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Optimization of Storage Parameters of Selected Fruits in Passive Cooling Structures

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Abstract

This study was carried out to determine the optimum storage parameters of selected fruit using three sets of four types of passive evaporative cooling structures made of two different materials clay and aluminium. One set consisted of four separate cooling chambers. Two cooling chambers were made with aluminium containers (cylindrical and square shapes) and the other two were made of clay container (cylindrical and rectangular). These containers were separately inserted ina bigger clay pot inter- spaced with clay soil of 5 cm (to form tin-in-pot, pot-in-pot, tin-in-wall and wall-in wall) with the outside structure wrapped with jute sack. The other two sets followed the same pattern with interspacing of 7 cm and 10 cm, respectively. The set with 7 cm interspace served as the control in which the interspace soil and jute sacks were constantly wetted with water. The other two sets (5 cm and 10 cm interspaced soil) were constantly wetted with salt solution (sodium chloride) to keep the soil in moist condition. Freshly harvested matured oranges and bananas were used for the experiments and temperature, relative humidity and decay were monitored daily. The weight, β carotene, vitamin C, vitamin E, lycopene, bacterial and fungal counts of these produce were determined at intervals of three days for a period of 21 days for oranges and 10 days for bananas. Further analysis by optimisation process revealed optimum storage conditions for stored produce using Essential regression software package. Optimum values of 951.42 g, 22.76/IU, 48.60/mg/100ml, 2.89/mg/ml and 3.27/mg/ml were obtained for weight, β carotene, vitamin C, vitamin E and lycopene contents, respectively for stored oranges at various conditions. Also 238.34g, 12.43/IU,24.23/mg/100ml, 2.52/ mg/ml and 2.88/mg/ml were obtained for weight, β carotene, vitamin C, vitamin E and lycopene contents, respectively for stored bananas at various conditions

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Introduction

Postharvest losses are estimated to range from 10 to 30% per year despite the use of modern storage facilities and techniques (Harvey, 1978). Refrigeration cool storage is the best method of storing fruits but is too expensive to procure and maintain. Consequently, in developing countries, there is an interest in simple low cost alternatives, depending on evaporative cooling which is simple and does not require any external power supply (FAO, 1989). Owing to inappropriate post harvest storage, it is estimated that about 20 - 3 0 % of total fruits are lost after harvesting (Kader, 1987). Losses from lack of storage and improper transportation, processing and packaging have been estimated to be more than 4 0 to 5 0 % in the tropics (FAO, 1995). Evaporative cooling system (ECS) is a very good economic substitute in most tropical countries where the hot weather conditions make natural evaporation of water an effective method of achieving a cool and humidified environment.

Evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface of the structure. The cooling achieved by this device also results in high relative humidity of the air in the cooling chamber from which the evaporation takes place relative to ambient air. The atmosphere in the chamber therefore becomes more conducive for fruit and vegetable storage. The growth and metabolism of microorganisms are slowed down and if the temperature is low enough in the system, growth of all microorganisms virtually ceases (Rouraa *et. al.*, 2000; ITC, 2002).

Preventing microbial growth is one major practice of improving the storability of fresh agricultural produce. It is therefore prudent to preserve foods by preventing microbial growth. Typical optimization goals might be to maximize the yield of a process, to target product specification with minimum variation in order to maintain specified tolerances. Unlike prediction, however, successful optimization required a cause-effect relationship between the predictors and response variables.

Materials and Methods

The experiment was carried out in Minna, Niger state, Nigeria and the samples of oranges and bananas were sourced from Bosso Market. The fresh produce were stored inside the three sets of four different types of passive evaporative cooling structures for a period of 16 and 10 days for oranges and bananas respectively.

Nutritional Parameters.

The nutritional parameters were analyzed in the laboratory using AOAC methods of analysis (1996). All measurements were performed in triplicate and results were given as mean ± standard error (SE).

Preparation of Salt Solution.

About 15000 parts/millions (ppm) solution of sodium chloride (NaCl) was prepared by dissolving 225g of NaCl in 15 litres of water at room temperature and 450g of NaCl in 30 litres of water at room temperature for keeping the four structures in moist condition in the 5 cm and 10 cm soil inter-space respectively. The four structures in the 7 cm soil interspace were kept in moist condition using 20 litres of water.

Microbial Analysis.

Ten grams each of fruit samples were suspended in a 90ml of sterile distilled water and was homogenized. The suspension was filtered through sterile wool and was serially diluted under aseptic solution. The total fungal and bacterial plate counts were determined using the methods of Collins *et al.* (2004).

Soil Analysis.

Bulk Density and Moisture Content.

The bulk density and moisture contents of the soil were determined in the laboratory using AOAC (1979) instruction guidelines.

Soil Solarization.

This was done by placing a transparent plastic tarp on the soil surface. The plastic tarp uses the heat of the sun to raise the soil temperature. This was done for four weeks in order to reduce the level of microorganisms in the soil prior to using them as lagging material. During this period, the soil samples were turned continuously to ensure uniform distribution of sun rays. The energy from the sun heats the soil to a very high degree, sterilizing it and killing off soil pests, diseases and weed. This was done at the peak of the dry season when the temperature was between 45°C to 50°C (Stephen, 2002).

Optimization Analysis.

The optimum storage conditions for the stored produce were determined using optimization technique with the aid of Essential regression software package.

Results and Discussion.

Critical values of the process parameters were determined through Essential regression computer software package and the results are presented in the Tables below. Table 1 show that in order to optimize weight of stored orange fruit, a temperature of 30.80°C, a relative humidity of 56.20%, a soil inter-space of 7cm, a soil moisture content of 82.74%, a fungal count of 1.6x10ppm, a bacterial count of 26.0x10cfu and a rectangular shaped storage structure should be considered. All these combinations of these processing parameters will give an optimum weight of 951.42g. Also, in order to get optimum β carotene of stored orange fruit, a temperature of 25.7°C, a relative humidity of 56.20%, a soil interspace of 10 cm, a clay material, a fungal count of 2.80 x 10ppm, a bacteria count of 14.00 x 10cfu, a soil moisture content of 78.18% and a bulk density of 0.78g/cm^3 should be considered. All these combinations of process parameters will give an optimum vitamin A of 22.76IU. In order to get optimum vitamin C of stored orange fruit, a temperature of 30.80°C, a relative humidity of 56.20%, a clay material for the storage structure, a fungal count of 2.80 x 10ppm, a bacteria count of 14.00 x 10cfu and a soil moisture content of 82.74%. All these combinations of process parameters will give an optimum vitamin C of 48.60mg/100ml. Also, to get optimum vitamin E of stored orange fruit, a temperature of

25.70°C, a relative humidity of 56.20%, a soil interspace of 10cm, a fungal count of 2.80 x 10ppm and a bacteria count of 14.00 x 10cfu. All these combinations of process parameters will give an optimum vitamin E of 2.89mg/ml. In order to get optimum lycopene of stored orange fruit, a temperature of 25.7°C, a relative humidity of 60.60% and a soil interspace of 5 cm should be considered. All these combinations of process parameters will give an optimum lycopene of 3.27mg/ml.

Table 1:Optimized Values of Process Parameters and Output for Stored Oranges

Parameters	T (°C)	R	S(cm)	λ	γ	F(x10)	σ(x10)	M	B	Optimized value	Nature of solution
Weight	30.80	56.20	7.0	2.0	-	1.60	26.00	82.74	-	951.42	Maximized
β carotene	25.70	56.20	10.0	-	2.00	2.80	14.00	78.18	0.78	22.76	Maximized
Vitamin C	30.80	56.20	-	-	2.00	2.80	14.00	82.74	-	48.60	Maximized
Vitamin E	25.70	-	10.0	-		2.80	14.00	-	-	2.89	Maximized
Lycopene	25.70	60.60	5.0	-		-	-	-	-	3.27	Maximized

T=temperature, R=Relative Humidity, S=Soil Inter-space, λ= Storage Structure (1=Tin in pot or Pot in pot, 2=Tin in wall or wall in wall), γ=Material Component (1=Aluminium component, 2=Clay component), F=Fungal Count, σ=Bacterial Count, M=Soil Moisture Content, B=Bulk Density.

In order to get to optimum weight of stored tomatoes, a bacterial count of 18 x10cfu and a bulk density of 0.88g/cm^3 should be considered. All these combinations will give an optimum weight of 238.34gm. Also, in order to get optimum β carotene of stored bananas, a temperature of 26.90°C a relative humidity of 77.80%, a rectangular structure made with aluminum material with a fungal count of 2.21 x 10ppm should be considered. These combinations will give an optimum vitamin A of 12.43IU. In order to get optimum vitamin C of stored bananas, a relative humidity of 73.60% and a bulk density of 0.88%. All these combinations of process parameters will give an optimum vitamin C of 24.23mg/100ml. Also, to get optimum vitamin E of stored bananas, a soil interspace of 10cm with a fungal count of 2.80 x 10ppm should be considered. These combinations will give an optimum vitamin E of 2.52mg/ml. In order to get optimum lycopene of stored bananas, a clay material, a fungal count of 2.80 x 10ppm and a bacteria count of 26.00 x 10cfu and a bulk density of 0.88g/cm^3 should be considered. All these combinations of process parameters will give an optimum lycopene of 2.88mg/ml .

Table 2:Optimized Values of Process Parameters and Output for Stored Bananas

Parameters	T (°C)	R	S(cm)	λ	γ	F(x10)	σ(x10)	M	B	Optimized value	Nature of solution
Weight	-	-	-	-	-	-	18.0	-	0.88	238.34	Maximized
β carotene	26.90	77.80	-	2.00	1.00	2.21	-	-	-	12.43	Maximized
Vitamin C	-	73.60	-	-		-	-	-	0.88	24.23	Maximized
Vitamin E	-	-	10.0	-		2.80	-	-	-	2.52	Maximized
Lycopene	-	-	-	-	2.00	2.80	26.0	-	0.88	2.88	Maximized

T=temperature, R=Relative Humidity, S=Soil Inter-space, λ=Storage Structure (1=Tin in pot or Pot in pot, 2=Tin in wall or wall in wall), γ=Material Component (1=Aluminium component, 2=Clay component), F=Fungal Count, σ=Bacterial Count, M=Soil Moisture Content, B=Bulk Density.

Finally, with the optimization analysis, it is possible to control the storage environment by fixing the values of parameters needed to achieve optimum nutritional values of stored produce. However, where the variable (s) has/have no effect on the nutritional values, any values within the values obtained in the experiment can be used. The results are as presented in Tables 3 to 4.

Table 3: Limits/Boundary of Factors used for Stored Oranges

Term	*σ(x10)*	*B*	*F(x10*	*Γ*	*R*	*S(cm)*	*M*	*T (°C)*	*λ*
Data Min	14.00	0.78	1.60	1.00	56.20	5.00	78.18	25.70	1.00
Data Avg	21.07	1.02	2.16	1.50	69.32	7.50	80.18	28.78	1.50
Data Max	26.00	1.42	2.80	2.00	84.90	10.00	82.74	30.80	2.00

Table 4: Limits/Boundary of Factors used for Stored Bananas

Term	σ(x10)	B	F(x10	Γ	R	S(cm)	M	T (°C)	λ
Data Min	18.00	0.88	1.20	1.00	73.60	5.00	68.40	25.20	1.00
Data Avg	23.15	0.96	1.87	1.50	75.82	7.50	80.32	26.39	1.50
Data Max	26.00	1.14	2.80	2.00	77.80	10.00	89.20	26.90	2.00

T=temperature, R=Relative Humidity, S=Soil Inter-space, λ=Soil Structure (1=Tin in pot or Pot in pot, 2=Tin in wall or wall in wall), γ=Material Component (1=Tin component, 2=Clay component), F=Fungal Count, σ=Bacterial Count, M=Soil Moisture Content, B=Bulk Density.

Conclusions.

The study focused on the optimization of storage parameters of selected fruits in passive evaporative cooling structures and the data generated from this study have been able to provide evidence that the information on the optimization analysis also provides critical values of the process parameters for selecting optimum nutritional values of stored produce.

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