but in *Amaranthus* and Celosia turgid produce had significantly higher colour quality than partially wilted produce. For *Telfairia,* thick lining x turgid and partial wilting had maximum colour grade of 5.0 as well as thin lining x turgid moisture content and non-lining x partial willed. These high colour quality grades were

Table 1. Effect of lining and initial moisture content of produce on the colour of three vegetables stored in vegetable basket for 8 days.

Lining (LN)	Initial moisture (IM) content of product	*Telfairia*	Mean of lining	*Amaranthus*	Mean of lining	*Celosia*	Mean of lining
Thick lining	Turgid	5.0	5.0	4.3	3.3	3.3	2.7
	Partially Wilted	5.0		2.3		2.0	
Thin lining	Turgid	5.0	4.3	3.7	3.3	5.0	3.3
	Partially Wilted	3.7		3.0		1.7	
Non-lining	Turgid	3.0	4.2	2.3	1.8	3.0	2.3
	Partially wilted	5.0	0.42	1.3	0.84	1.26	0.89
LSD 0.05 LN x IM		0.59	0.42	1.19	0.84	1.26	0.89
Mean on initial moisture content of produce	Turgid	4.4		3.4		3.8	
	Partially wilted	4.6		2.2		1.8	
LSD (0.05)		NS		0.68		0.73	

Table 2. Effect of lining and initial moisture content of produce on the colour of two fruit vegetables stored in vegetable basket for 8 days.

Lining (LN)	Initial moisture (IM) content of product	Okra	Mean of lining	Tomato	Mean of lining
Thick lining	Turgid	3.7	3.8	3.7	3.3
	Partially wilted	4.0		3.0	
Thin lining	Turgid	3.3	1.3		3.7
	Partially wilted	3.3		3.3	
Non-lining	Turgid	2..3	2.0	3.3	2.8
	Partially wilted	1.7		3.3	
LSD 0.05 LN x IM		0.94	0.66	NS	NS
Mean on initial moisture content of produce	Turgid	3.1		3.3	
	Partially wilted	3.0		2.9	
LSD (0.05)		NS		NS	

significantly higher than thin lining x partial wilting (3.7) and non-lining x turgid moisture content (3.0).

For *Amarunthus,* the highest colour score was in thick lining x turgid produce (4.3), which did not differ significantly from thin lining x turgid moisture but was higher than the rest of the treatment combinations. For *Celosia*, the highest quality scores (5.0) (Table 1) was produced in thin lining x turgid produce, which was significantly higher than other combinations at both levels of initial moisture content. Thick lining x turgid and non-lining x turgid produce had similar colour grade (3.3 and 3.0, respectively) which were significantly higher than partially wilted produced at all lining levels, except thick lining x initial moisture with a score of 2.0 which was statistically similar to non-thinning x turgid.

On fruit vegetables (Table 2), lining significantly affected the colour quality in okra but not in tomato; thick lining produced the highest colour score of 3.8. Initial moisture content did not affect colour quality in both crops. Lining x initial moisture content significantly affected the colour quality grade of okra but not of tomato. The highest colour grade (4.0) in okra (Table 2) occurred in thick lining x partially wilted which was not significantly different from thick lining x turgid produce (3.7). The lowest colour score of 1.7 was produced in non-lining x partially wilted moisture content in okra (Table 2).

Freshness

The result in Table 3 shows that lining and initial moisture content significantly affected the freshness of all the three leaf vegetables. Turgid moisture content consistently produced higher score on freshness quality for all three leaf vegetables than partially wilted moisture content, which consistently produced the lower scores on freshness (Table 3). Also lining x initial moisture content had significant effect on freshness of the three horticultural produce. The highest score 'of freshness (5.0) (Table 3) was produced in *Telfairia* by thick lining x turgid moisture content. This did not differ significantly with thin lining x turgid moisture content (4.7). Other combinations were statistically 'different from each other

Table 3. Effect of lining and initial moisture content of produce on freshness of three vegetables stored in vegetable baskets.

Lining (LN)	Initial moisture (IM) content of product	*Telfaira*	Mean of lining	*Amaranthus*	Mean of lining	Celosia	Mean of lining
Thick lining	Turgid	5.0	4.0	4.7	3.3	4.0	3.5
	Partially wilted	3.0		2.0		3.0	
Thin lining	Turgid	4.7	3.8	4.7	4.2	4.3	3.0
	Partially wilted	3.0		3.7		1.0	
Non-lining	Turgid	4.0	3.2	2.3	1.8	2.0	1.6
	Partially wilted	2.3		1.3		1.7	
LSD 0.05 LN x IM		0.59	0.42	1.19	0.84	1.03	0.73
Mean on initial moisture content of produce	Turgid	4.6		3.9		3.4	
	Partially wilted	2.8		1.6		2.1	
LSD (0.05)		0.34		0.22		0.59	

Table 4. Effect of lining and initial moisture content of produce on freshness of two fruit vegetables stored in vegetable baskets.

Lining (LN)	Initial moisture (IM) content of product	Okra	Mean of lining	Tomato	Mean of lining
Thick lining	Turgid	3.7	3.2	3.3	2.3
	Partially wilted	2.7		1.3	
Thin lining	Turgid	2.7	2.3	2.3	1.8
	Partially wilted	2.0		1.3	
Non-lining	Turgid	2.7	2.3	2.7	2.8
	Partially wilted	2.0		3.0	
LSD 0.05 LN x IM		0.84	0.59	1.19	0.84
Mean on initial moisture content of produce	Turgid	3.0		2.8	
	Partially wilted	2.2		1.9	
LSD (0.05)		0.84		0.68	

in *Telfairia.* The lowest score of freshness (2.3) was produced by non-lining x partially wilted moisture content. Lining significantly affected the freshness of *Telfairia,* thick lining produced the highest score followed by thin lining, while the least was non-lining. This trend was repeated in *Celosia* for *Amaranthus,* thin lining produced the highest freshness followed by thick lining and non-lining being the least.

For *Amaranthus,* the highest score on freshness quality (4.7) was produced by thick lining x turgid moisture content and thin lining x turgid moisture. The least freshness score (1.3) was produced by non-lining x partially wilted. For *Celosia,* thin lining x turgid moisture content with a score of (4.3) was statistically higher than all other combinations except thick lining x turgid moisture content (4.0). Non-lining x partially willed (1.7), non-lining x turgid produce (2.0), thin lining x partially wilted (1.0) were statistically similar and had the lowest freshness scores. On fruit vegetables (Table 4), lining and initial moisture content significantly affected the freshness of two fruit vegetables okra and tomato.

For fruit vegetables (Table 4), thick lining produced the highest score but thin-lining and non-lining were the same in okra. For tomato, non-lining produced the highest score (2.8) followed by 2.3 score in thick lining while the least was 1.8 score produced in non-lining. For okra, the highest freshness of 3.7 score was produced by thick lining x turgid moisture content, while the lowest quality was observed in thin lining x partially willed and non-lining x partially wilted moisture content produced significantly higher score than the other combinations. For tomato, the highest quality score of 3.3 was also produced by thick lining x turgid moisture content, followed by the score of 3.0 (Table 4) produced by non-lining x partially wilted and 2.7 score observed in non-lining x turgid moisture content. These were statistically similar and higher than the other lining x turgid moisture content which consistently produced a higher quality score than partially willed. Generally, the freshness scores in fruit vegetables were lower than those in leaf vegetables.

Length of time of storage

Table 5 shows that both lining and initial moisture content

Table 5. Effect of lining and initial moisture content of produce on length of time of storage (days) of three leaf vegetables stored in vegetable basket.

Lining (LN)	Initial moisture (IM) content of product	*Telfaira*	Mean of lining	*Amaranthus*	Mean of lining	*Celosia*	Mean of lining
Thick lining	Turgid	7.7	6.0	7.7	6.0	7.7	6.0
	Partially wilted	4.3		4.3		4.3	
Thin lining	Turgid	7.0	5.7	7.0	5.5	7.3	5.5
	Partially wilted	4.3		4.0		3.7	
Non-lining	Turgid	4.3	3.8	3.3	5.7	4.5	4.7
	Partially wilted	3.3		3.3		4.0	
LSD 0.05 LN x IM		1.19	0.84	1.33	0.94	0.94	0.66
Mean on initial moisture content of produce	Turgid	6.3		6.8		6.9	
	Partially wilted	4.0		3.9		4.0	
LSD (0.05)		0.68		0.77		0.54	

Table 6. Effect of lining and initial moisture content of produce on length of time of storage (days) of two vegetables stored in vegetable basket

Lining (LN)	Initial moisture (IM) content of product	Okra	Mean of lining	Tomato	Mean of lining
Thick Lining	Turgid	3.7	3.5	5.0	4.3
	Partially wilted	3.3		3.7	
Thin lining	Turgid	3.7	3.5	4.7	4.2
	Partially wilted	3.3		3.7	
Non-lining	Turgid	3.0	2.8	3.0	3.0
	Partially wilted	2.7		3.0	
LSD 0.05 LN x IM		1.19	NS	1.03	0.73
Mean on initial moisture content of produce	Turgid	3.4		4.2	
	Partially wilted	3.1		3.4	
LSD (0.05)		NS		0.59	

had a highly significant effect on storage duration of the three leaf vegetables. Also lining x initial moisture content of the produce significantly influenced the length of time of storage of the three horticultural produce. For *Telfairia*, the longest storage time 7.7 days was produced in thick lining x turgid, followed by 7.0 days (Table 5) produced in thin lining x turgid. These two were significantly higher than the other combinations. The shortest storage time of (3.3 days) (Table 5) occurred in non-lining x partially wilted. Turgid produce stored longer than the partially willed in the *Telfairia* (Table 5).

For *Amaranthus* (Table 5) the longest time of storage (7.7 days) was produced in thick lining x turgid, and followed closely by 7.0 days in thin lining x turgid. As in *Telfairia*, these two were significantly higher than other lining x initial moisture treatment combinations. The shortest time of storage of 3.3 days (Table 5) was in non-lining x partially wilted. Turgid produce also has a longer-storage length than the partially wilted for *Amaranthus.*

In *Celosia* (Table 5), longest storage time (7.7 days) was in thick lining x turgid, followed by (7.3 days) in thin lining x turgid which did not differ significantly from each other. The shortest storage time of 3.7 days (Table 5) was produced in thin lining x partially wilted and it did not differ from other lining x partially willed combinations. Thick lining consistently produced a longer storage time than thin lining and non-lining materials. On fruit vegetables (Table 6), lining had a significant effect on tomato but not in okra. Thick lining and thin lining produced similar time of storage in tomato (4.3 and 4.2 days) but longer than non-lining (3.0 days). Also turgid produce stored longer than the partially willed in both vegetables, but was significant only in tomato. Lining x initial moisture content significantly affected the storage length in tomato but not in okra. The longest storage length of 3.7 days (Table 6) was produced in thick lining x turgid and thin lining x turgid in tomato. The least storage length was in non-lining x partially willed in tomato storage (2.7 days). In okra the longest time of storage 5.0 days (Table 6) was produced in thick lining x turgid followed by (4.7) produced in thin lining, x turgid, the least time of storage was produced in non-lining at both levels of initial moisture. Turgid 'produce stored best at all the three lining levels.

DISCUSSION

Effects of lining and initial moisture content on physical qualities of produce

The result also showed that lining and initial moisture content significantly enhanced colour and freshness retention in leaf vegetables. A mean quality score of 5.00, which is very fresh with no trace of bleaching, was obtained in both colour and freshness in leaf vegetable. This result is similar to Nwufo et al. (1990), who reported that sealed leaves in polyethylene bag which was similar to the lining used in this study maintained their green fresh appearance at low temperature. Aworh (2011) observed that leaf vegetables packed with polyethylene and polypropylene recorded the lowest weight loss compared to those packed with paper materials. The result also agrees with Imonikebe (2013) who suggested that films or other materials suitable enough should be used for the lining of boxes used for the transportation of perishable produce in Australia.

The physical qualities of the fruit vegetables were considerably depressed. A mean quality colour and freshness score of 3.3 and 2.6 were obtained, respectively. This result is in disagreement with Babatola (1998) who reported that mature green tomatoes stored in the evaporative coolants system retained their colour and firmness. He obtained a quality scale of 4 indicating the fruit were very firm. The reason for the difference could be because of the difference in the age and ripeness of fruit used. Also, the high humidity favoured the growth of micro-organisms which intensified the deterioration of the ripe fruit vegetables used in this study. This is in agreement with Obetta et al. (2011) who reported that the benefits of storage humidity manipulations were not at the expense of losses due to decay by mycopathogens.

Effects of lining and initial moisture content on length of storage of produce stored in vegetable basket

The result shows that leaf produce stored in the vegetable basket lasted longer than those stored on the laboratory bench. This is in agreement with the report of Amrat et al. (2013) who reported that evaporative coolant system is appropriate for storage if many tropical leaf vegetables. This is in disagreement to Babatola (1998) who in his earlier work on shelf-life extension of green tomato fruits using evaporative coolant system reported that ECS gave the best quality followed by refrigerator and open shelf in terms of colour, firmness, weight loss and day to ripening. The disagreement could be because the fruit vegetables used in this study were already ripe, and storage in evaporative coolant could not stop further deterioration. Rather, fruit vegetables stored on laboratory benches lasted longer than those stored in the evaporative coolants. This could be as a result of lower humidity on the laboratory bench compared with higher humidity in evaporative coolants which enhances deterioration of already turgid fruit vegetables.

Conclusion and recommendation

Post-harvest preservation of fruits and vegetables is a sure way of achieving sustainability in global food supplies; increased production will do little to alleviate poverty and over-come distribution problem that already plague the world food supplies without adequate postharvest preservation. To ensure adequate storage and shelf- life extension of fruits and vegetable, least expensive but adequate and easily affordable technology such as vegetable basket is indispensible.

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