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Review

A review of shelf-life extension studies of Nigerian indigenous fresh fruits and vegetables in the Nigerian Stored Products Research Institute

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The Nigerian Stored Products Research Institute has been conducting research in technology development suitable for post-harvest handling of Nigerian indigenous fruits and vegetables for extension of the shelf-life of these commodities, retention of nutrients and aesthetics of fresh produce in storage, enhancement of the nutritional status and earning capacity of both the rural and urban poor through proper handling, storage, marketing and consumption of fruits and vegetables; and production of the best quality fruits/vegetables for local and export markets over three decades. The research work carried out and the technologies developed for handling of Nigerian indigenous fruits/vegetables post-harvest for the farm, market and domestic levels of storage are discussed subsequently. These indigenous fruits and vegetables are prone to chill injury when kept at low temperatures. However, storage structures developed by the Nigerian Stored Products Research Institute over the years, such as the evaporative coolers and cooler baskets which could record some temperature drop from the ambient, have been used in extending the shelf-life of fresh fruits and vegetables. Packing (wrapping) materials have also showed promise in extending shelf life of Nigerian indigenous fresh produce. The season and time of harvest also play an important role in storage of fruits and vegetables. Garden eggs have very short shelf-life of 7 days during the dry harmattan months in Nigeria. Fresh fluted pumpkin *Telfairia occidentalis* 'ugu' leaves can only be kept for 6 days at 29.1°C and 64.5%rh beyond which physiological breakdown of tissues lead to deterioration and total loss. Fresh pawpaw (*Carica papaya* L.) fruits, individually wrapped with waxed paper (TIXO) kept at ambient conditions in plastic crate, have a shelf-life of 17 days as compared to fresh pawpaw fruits in evaporative coolers for 7 days. In hot dry weather of the Northern parts of Nigeria, oranges stored in evaporative cooler (EC) Metal-in-Brick wall have a shelf-life of 10 weeks. Adoption of these technologies will play a very vital role in post-harvest loss reduction in fresh fruits and vegetables along the food chain, increase income and improve nutrition for all stakeholders. The interventions to maintain food quality and safety for reduction of postharvest losses in Nigerian indigenous fruits and vegetables through Research activities in NSPRI for three decades are the focus of this review paper.

Key words: Postharvest, technologies, fruits, vegetables, shelf-life.

INTRODUCTION

The Nigerian Stored Products Research Institute (NSPRI) is one of the National Agricultural Research Institutes in Nigeria. The NSPRI carries out researches on postharvest technology and storage of agricultural products and has five out-stations covering different agro-ecological zones of Nigeria including two sea ports. At inception, it was known as the West African Stored Products Research Unit (WASPRU) covering the British Colonies of West Africa under the supervision of the Federal Ministry of Trade under the colonial masters who were mainly concerned with export cash crops (cocoa, palm produce, groundnuts and rubber). On Nigeria's attainment of Independence in 1960, the WASPRU became the present Nigerian Stored Products Research Institute and the only postharvest institute in Nigeria and

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sub-Saharan Africa.

The institute, in line with Nigeria National Agricultural policies, conducts researches in bulk storage problems of local foods/crops, both durables (grain legumes, oil seeds and beverage crops, example, cocoa and kola and perishables (roots, tubers, fruits/vegetables and animal products as fish and meat).

The main research topics at present in the NSPRI are the following:

i. Researches to improve and maintain the quality of Nigerian food crops;
ii. Special studies on food contaminants, pests, pesticides/residues, and other anti-nutrients in stored food products;
iii. Researches to retain/enhance the nutrients and the aesthetics of fresh produce in storage;
iv. Researches aimed at improving fruit and vegetable quality for local and export markets;
v. Extension of research findings through publications, training of stakeholders in various postharvest aspects of different crops.

RESEARCH PERSPECTIVE

Food preservation is more than engineering and its proper understanding must involve the relationship between engineering, nutritional, biochemical, microbiological, entomological and economic aspects of preservation. Only the amalgam of these can be considered to encompass food preservation as a whole. For this reason, the NSPRI has a multi-disciplinary approach as clearly evidenced by the above listed research topics.

Under tropical and sub-tropical conditions, most crops deteriorate rapidly after harvest ceasing to be marketable. Spoilage can either be complete, as following the development of pathogenic microorganisms or partially, when a significant decrease of nutritional value and/or development of toxic byproducts occurs. The nutritional loss of fresh fruits and vegetables is mainly caused by a fast and extended oxidation of health compounds (example, vitamins, amino acids, etc.). In addition to the pre-harvest losses the ones occurring after harvest contribute significantly to world food shortages especially in developing countries including Nigeria where storage facilities are limited.

Most food preservation processes are only effective by employing a low temperature chain from the field to the fork. Low temperature storage with high humidity and high concentration of solutes delay the loss of nutrients and obstruct microbial growth. Delays between the harvest and utilization of crops are inevitable and the highly perishable crops (roots, tubers, fruits and vegetables) are prone to quality loss during the intervening period. The world's major food preservation process is still fresh storage of these crops which is a great challenge in the hot and humid tropical conditions especially where a cold chain policy is difficult or even impossible to become accustomed.

FOOD QUALITY AND SAFETY

The major disadvantages of food produce storage and distribution are the limits it imposes on shelf-life, the difficulty in predicting storage life of different perishable crop varieties. There is lack of control over distribution conditions which occurs in the Nigerian situation especially in the local markets. The perishables are often packed and transported under circumstances that accentuate their rapid deterioration from the farm gate to the market. Postharvest losses in these produce are high and reach the consumers in conditions that are inimical to food quality and safety. Appropriate preservation technologies for the highly perishable crops can reduce postharvest losses and fill the needs of the developing countries which can least afford the postharvest losses that occur in these countries. The interventions to maintain food quality and safety for reduction of postharvest losses in Nigerian indigenous fruits and vegetables through Research activities in NSPRI for three decades are the focus of this review paper.

NIGERIAN INDIGENOUS FRUITS AND VEGETABLES

There is a great diversity of fruits and vegetables in the tropical and sub-tropical regions of the world. In Nigeria, there is abundance of seasonal fruits which replace others as soon as these are out of season. In the humid Southern Nigeria for example, the star apple (*Chrsophyllum albidum*) replaces *Citrus* (genus) which are off season from the end of January. Mangoes, cashews, and avocado pears are in season after the star apple. Many Nigerian indigenous fruits and vegetables are native to different ecological zones of the country. However, some of these species have been introduced to other parts of the country. The fluted pumpkin (*Telfairia occidentalis*) which in the past was cultivated exclusively in Eastern Nigeria is now a national vegetable and grown in all parts of Nigeria because of its nutritional importance. Most Nigerian indigenous vegetables are cultivated all year round especially as dry season crops with irrigation, while others which grow in the wild for example *Gnetum africanum* (ukazi) and *Piper guinenses* (uziza) are cultivated under the agro forestry farming system.

Fruits and vegetables are important in both human and animal nutrition. These crops provide nutrients such as minerals, vitamins and dietary fibre which are essential for animal and human health. Some of these fruits are also rich sources of antioxidants which play a role in

cancer prevention from environmental pollutants such as polycyclic aromatic hydrocarbons (PAHS) emitted from fossil fuels which are now of great concern globally.

Fruits and vegetables are cultivated in Nigeria for economic purposes both in the rural and urban environments. Some of the perennial fruits trees such as citrus, avocado pear, guava and others are planted as ornamental trees in homesteads. The annuals such as tomatoes, leaf vegetables, garden eggs and okra may be cultivated either as seasonal or irrigated crops. Farm and market surveys (NSPRI Port Harcourt, unpublished data) showed that the prices of these commodities are more than doubled during their off-season period. The producers hardly benefit from these price increases because of the lopsided marketing system where the collectors (middlemen) sell to retailers.

In Nigeria, economic losses by farmers are in part related to crop deterioration along the food chain, especially by inadequate storage and transportation to distant markets where fruits and vegetables would yield better economic returns. This is particularly during the peak season of fruits and vegetables when there is glut in local markets and crops are sold at very low prices.

The Nigerian Stored Products Research Institute has been conducting research in technology development suitable for postharvest handling of Nigerian indigenous fruits and vegetables for over three decades. The general objectives of postharvest research for fruits and vegetables in the Institute are:

i. Extension of the shelf-life these commodities;
ii. Retention of nutrients and aesthetics of fresh produce in storage;
iii. Enhancement of the nutritional status and earning capacity of both the rural and urban poor through proper handling, storage, marketing and consumption of fruits and vegetables;
iv. Production of best quality fruits/vegetables for local and export markets.

For over three decades, the NSPRI has been conducting researches in postharvest handling and technology with the aim to extend the shelf-life of Nigerian indigenous fruits and vegetables and to disseminate results of the most promising storage techniques for each fruit species of the different ecological zones of Nigeria. Here follows a review of some of these researches and the benefits of the results to the economic outcome of Nigerian agriculture.

Research work carried out and technologies developed for handling Nigerian indigenous fruits/vegetables postharvest for the farm, market and domestic levels of storage are discussed subsequently.

Each fruit/vegetable react differently to the same environmental conditions, hence, their shelf-life differs under these conditions. Fruit/vegetable Post-harvest Research activities focus on development of the most suitable storage technique for each fruit species in the different ecological zones of Nigeria.

EXTENSION OF SHELF-LIFE OF VARIOUS NIGERIAN INDIGENOUS FRUITS AND VEGETABLES

Garden eggs (*Solanum aethiopicum* L.)

Garden eggs are annuals fruit that are cultivated in all the agro-ecological zones of Nigeria and also widely distributed in Africa. There are many varieties of garden eggs, each variety is peculiar to the locality where it is cultivated. The fruits are among the most appealing vegetables to sight as they have a wide range of colours, from white, cream, yellow, green, lime, orange, pink, red, purple and dusty black. The fruits can be stripped and multicoloured. Garden eggs have both nutritional and medicinal values. It is a fruit of choice by diabetic patients. The fruits are claimed to alleviate liver ailments (Lawande and Chavan, 1998) and has antioxidant properties (A. Ade, NSPRI, 'Ilorin', personal communication). Garden eggs deteriorate within two to three days after harvest especially when the stalk and calyx are removed and fruits are exposed to warm temperatures. The problem of wastage of fruits during the peak season is enormous especially in transporting to the marketing outlets as well as holding at the retail points in both urban and rural markets.

Studies on shelf-life extension of garden eggs at various times and seasons of the year using a novel fruit/vegetable cooler basket was carried out by the NSPRI 'Ilorin' in the Central Zone of Nigeria. The objective of the experiments was to determine the most effective storage conditions for the fruits that will be beneficial to the stakeholders (farmers, traders and consumers).

Storage of garden eggs 1

The cooler baskets (CB) were constructed with plastic baskets (each having a capacity for 15 kg of fresh fruits) with lid overlaid with tight polystyrene foam and covered with polypropylene material. The baskets were conditioned for storage before use by dipping both lid and basket in clean water and draining for about 1 h.

Freshly harvested garden eggs purchased in a local fruit market in Ilorin metropolis were sorted, washed, drained thoroughly and stored in the cooler baskets. The control fruits were stored in open plastic crates. Both the test and the control batches of fruits were on shelves in a ventilated fruit/vegetable shade. The temperature and relative humidity (RH) of the shade (ambient) and those of the storage cooler baskets and crates were recorded daily. The baskets were moistened on the outside whenever drying was observed. Fruits were examined for

colour, texture and weight changes and signs of deterioration. Fruit flavor and acceptability were assessed by palatability test after termination of storage.

The average ambient temperature and RH recorded during the storage period in October 2005 in the fruit/vegetable shade was 25°C and 42% RH. The cooler basket recorded average temperature of 22°C and 65% RH. The garden eggs had a shelf-life of 7 days without spoilage in the cooler baskets. The control fruits were shrivelled and changed colour within the same period. Palatability test showed that the fruits in the baskets had an off-flavour due to moisture absorption from the storage atmosphere of the baskets which also resulted in slight weight increase of fruits during storage (Ubani and Suleiman, 2008).

Storage of garden eggs 2

The fruits were purchased from the fruit market in Ilorin in August 2007. They were sorted into small, medium and large sizes and prepared as in Experiment 1 earlier for storage. The three sizes of garden eggs were stored in the cooler baskets (test) and open plastic crates (control) kept in a ventilated room in NSPRI's on-station Fruit/Vegetable Processing Centre Ilorin. Daily room temperature and relative humidity and those of the storage structures were recorded. Fruits were examined for colour, texture and weight changes during the storage period.

The garden eggs storage was terminated on the 9th day. The average room temperature was 26.5°C and 61% RH. The cooler baskets recorded an average of 28.5°C during the storage of fruits and the crates 28.3°C. The temperature build-up in the storage structures resulted in fruit spoilage due to rotting in the cooler baskets and mouldiness in the open crates. Fruit loss in the cooler baskets was 25.5, 19.7 and 26% for the small, medium and large sizes of fruit respectively on the 7th day of storage. The control had 18.67, 9.33 and 4% spoilage for small, medium and large sizes of fruits within the same storage period (Ubani et al., 2008).

Storage of garden eggs 3

Garden eggs were harvested and purchased from a farm in the lower Niger River Basin at Ejigba, Kogi State Nigeria, about 150 km from Ilorin on 30th August 2007. The fruits were sorted into mixed sizes and prepared for storage with the cooler baskets and plastic crates in the fruit/vegetable shade.

The average ambient temperature was 27.8°C and 70.6% RH at this period. The cooler baskets (CB) recorded 27.2°C and open crates 29°C temperature, respectively. Fruits were stored for 16 days and had 57 and 47% spoilage in cooler baskets and open plastic crates, respectively. Deterioration of fruits was highest on the 8th and 11th days in storage. On the 7th day, there was only 10% loss of fruits due to rotting in the cooler baskets (Ubani et al., 2008).

Storage of garden eggs 4

Fruits were purchased in the off-season during the harmattan (a very dry, hot and dusty period between mid November and early March) season in February 2008 from a local fruit market in Ilorin. Fruits were sorted and prepared for storage in the cooler baskets and the control in open plastic crates. The average ambient temperature 36.6°C and 16.6% RH at this period in the fruit/vegetable shade. The storage atmosphere in the cooler baskets was 28.6°C on the average. The fruits were stored for only 5 days and only 43% of the fruits were recovered fresh and wholesome. There was 13% weight loss of the fruits due to shriveling over the five day period. There was no rotting or decay of fruits both in the test and control batches. The control fruits recorded 100% loss due to dehydration after the five days (Ubani et al., 2008).

These trials in the storage of garden eggs show that the surrounding environment of the cooler baskets holding the fruits, time and season of the year are important factors in the shelf-life extension of the fruits. The shelf-life of garden eggs in the cooler baskets is 7 days in a well ventilated environment such as the fruit/vegetable shade under ambient conditions of 27^{o}C temperature and 70% RH. The cooler baskets (CB) normally record some temperature drop from the ambient in this environment. At high temperatures (37^{o}C) and low (16% RH), garden eggs have a shelf-life of 4 days in the cooler baskets; beyond this time shriveling due to extensive moisture loss is the major cause of fruit spoilage and loss.

Storage of pawpaw fruits *(Carica papaya* L.)

Pawpaw fruit is of nutritional, therapeutic and economic importance in the tropics. The fruits are good a sources of β-carotene, vitamin C, minerals especially potassium and magnesium, soluble fibre and carbohydrates. The water content is high in ripe fruits. The unripe fruit is a source of papain used in food and pharmaceutical industries.

The pawpaw fruit is highly perishable and 100% loss may be recorded for the fruit due to improper harvesting, handling and storage postharvest. The fruit is usually harvested at the breaker pawpaw fruits (Solo variety) from an orchard in the National Horticultural Research Institute (NIHORT) Idi-Ishin Ibada, Nigeria were harvested at the breaker stage of ripening and transported to the laboratory in NSPRI 'Ibadan'. The fruits were wiped with wet tissue paper to remove surface dirt,

Table 1. Nutrient content of fresh pawpaw fruits stored at ambient condition in wrapping materials.

Sample treatment	Vitamin C (mg/100 g)	Titratable acidity (ml 0.1 N NaOH)	Total sugars (mg/g)
Initial			
Ripe	42.8	0.46	11.72
Unripe	21.4	0.92	11.32
Terminal			
Newspaper wrap (ripe)	62.0	0.85	10.60
Waxed paper	67.0	-	-
Control, no wrap (ripe)	60.0	60.0	11.34

Source: Ubani ON, NSPRI 'Ibadan', 1989.

and stored in NSPRI's evaporative coolers (EC) each of 5 kg capacity. The control fruits were kept in open fruit crates on the laboratory bench. Fruits were examined every two days for ripening (colour change) and signs of deterioration (localized softening, mouldiness, pitting and rotting).

Mechanical damage during harvesting and transportation of the fruit is a major cause of losses during storage of pawpaw fruit.

SHELF-LIFE OF FRESH PAWPAW FRUITS IN EVAPORATIVE COOLERS

The fruits in the evaporative coolers ripened in 7 days and the control in 6 days. The fruits had a shelf-life of 23 days and 50% loss in the EC due to rotting at the termination of storage. The control fruits had a shelf-life of 9 days with 50% loss due to spoilage within the storage period (Ubani, 1991).

STORABILITY OF INDIVIDUALLY WRAPPED PAWPAW FRUITS AT AMBIENT CONDITIONS

Freshly harvested pawpaw fruits (Solo variety) at the breaker stage of ripening were cleaned and wrapped individually with waxed paper (TIXO) and News paper in 6 replicates. The control fruits were not wrapped. The three treatments were kept in plastic fruit crates on the laboratory bench at ambient conditions.

The fruits had a shelf-life of 17 days. The control and the test fruits commenced ripening within 3 days. The control fruits and those wrapped with newspaper ripened over five days unevenly with unattractive yellow colour. Fruits wrapped with waxed paper ripened over 8 days with an attractive yellow colour.

The percentage losses due to spoilage after storage were 50% for control, 17% for both the newspaper and waxed paper wrap treatments. The fruits were analysed initially and finally for Vitamin C, titratable acidity and total sugar as shown in Table 1.

There was appreciable increase in Vitamin C content of the fruits during storage with slight decrease in total sugars. There were no weight changes in the fruits during and after storage. The wholesome fruits from all treatment were organolleptically acceptable in a palatability test. There was no off -flavor of fruits. However one of the fruits wrapped in waxed paper was mouldy from the stalk end to the seeds. The result show that ripening could be delayed in pawpaw fruits when wrapped in waxed paper and fruits can be stored for more than two weeks under ambient conditions.

Processing and storage of unripe pawpaw slices

Production of unripe pawpaw slices is an indigenous technology for preservation of pawpaw fruits among the Tivs of Benue State in Nigeria. The dried fruit slices are used to prepare soups and sauces.

Mature unripe fruits are usually harvested during the peak production season between November and February. Fruits are wiped with wet cloth to remove surface dirt, peeled and sliced (0.5 cm thickness). Slices are sun-dried, packed in black polythene or polypropylene bags for storage and marketing by the processors during the off-season. These commercial samples have been stored hermetically for 30 months (Okonkwo et al., 2009).

The indigenous processing method was modified and improved upon in the laboratory by the application of the hazard analysis, and critical control points (HACCP) system. 1.5 cm slices were either sun-dried in aluminum trays on a platform or mechanically in a multipurpose dryer at 70°C for 11 and 24 h continuously. The dry samples were packed in thick gauge food grade polyethylene films and stored in a hermetic container (Plastic drum with sealed lid) for 18 months. Moisture content of the dry slices was in the range 9.6 to 10.3%. Moisture re-absorption (weight increase), changes in colour, texture and aroma were not observed in the stored slices during and at the termination of the experiment. There were no significant changes in the

proximate content of the slices during and after storage. The thicker slices were organolleptically more preferred than the thinner slices (Jagtiani, 1980; Okonkwo et al., 2009). Production of pawpaw slices have potentials for reduction of postharvest losses of the fruits in the tropics with reference to Nigeria.

Storage of oranges [*Citrus sinensis* (L.) Osbeck]

Citrus fruits are among the most important fruit crops in the tropical and subtropical regions. Oranges are a component of the diet of many people globally because of their supply of vitamin C, which is essential in human nutrition.

Citrus fruits are non-climacteric fruits and have a relatively long postharvest life compared to other fruits. Oranges are seasonal in Nigeria with the peak production season and availability during the dry season from late October to late January. The problem of postharvest loss of the fruits at farm, market and domestic levels has been of great concern to all stakeholders. Wastage occurs during harvesting and transportation of the fruits for the fresh market due to mechanical damage, which in turn gives rise to pathological damages of the fruits. Oranges have storage problems which include blue and green mould rot at high temperatures and chill injury which leads to pitting at temperatures below 2 to 3°C. Weight loss due to dehydration in *Citrus* during storage is also a contributing factor in postharvest losses. This problem has been minimized by waxing, seal packaging and storage in sub-ambient conditions (Ben-Yehoshua, 1979; Bayindirli et al., 1995).

Several trials on weight loss reduction in oranges have been carried out in NSPRI. Simple storage techniques applied for preservation of oranges are briefly discussed.

Fungicidal wax treatment and sealed packaging of oranges for storage

Freshly harvested ‘Agege’ sweet oranges were coated with a proprietary wax emulsion containing the fungicide Benlate, sealed in perforated and un-perforated polyethylene films. Storage of fruits was at ambient conditions and sub-ambient condition in the refrigerator. The control had no treatment both in ambient and sub-ambient conditions. They were monitored for weight changes, vitamin C content and deteriorations for 12 weeks in storage.

Waxing and sealed packaging in perforated polyethylene films with storage at ambient conditions and sealed packaging in perforated polyethylene films without wax treatment at sub-ambient conditions were effective techniques in the extension of shelf-high of the oranges. The vitamin C content of the fruits did not change significantly (57 to 59 mg/100 g) during the storage periods (Opadokun and Ubani, 1983; Opadokun and Akalusi, 1987).

WRAPPING OF ORANGES WITH DIFFERENT MATERIALS DURING STORAGE

`Agege I` variety of sweet oranges was harvested from NIHORT ‘Ibadan’ in early January. Fruit was harvested and transported with care to avoid mechanical damage. Fruits were cleaned with soft tissue to remove surface dirt, wrapped with materials in five treatment groups as follows: Waxed paper, waxed envelopes, News paper, green banana leaves and control. The control was stored in an open plastic crate. All treatments were at ambient conditions of 25 ± 3°C and 68 ± 5% RH.

Fruits were monitored weekly for weight changes, and signs of deterioration, vitamin C, total sugars and titratable acidity contents. Terminal samples were assessed organolleptically for acceptability with a Hedonic scale of 1 to 5 for texture, peel colour and flavour.

Weight loss was highest in the newspaper wrapped and control fruits which also had dry rot, peel shrinkage and ring granulation at the end of 7 weeks of storage. The waxed paper wraps and banana leaves were effective in reducing weight loss and peel drying (Ubani, 2006).

Storage of oranges in evaporative cooler

Oranges were stored in the EC (with capacity for 300 kg of fresh fruit) for 6 weeks with control fruits at ambient conditions. The temperature drop from the ambient was 3°C and 55% RH on the average. The rate of weight loss of the oranges in the EC was reduced. The control fruits lost weight rapidly resulting in fresh weight loss of 31.1% after 1 month in storage and actually lost appeal on the 14th day in storage. Fruits in the EC had weight loss of 4.2% and were in good and acceptable after 6 weeks storage (Babarinsa et al., 1986).

Storage of mangoes *(Mangifera indica* L.)

Mangoes are climacteric fruits which are highly perishable and can only be kept under ambient conditions after harvest for a few days when nature and green. Ripe fruits deteriorate rapidly and in the open markets attract flies because of the fruit acid responsible for the characteristic mango flavour. The mango season is very short usually April to June in Nigeria when late maturing varieties are available. Despite the brief seasonality of the fruits, there is much post harvest loss at the farm level due to difficulty in transportation of fresh fruits to distant or even local markets. Fruit loss is also

Table 2. Nutrient contents in the pulp and peel of 'Julie' mangoes during storage.

Day	Sample/treatment	Vitamin C mg/100 g			Soluble sugars (mg/g)
		Pulp	Peel	P+P	
0 (Initial)	unripe fruit	17.9	40.5	37.5	14.3
10	A	17.7	-	66.4	72.0
	B	22.1	-	39.9	160.0
	C	15.3	-	25.5	114.0
	D	26.6	-	44.2	110.0
	E	18.05	-	42.4	108.0
	F	17.3	20.4	18.05	66.0
40	E	25.9	74.6	23.5	154.0
	F	18.8	-	25.1	112.0

Source: Ubani ON, NSPRI 'Ibadan' (1989).

much at the market level due to improper handling and storage of fruits before disposal. Mangoes are also lost at the domestic level when fruits cannot be held at ambient conditions for more than one or two days after ripening depending on the variety. Reduction of post harvest loss of mangoes in South-west Nigeria has been approached using different storage methods.

Production of mango slices, lather and juice have been experimented on as techniques for post harvest loss reduction of mangoes in Southwest Nigeria (William et al., 2000; Babatola and Babalola, Stakeholders' meeting on the processing of mango to slices for local and export market, Abuja, 2006). However, mango consumers have greater preference for the fresh fruits.

Storage of fresh mangoes in wrapping materials

The mango variety 'Julie' harvested mature, unripe, firm and wholesome from NIHORT orchard Ibadan. They were prepared for storage in three treatment groups. Fruits were cleaned with soft tissue paper to remove surface dirt and randomly selected for storage in:

(A) Woven basket lined and covered with green banana leaves (as practiced by farmers);
(B) Waxed-paper- lined perforated cartons (made of fibreboards);
(C) Cartons with fruits individually wrapped in waxed-paper;
(D) Open plastic fruit crates (control).

All treatment groups were kept at ambient conditions on the laboratory bench. A second batch of fresh fruits was stored in sub-ambient conditions (E) in perforated polyethylene films and (F) individually wrapped in waxed-paper kept in perforated high density polyethylene films. Storage was in the fruit/vegetable compartment of the refrigerator at 12°C.

The physicochemical parameters including weight, colour, firmness, Vitamin C and soluble sugars were measured for the fruits before and after the storage period. Fruits were examined every two days for ripening, weight changes and signs of deterioration.

The storage of fruits at ambient conditions was 10 and 40 days in the sub-ambient condition. After storage, the fruits in the woven basket (A) ripened with unattractive yellow colour with green patches. Weight loss was 30.5% of the initial weight and 33% spoilage was recorded for this treatment. The fruits in treatment (B) were fairly soft and not well ripened after storage. There was 67% spoilage and 64.2% loss in weight of fruits in this treatment.

Fruits in treatment (C) were very firm and ripened with an attractive yellow colour after storage. Weight loss was 10.3 with 16% spoilage of fruits. The control fruits (D) did not ripe well. These had unattractive yellow colour with green patches. The fruits were shriveled and soft at the stem end. Weight loss was 65% and spoilage 16% in this treatment.

Treatments E and F in sub-ambient conditions were stored for 40 days. There was no loss in weight or spoilage in fruits in these treatments after 10 days. The individually wrapped fruits in F were firm with attractive yellow colour at this time. There was progressive spoilage of the fruits beyond this period in Treatments E and F till the experiment was terminated after 40 days storage. There was 80% loss of fruits in both treatments after 40 days. There was also pitting and softening of fruits. The fruits in the waxed paper inside the polythene film had 35.2% loss in weight and those in the polythene film only 7.4% weight loss.

The biochemical parameter (nutrients) monitored are shown in Table 2. Fungi isolate from the spoiled fruits were all soil fungi namely *Geotrichum albidum Cladosporium, fulvum, Fusarium maniliformis, Rhizopus*

Table 3. Varietal differences in storage of fresh tomato fruits.

	Percentage* storage losses after 7 weeks		
Tomato variety	**Pathological damage (%)**	**Weight loss (%)**	**Wholesome fruit (%)**
Euromech	30	18	52
Early stone	38	40	12
Roma V. F.	46	32	22
Piacenza	74	22	4

*Mean values source: Okoye et al. (1986).

arrhizus.

Storage of fresh tomatoes

Tomatoes are consumed globally. In Nigeria, the main production season is during the dry months of the year in the Northern part of the country where the bulk of tomatoes consumed in Nigeria are produced. In the Southwest, the main production season is in the wet months between July and September. The fruits are soft berries and need special postharvest handing to minimize mechanical damage during transportation to the marketing outlets. At the retail and domestic levels, there is need to keep the fruits wholesome for consumers as the major problems after harvest are mould infestation of the damaged fruits. Studies were carried out on the shelf-life of fresh tomato varieties at ambient conditions.

Shelf-life of four tomato varieties at ambient conditions

Tomato varieties (Euromech, Roma V.F., Early Stone and Piacenza), cultivated under irrigation at the Institute of Agricultural Research Farm Samaru, Kaduna State were harvested and transported to NSPRI 'Ibadan' during the execution of the Nationally Coordinated Project on Fruits and Vegetable (North↔South Transportation of fruits and vegetables). Fruits were transported in plastic craters, sorted and stored in the same containers on the laboratory bench at 23.5 to 24.8°C temperature and 66.8 to 78.8% RH ambient conditions. Fruits were examined weekly for physical changes and analyzed initially and terminally for titratable acidity and total sugars.

The tomatoes were stored for 7 weeks and the effect of varietal differences is shown on Table 3. The biochemical parameters were similar and did not vary from the initial values after the storage period. Total sugars wraped between 1.08 to 3.43 mg/100 g. Acidity was 37.7 to 47.1 ml 0.1 N NaOH/100 g. Roma VF was more acidic than the other varieties.

Euromech had the longest shelf-life in good quality followed by Roma V.F., Early Stone and Piacenza varieties. The Piacenza variety was unacceptable after the 3rd week of storage. After the 5th week in storage, the seeds of the Early Stone and Roma varieties started sprouting internally even when the skin was still apparently wholesome. The above study showed that Euromech has potentials for fresh storage over a long period even at ambient conditions (Okoye et al., 1986).

Shelf-life of tomatoes (early stone variety) in the fruit and vegetable cooler basket

Fresh tomatoes were bought from a local fruit market in Ilorin Metropolis during the harmattan season in February 2008. The fruits were sorted, washed and drained in a fruit crate. The fruits were then stored in the cooler baskets in a fruit/vegetable shade and the control fruit in open fruit crate in the shade. Fruits were examined daily for signs of spoilage and monitored for weight changes.

The average ambient temperature was 37 ± 2°C and 16% RH in the fruit/vegetable shade. The temperature in the cooler baskets was 27 ± 2°C. The fruits had storage life of only 9 days in the cooler baskets and there was 20.4% loss of fruits due to fungal infection. The wholesome fruits did not record weight loss during storage. The control fruits showed signs of skin shrinkage and weight loss during storage (Ubani et al., 2008).

Storage of okra (*Abelmoschus esculentus* (L.) Moench)

Okra is widely cultivated and consumed in Nigeria as well as other African countries. It is the second most important vegetable in the market especially in West Africa after tomatoes. Fruits are harvested at a very early stage of 3 to 4 days from flowering when they are still tender or when they are close to their maximum size and not yet fibrous (6 to 7 days) when the tips can snap. Okra is rich in minerals especially calcium and also vitamins. It is used as a source of gums.

Shelf-life of fresh okra in cooler baskets

Freshly harvested okra fruits were purchased from a local

market in Ilorin. The fruits were sorted and only wholesome fruits were stored in the cooler baskets. The cooler baskets were washed in clean water and allowed to drain and further dried on the inside with a clean napkin to reduce the okra contact with surface water. Fruits were weighed in batches before storage.

The control fruits were stored in open plastic crate and covered with fresh mango leaves to simulate the practice of the women traders. The storage containers were kept in a fruit/vegetable shade. The ambient temperature, relative humidity and the temperature in the storage containers were recorded daily. Fruits were examined every two days for signs of deterioration, colour changes, wilting and rotting. Spoilt fruits were sorted and removed from the batches and the weight changes of the fruits recorded.

The fruits were stored for 14 days. The average ambient temperature was 32.2°C and 44% RH. The temperature of cooler baskets during storage of the fruits was 29.10°C. After the 7th day of storage, there was 37.5% loss in fruits due to spoilage and the control had 70% loss. At the 14th day, the fruits lost 75.9% of the original weight in the cooler basket and the whole some fruits remained tender. The control fruits lost 90% of their initial weight, changed colour with loss of the mucilage (Ubani et al., 2010).

Storage of leaf vegetables

Leaf vegetables are highly perishable and under the hot tropical conditions cannot keep fresh for more than 24 h. They are essential part of the diet providing micronutrients and dietary fibre. The poor post-harvest handling and storage practices of leaf vegetables predispose them to huge losses after harvest. Good post-harvest practices will improve nutrition and economic returns for stakeholders.

Storage of fresh fluted pumpkin leaves (*T. occidentalis* Hook. F.)

Fluted pumpkin (Ugu) is cultivated in the South-eastern Nigeria and is a popular leaf vegetable among many communities in South-eastern Nigeria and particularly among the Igbos. This vegetable is no longer restricted to South-eastern Nigeria, but cultivated and eaten in all the agro-ecological zones of Nigeria and has become a 'national' vegetable. Fluted pumpkin leaves are recommended for malnourished children, pregnant women and adults with nutritional problems in Nigerian hospitals.

The shoots are harvested when they are up to 50 cm long. Traditionally, the tips of first shoots after germination are cut and discarded for new shoots to form. Shoots are pruned during harvesting. The plants are damaged when leaves are hand-picked and this hinders development of side shoots.

Farmers tie the harvested long shoots in bundles which are heaped under the shade of a tree or covered with green leaves before transportation to the markets. In the markets, the bundles are heaped in stalls and this often results in heat build-up in the bundles, leading to loss of chlorophyll and decay (Ubani et al., 1997). Fluted pumpkin cultivation and marketing is currently a thriving business in Nigeria among farmers and traders. Improved post-harvest handling and storage of this important vegetable is of importance to the stakeholders including the consumers.

Fluted pumpkin shoots were harvested from a farm at a village near Asa Dam in Ilorin in the cool hours of the morning and transported in a polypropylene bag to NSPRI. The vines were cut to length of 55 cm to include the tip of the shoots with very young leaves. The shoots were portioned into 1.5 kg batched and stored in the cooler baskets conditions for storage of the vegetables. The control batch was stored in an open plastic crate. Both the test and control samples were kept in a well ventilated fruit and vegetable shade. The ambient and storage structural temperature and relative humidity were monitored during the storage period. The vegetables were examined daily for signs of deterioration.

The average ambient temperature was 29 ± 1°C and 64 ± 5% RH during the storage period. The storage atmosphere temperature was 27 ± 2°C and 70 ± 5% RH in the cooler baskets. The fluted pumpkin leaves and remained fresh for 6 days in the cooler baskets and there were no weight changes. The tips of the shoots having the very young leaves showed signs of pathological spoilage on the second day in the baskets and tips were removed from the shoots. The control batch recorded weight loss due to wilting of the leaves. On the 7^{th} day of storage, there was massive deterioration in terms of leaf decay and chlorophyll loss in the test samples. Both the control and test samples had 100% loss on the 7th day in storage (Ubani et al., 2010).

Conclusions

The results of the studies on handling and storage of various Nigerian indigenous fresh fruits and vegetables show that several factors contribute to shelf-life extension of these commodities in the Nigerian environment. The nature of the crop and varietal differences is an important factor in storage of fruits and vegetables. This was evident in the studies with different tomato varieties produced in Northern Nigeria. The season and time of harvest also play an important role in storage of fruits and vegetables. Garden eggs have very short shelf-life during the dry harmattan months in Nigeria.

Fresh fluted pumpkin leaves can only be kept for 6 days beyond which physiological breakdown of tissues

lead to deterioration and total loss. These indigenous fruits and vegetables are prone to chill injury when kept at low temperatures. However, storage structures developed by the Nigerian Stored Products Research Institute over the years such as the evaporative coolers and cooler baskets which could record some temperature drop from the ambient have been used in extending the shelf-life of fresh fruits and vegetables. Packing (wrapping) materials also have shown promise in extending shelf life of Nigerian indigenous fresh produce.

Adoption of these technologies will play a very vital role in postharvest loss reduction in fresh fruits and vegetables along the food chain, increase income and improve nutrition for all stakeholders.

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