EFFECT OF WATER QUALITY AND AIR MOVEMENT ON THE PRESERVATION OF FRESH AGRICULTURAL PRODUCE IN VEGETABLE BASKETS

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ABSTRACT

Studies were carried out on the quality of water treatments and air movement on stored fresh vegetable produce. Three water qualities including open stream, tap and disinfected water and two air movements comprising natural and enhanced air were tested. Controls were maintained on benches at ambient laboratory conditions. Freshly harvested leafy vegetables used included fluted pumpkin (*Telfairia occidentalis* (H.), Indian spinach (*Celosia argentea* L.) and African spinach (*Amaranthus cruentus* L.). The fruit vegetables were tomato (*Lycopersicom esculentus* M.) and okro (*Abelmoschus esculentus* L.). A total of eighteen vegetable baskets serving as evaporative coolants were used as the storage packages. The temperature and relative humidity inside the baskets and the ambient surroundings during the experimental period were recorded. Other parameters recorded included length of storage, disease incidence and frequency, severity of infection and visual quality of produce. Results showed that quality of water treatment did not produce any significant effect. However, enhanced air movement significantly ($P<0.05$) reduced both the temperature and relative humidity within the produce to about 3°C±1 lower than the ambient conditions. Shelf lives of the produce were 2 to 5, 2 t o8 and 2 to 6 days longer for *T. occidentalis*, *C. argentea* and *A. cruentus*, respectively. The shelf lives of the fruit vegetables were 14 and 8 days at ambient condition; 8 and 4 days in the coolant baskets for *A. esculentus* and *L. esculentus*, respectively. Fungal isolates from spoilt produce included *Fusarium moniliforme* (S.), *Rhizopus stolonifer* (C.), *Cladosporium fulvum* (E.), *Aspergillus niger* (T.), *Curvularia lunata* (W.) and *Cochliobulus miyabeanus* (I.).

Key words: Water quality, air movement, storage of fresh vegetables.

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INTRODUCTION

Postharvest loss has been defined as any change in the availability, edibility and wholesomeness or quality of food that prevent it from being eaten by man (Mbuk *et al*. 2011). Fruits and vegetables are classified as very highly perishable produce in their natural state after harvest (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 respiration rate (Atanda *et al*.2011).Postharvest is the bane of agricultural production in Nigeria. Available data indicate that postharvest losses may be as high as 50% and above in Nigeria (Agoda et *et al*.2011). This emphasizes the fact that it is not sufficient for the nation to plan a food sufficiency programme, if appropriate measures are not identified and specified for minimizing postharvest losses from the field to marketing (Shulka *et al.* 2010, Imonikebe, 2013). In fact, large quantities of fruits and vegetables are being 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(Aworh ,2011). 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 production to period of low production (Agoda *et al*. 2011).Therefore, adequate storage should help to solve the problem of excess supply during the fruiting season when supply exceeds demand with consequent low prices (Idah *et al*. 2007).

Also environmental factors which hasten deterioration of produce after harvest must be modified appreciably to provide suitable atmosphere for the storage of these produces .This is achieved through appropriate technology. The technology should be available, adequate, affordable and easily adoptable to farmers (Amrat *et al*.2013).An example of an appropriate technology is the evaporative coolant system (ECS) or the vegetable basket (Nwufo *et al*.1990).

The evaporative coolant is adaptable to the environment where the 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. Evaporative coolant system (ECS) is a process of producing a cooling effect as a result of evaporation of liquid (Liberty *et el.* 2013a). Electricity is not needed .It is based on the principle of adiabatic cooling of unsaturated air when it comes in contact with water (liquid) for a sufficiently long time (Liberty *et al.* 2013b). Evaporative coolant is capable of reducing the temperature and producing appropriate humidity suitable for the storage of many tropical fruits and vegetables (Amrat *et al.2013).*

THE VEGETABLE BASKET

The vegetable basket is a model of an evaporative coolant as earlier said. The frame of the basket is constructed with raffia fronds or cane and flexible materials (NSPRI, 1990). They are constructed at different capacities depending on need and financial disposition of the farmers. Both inside and outside of the box frame are lined with thick absorbent materials such as jute bag (NSPRI, 1990). The lining must be well fitted on the surface of the frame so as to have smooth surface without folds

OBJECTIVE OF THE STUDY

To investigate some factors that affect effectiveness of vegetable basket in the preservation of horticultural produce.

MATERIALS AND METHOD

A total of eighteen "vegetable baskets" were used for the storage. The experiment consisted of two factors: water quality and air movement. Three levels of water included: open stream water, tap water and disinfected water. Air movement had two levels: natural air movement and enhanced air movement. There were a total of 3 x 2 treatment combinations with three replications. The experiment was laid out in a completely randomized design. The experiment was carried out at the green house laboratory of University of Nigeria Nsukka. The vegetable which were harvested fresh from the University experimental farm were wetted with these sources of water. Enhanced air movement was achieved by the use of ceiling fan{ newclime },which were ran at number 5 point of the regulator. The five produce were used in the experiment. Each produce was stored at a time.

DATA COLLECTION

Data were collected on the following: temperature and relative humidity which were measured by the use of the thermocouple and hygrometer respectively, number of days of storage of producer without visible deterioration, severity of the pathogenic disease infection, produce visual quality characteristics after storage. Quality attributes included fresheners and colour: These were measured by using a five point grading score as suggested by Snedecor et al (1967), for subjective evaluation. The grading scores for visual attributes are as follows.

5 = Very fresh and trace of colour bleaching

4 = Fresh and fairly green

3 = slightly fresh and slightly bleached

2 = poorly fresh and bleached

1 = Onset of deterioration

The severity of pathogenic disease infection was also measured by the use of a five point score which are as follows:

1 = No disease

2 = Trace

3 = Slight

4 = Moderate

5 = Severe disease

Disease frequency: For disease frequency, the total number of spoilt fruits after storage was counted. The spoilt fruits due to pathogenic factor were sorted according to the similarities of the symptoms observed on them. The percentage incidence of each disease type was calculated as follows:

$$\frac{\text{Number of spoilt fruits due to x}}{\text{Total number of spoilt fruits}} \times \frac{100}{1}$$

Where x = type of disease symptom

Disease incidence: The disease incidence was calculated thus:

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

Where x = type of disease symptom

RESULTS AND DISCUSSION

Effect of Water Quality and Air Movement on Produce Quality in the Evaporative Coolant

Produce Quality: Colour

Water quality and air movement had significant effects on the colour quality of the five horticultural produce stored. The result on (table 1) showed that among the three leaf vegetables, water quality significantly affected the colour of *Amaranthus* but not *Telfairia* and *Celosia.* Open stream produce the highest colour quality (4.39) while tap water and disinfected water were similar. Air movement on the other hand did not affect colour quality of two vegetables – *Telfairia* and *Amaranthus* but it significantly affected colour quality of *Celosia* where natural air movement (4.22) was better than enhanced (3.89).

Water quality x Air movement had significant effect on colour quality of *Telfairia* and *Amaranthus* but not on *Celosia.* The highest quality in *Telfairia* with score of 4.0 was in tap water x Natural air movement. The other combinations did not differ among themselves. For *Amaranthus,* open stream x natural air movement had the highest colour grade of 4.67 which was significantly higher than tap water at both natural and enhanced air movement and disinfected water at enhanced air movement each with a score of 3.67

On fruit vegetables (Table 2), water quality significantly affected produce colour quality. Disinfected water produced the highest colour quality in both Okra, with a score of 4.0 and tomato with a score of 3.83 while open stream water produced the least colour quality which were 3.50 in Okra and 3.17 in tomato

Table 1: Effect of water quality and air movement on colour of three leaf vegetable stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Telfairia*	Mean of Water Quality	*Amaranthus*	Mean of Water Quality	Celosia	Mean of Water Quality
Open Stream	Natural	3.67	3.50	4.67	4.33	4.33	4.17
	Enhanced	3.33		4.00		4.00	
Tap Water	Natural	4.00	3.83	3.67	3.67	4.33	4.17
	Enhanced	3.67		4.00		4.00	
Disinfected	Natural	3.67	3.67	4.00	3.83	4.00	3.83
	Enhanced	3.67		3.67		3.67	
LSD0.05WQ×AM		0.50	NS	0.69	0.49	NS	NS
Mean of Air Movement	Natural	3.78		4.11		4.22	
	Enhanced	3.58		3.78		3.89	
LSD(0.05)		NS		NS		0.51	

Table 2: Effects of water quality and movement on colour of two fruit vegetables stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Okro*	Mean of Water Quality	*Tomato*	Mean of Water Quality
Open Stream	Natural	4.00	3.50	3.33	4.33
	Enhanced	3.00		3.00	
Tap Water	Natural	3.67	3.67	3.67	3.67
	Enhanced	3.67		3.67	
Disinfected	Natural	4.00	4.00	3.67	3.83
	Enhanced	3.67		4.00	
LSD0.05WQ×AM		0.20	0.10	0.39	0.28
Mean of Air Movement	Natural	3.89		3.56	
	Enhanced	3.56		3.56	
LSD(0.05)		0.03		NS	

On the other hand, air movement affected colour quality of Okra but not tomato. Natural air movement produced better produce colour in Okra than enhanced air movement.

Water quality x air movement produced significant effect on colour quality of Okro and tomato (Table 2). In Okro the highest colour grade which was 4.0, occurred in open stream water x natural air movement, and at disinfected water at both natural and enhanced air movement. These were higher than tap water at both natural and enhanced air movement, each with a colour grade of 3.67. The least colour grade in Okro was recorded in open stream x enhance air movement with a colour grade of 3.0. In tomato, the lowest colour grade was also 3.0, and it occurred in open stream x enhanced air movement while the highest colour grade (4.0) was in disinfected water x enhanced air movement.

Freshness

Table 3 showed that in the three leaf vegetable, water quality significantly affected only the freshness of *Amaranthus* but not *Telfairia* or *Celosia.* Disinfected water produced the highest score of 4.83 while open stream and tap water had identical score 4.33 each in *Amaranthus.* Air movement on the other hand did not affect the freshness of any of the three vegetables significantly.

Water quality x air movement had a significant effect on freshness of produce in all the three leaf vegetables – *Telfairia, Amaranthus* and *Celosia.* The highest quality score in *Telfairia,* 4.67 was in tap water x enhanced air movement while the lowest score of 3.67 was in disinfected water x air movement. The other combination did not differ significantly among themselves in *Telfairia.*

The highest quality score in *Amaranthus* was 5.00 (Table 3), observed in disinfected water x natural air movement, while the lowest was in tap water× natural air movement with a score of 4.0. Disinfected water× natural air movement, which had the highest score,

Table 3: Effect of water quality and air movement on freshness of three leafy vegetables stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Telfairia*	Mean of Water Quality	*Amaranthus*	Mean of Water Quality	Celosia	Mean of Water Quality
Open Stream	Natural	4.33	4.33	4.33	4.33	4.67	4.50
	Enhanced	4.33		4.33		4.33	
Tap Water	Natural	4.00	4.33	4.00	4.33	3.67	4.17
	Enhanced	4.67		4.67		4.67	
Disinfected	Natural	4.33	4.00	5.00	4.83	4.67	4.50
	Enhanced	3.67		4.67		4.33	
LSD0.05WQ×AM		0.50	NS	0.40	0.28	0.59	NS
Mean of Air Movement	Natural	4.22		4.44		4.44	
	Enhanced	4.22		4.56		4.33	
LSD(0.05)		NS		NS		NS	

significantly differed from open stream x natural and enhanced air movement each had a score of 4.33. In *Celosia,* the highest quality scores were observed in open stream x natural air movement, tap water x enhanced air movement and disinfected water x natural air movement each with a score of 4.67. They did not differ significantly from open stream x enhanced air movement and disinfected water x enhanced air movement each with a score of 4.33, but differed with tap water x natural air movement with a score of 3.67. On fruit vegetable (Table 4), water quality affected freshness in Okro and in tomato. Tap water produced the highest produce freshness in both Okro and tomato. In Okro disinfected water also produced a significantly better freshness

Table 4: Effects of water quality and movement on freshness of two fruit vegetables stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Okro*	Mean of Water Quality	*Tomato*	Mean of Water Quality
Open Stream	Natural	3.33	3.33	1.67	1.50
	Enhanced	3.33		1.33	
Tap Water	Natural	3.67	4.17	2.00	1.83
	Enhanced	4.67		1.67	
Disinfected	Natural	4.00	3.88	1.00	1.33
	Enhanced	3.67		1.67	
LSD0.05WQ×AM		1.09	0.27	0.40	0.28
Mean of Air Movement	Natural	3.67		1.56	
	Enhanced	3.89		1.56	
LSD(0.05)		0.18		NS	

than the open stream water. But in tomato disinfected water had identical freshness as open stream. Natural air movement produced a better freshness quality in Okro than enhanced air movement, while in tomato enhanced air movement and natural air movement did not differ.

Water quality x air movement significantly affected the freshness of Okro and tomato (Table 4). In Okro, the highest freshness score was 4.67 which was in tap water x enhanced air movement and was significantly higher than open stream water at both natural and enhanced air movements, but similar to the other water quality x air movement combinations. In tomato, the lowest freshness grade was 1.00 observed in disinfected water x natural movement while the highest score was 2.00 in tap water x natural air movement.

LENGTH OF TIME OF STORAGE

Table 5 showed that water quality significantly affected length of time of storage of the three leaf vegetables stored in vegetable basket. Also air movement significantly affected the length of time of storage of the three leaf vegetables. For *Telfairia,* the highest length of time of storage of (4.2 days) was obtained in open stream water followed by (3.7 days) recorded in tap water while the least was (3.2 days) was obtained in disinfected water. For *Amaranthus,* the highest length of time of storage of (4.8 days) was obtained in open stream water followed by (4.2 days) in disinfected water. The same trend was observed in *Celosia* with (6.7, 5.5 and 5.0 days) respectively. In fruit vegetable (Table 5) the trend was also repeated.

Water quality x air movement had a significant effect on length of storage of the three leaf vegetables stored in vegetable basket. The highest storage time (4.7 days) for *Telfairia* was recorded in tap water x natural air movement followed by (4.0 days) (Table 5) recorded in tap water x natural air movement (2.7 days). The shortest storage length was recorded in disinfected x enhanced air movement. Open stream x natural air movement was significantly different from others except in tap water x natural air movement. Open stream x enhanced air movement was statistically the same with disinfected x natural air movement with storage period of (3.7 days) ((Table 5).

The longest storage duration (6.0 days) for *Amaranthus* also occurred in open stream x natural air movement followed by (5.3 days) (Table 5) in tap water x natural air movement, and 5.0 days recorded in disinfected x natural air movement. The shortest storage duration occurred in disinfected x enhanced air movement. The shortest storage duration occurred in disinfected x enhanced air movement. (2.7 days).

In *Celosia,* the longest storage duration of (7.7 days) (Table 5) was recorded in open stream x natural air movement followed by (6.7 days) in tap water x natural air movement and (6.3 days) (Table 5) in disinfected by natural air movement. The shortest storage length was recorded in disinfected x enhanced air movement. There was also a high significant difference between natural and enhanced air movement. In all the three leaf vegetables enhanced air movement had lower storage length.

Table 5: Effect of water quality and air movement on the length of storage of three leafy vegetables stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Telfairia*	Mean of Water Quality	*Amaranthus*	Mean of Water Quality	Celosia	Mean of Water Quality
Open Stream	Natural	4.70	4.20	6.00	4.80	7.70	6.70
	Enhanced	3.70		3.70		5.70	
Tap Water	Natural	4.00	3.70	5.30	4.20	6.70	5.50
	Enhanced	3.33		3.00		4.30	
Disinfected	Natural	3.70	3.20	5.00	3.88	6.30	5.00
	Enhanced	2.70		2.70		3.70	
LSD0.05WQ×AM		0.94	0.66	1.26	0.89	1.03	0.73
Mean of Air Movement	Natural	4.10		5.40		6.90	
	Enhanced	3.20		3.10		4.60	
LSD(0.05)		0.54		0.73		0.59	

On fruit vegetable (Table 6), water quality affected length of time of storage for tomato but did not in Okro. There was a longer storage time in tomato than in Okro. Air movement also had a significant effect in both fruit vegetables with a longer storage time at natural air movement than enhanced.

Table 6: Effects of water quality and movement on the length of storage of two fruit vegetables stored in vegetable basket

Water Quality (WQ)	Air Movement (AM)	*Okro*	Mean of Water Quality	*Tomato*	Mean of Water Quality
Open Stream	Natural	4.00	3.70	8.00	6.20
	Enhanced	3.30		4.30	
Tap Water	Natural	3.70	3.50	6.00	5.20
	Enhanced	3.33		4.30	
Disinfected	Natural	3.33	3.20	6.30	5.00
	Enhanced	3.00		3.70	
LSD0.05WQ×AM		0.84	NS	1.11	0.78
Mean of Air Movement	Natural	3.70		6.8	
	Enhanced	3.20		4.10	
LSD(0.05)		0.48		0.64	

Water quality x air movement significantly affected the length of times of storage of both okro and tomato. In okro (Table 6), the longest time of storage was recorded in open stream x natural air movement followed by tap water x natural air movement (4.0 days and 3.7 days) respectively. Enhanced air movement were statistically the same in all the water quality levels and were also lower than natural air movement. In tomato (Table 6), the longest storage time (8.0 days) was recorded in open stream x natural air movement followed by (6.3 days) in disinfected x natural air movement and (6.0 days) (table 6) in tap water x natural air movement. The shortest storage duration was recorded in disinfected x enhanced air movement (3.7 days). Also natural air movement produced a longer storage time than the enhanced air movement

DISCUSSION

Effects of Water Quality and Air Movement on Qualities of the Produce

The combined effect of water quality and air movement enhanced the retention of the quality of the vegetables. A freshness score of 4.62 was obtained in *Amaranthus* and *Celosia* and a colour score of 4.67 was obtained in *Telfairia.* This result corroborated with the report of Nigerian Stored Product Research Institute (1990). They reported that storing leaf vegetable inside vegetables baskets wetted with portable water conserves the freshness and colour of the produce. According to their study the leaf vegetables should be kept inside the vegetable baskets and the baskets should be wetted regularly. The result was also similar to the work done by Babatola *et al* (2001) who reported that the leafy vegetables stored under the evaporative coolant had the best quality in terms of freshness, colour retention and marketability with less loss. According to their study, the next best was when vegetables were stored in refrigerator and the least quality vegetable stored was those on the laboratory desk.

The result also showed that the qualities of fruit vegetables deteriorated faster than storage in laboratory bench. The reason could be because the leafy vegetables have large surface areas which enhance larger water loss and evaporative cooling (Atanda *et al.* 2011). For the fruit vegetables, evaporative cooling was low due to low evaporative surface which the fruit vegetables do not have. Also coupled with the larger water content in the fruit vegetables any increase in humidity around the storage environment will be inimical.

But Babatola (1998) in his earlier work on the shelf-life extension of tomatoes using evaporative coolant system reported that the ECS gave the best quality followed by refrigerator and open shelf in terms of colour, firmness, weight loss and the days to ripening. This was in disagreement with the result obtained in this study because the tomato fruits used were already ripe while the ones he used were unripe. 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. Therefore, the difference in the ages of the fruits used may explain the different results obtained. But Amrat *et al.* (2013) reported that the evaporative coolant system is appropriate for the storage of many tropical leaf vegetables. This is not unconnected with the large area / volume ratio of leaf vegetables compared with fruit vegetables. The vegetable baskets were able to produce a temperature of 3·C lower than the ambient. The result corroborate with the report of Amrat *et al.* (2013*)* who observed *that* evaporative coolant is capable of reducing the temperature and producing appropriate humidity suitable for the storage of many tropical fruits and 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 overcome 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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