FACTORS ESSENTIAL FOR POST-HARVEST SHELF-LIFE EXTENSION OF *CARICA PAPAYA* L FRUITS

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Abstract

The burden of disease of Carica papaya L may account for its reduced commercial value. As much as the fruit is cherished amongst Nigerians its cultivation at commercial scale is limited. There are presently no industries in Nigeria utilizing the fruits or part of the plant for beverage production or in other industrial processes. This study was carried out to identify those factors that can be modified to extend the shelf-life of the fruit thereby enhancing its industrial value as a commercial crop. A 4 year field and experimental investigations in a monoculture C. papaya model demonstration farm revealed the following. Maturity of fruit and timing harvest are most critical in prolonging and by 25% shelf-life of healthy harvested fruit. Age of the plant which co-related with susceptibility to disease was evident in stands 2 years and older. Mechanical damage associated with harvesting technique and activities of pests (arthropods, molluscs, millipedes and bird), and farm maintenance played significant roles on the post-harvest quality of the fruit. Adequate understanding of the interplay of these factors and their regulation can be harnessed for extending the shelf-life of C. papaya fruit.

Keywords: *carica papaya fruit, disease incidence, post-harvest, shelf-life*

1. INTRODUCTION

Fruits and vegetables play a vital role in human nutrition by supplying the necessary growth factors such as vitamins and essential minerals, antioxidants and many phytonutrients (Alhindi et al. 2011; Kalia and Gupta, 2006). The Food and Agriculture Organization (FAO) reported worldwide papaya production of approximately 11.2 million tons in 2010; papaya accounting same year the largest share of tropical fruit production in developing countries (Bautista-Baños et al. 2013). The perishable nature of fruits and vegetables require that these are eaten immediately or processed for added values. Where processing facilities are not available, over 20% of harvests have been reported loss to microbial attack (Akinmusire, 2011; Alhindi et al. 2011) and may be as high as 80% (Arshad et al. 2003).

Post-harvest *C. papaya* fruit diseases have been associated mainly with pre-harvest conditions which result in the propagation of the pathogens in fruit post-harvest. Amongst these are prevailing weather which determine the availability of and amount of microbial inoculums, ease of spread of disease agents within farm and soil fertility that invariably accounts for the resistance of the plant to pathogen attack (Spotts et al. 1999; Sams, 1994) and farm management especially as it relates to use of fungicidal sprays pre-harvest (Sholberg and Bedford, 1999; Sugar and Spotts, 1995). Likewise, post-harvest conditions which may impact on fruit quality on storage and affect marketability have been identified with handling, mode of transportation, pre-treatment of fruit before storage and conditions of storage facility and environment (Cenci et al. 1997; Paull et al. 1997; Quintana and Paull, 1993). Adequate understanding of factors that account to fruit losses is sine qua non in devising control strategies against fruit deterioration. Furthermore, the enormous losses of raw materials consistently will not guarantee sustainable industrial investment in the crop. This study was therefore carried out to identify factors contributing adversely to retention of fruit quality post-harvest.

2. METHODS

2.1. General model

This study was carried out with fruits obtained from the Covenant University Pawpaw Research and Demonstration Farm which was first cultivated in 2009. First fruits harvests were in October 2010 through February 2011. Incidence of diseases of *C. papaya* in the Farm per year was monitored and the effect on post-harvest quality of fruits was studied. Other factors evaluated were methods of fruit harvesting, handling and transportation of fruit. But more significantly was the effect of harvest timing on the quality and shelf-life of fruits. The role of age of plant to disease susceptibility was also determined. The contributory role of farm management practice to the post-harvest quality and shelf-life retention of fruit was determined.

2.2. Harvest timing and effect of bruises on fruit post-harvest shelf-life

Relatively healthy fruits were grouped into three classes: CLA: firm matured fruits with no mechanical injury and early signs of ripening (first, ¼ colour break- CLA1); firm matured fruits with minor bruises and ¼ colour break (CLA2); firm matured fruits with major bruises and ¼ colour break (CLA3). Class B consists of fruits as in CLA but with ½ colour break and grouped as CLB1, CLB2 and CLB3. Class C was fruits assumed to be mature but with no colour breaks that fell into physical damaged groups as CLC1, CLC2 and CLC3. Spoilt or fruits with broken pulp were not included in this study. Fruits were weighed and differences in weight of more than 30g do not meet the criterion for inclusion in a group. Fruits in the above categories that ripen or got spoilt within 48 h of harvest were excluded from study. Minor bruises were defined as scratches on skin of fruit usually limited to the surface and associated with field factors such as fruit contact with stem or the activity of vectors or weather conditions. Major bruises were physical and associated with injuries from felling of fruit on hard surface or injury with harvesting tool. Fruits under each classification were studied in line with post-harvest features as earlier indicated. In each grouping were 10 fruits and the study were carried out in 2010-2011, 2011-2012 and 2012-2013 and 2013-2014 harvest seasons.

2.3. Statistical Analysis

The data obtained were analysed using the Duncan's multiple range tests with $P \leq 0.05, 0.01, 0.001$ for significance.

3. RESULTS AND DISCUSSION

Ninety percent healthy fruits imply not more than one spoilt fruit was observed on a tree at harvest. Percentage yield of the farm declined from 95% in 2011 to 54% in 2014 ($P < 0.001$) (Table 1). The decline in *C. papaya* yield had been reported in many papaya producing nations and microbial deterioration has accounted for a greater proportion of these losses (Koffi et al. 2010; Ventura et al. 2004). It is important to note that while post-harvest losses may account for between 10 to 50 % for most fruits (Akinmusire, 2011; Agrios, 2005; Kader, 2002), losses associated with pest infestation and disease incidences in orchards have resulted in the entire loss of annual harvest (Koffi et al. 2010; Hausbeck and Lamour, 2004; Erwin and Ribeiro, 1996; Kreutzer, 1937). Therefore measures to control pests and diseases occurrences in the field will be the first step in securing healthy and bumper harvest.

Table 1. Harvest yield from 2011-2014

Year	Annual farm yield† (%)
2011	95
2012	89
2013	75*
2014	54**

*---level of significance at $P \leq 0.05, 0.001$

† Yield calculated as number of fruiting tree producing 90% healthy fruit and not less than 10 fruits at peak harvest. The number of fruiting trees per year or season varied and this was computed into the calculation.

The percentages of harvested fruits that ripen or got spoilt on storage between 3-5 days and 6-8 days during the four harvest seasons are given in Table 2. Fruits from trees within their first two fruiting seasons have between 67-70% ripened within 3-5 days post-harvest and 15-20% on 6-8 days storage at 19-22^{o} C. No post-harvest treatment was given so the storage condition simulated the conventional handling procedures of taking fruits from farm to market. The only modification was the relative low temperature (19-22^{o} C) for which this data was based. In Nigeria atmospheric temperature averages 27^{o} C in many months but may be as high as 30^{o} C in hotter months. As the plant ages, the percentage of fruits ripening within the storage periods declined significantly. The reverse was the case for fruits that fail to ripen or got spoilt after harvest. Fruits from trees with spoilt fruits averaging 2 spoilt fruit per harvest had reduced shelf life compared with fruits from trees with healthy fruits at each harvest time. Infected trees resulted in 25% reduction in shelf-life. Therefore fruit conditions pre-harvest will impact on the overall shelf-life post harvest; poor fruit quality will undoubtedly not improve on the shelf-life irrespective of post-harvest treatment and handling. The data presented here show the interplay between plants age and susceptibility to diseases in response to which Persley (2003) had earlier recommended the removal of infected tree from the farm as the best method of control. Infections were more predominant amongst trees older than 2 years which is equivalent to the third harvest season (data not shown). The disease incidences were low in 2011 (2%) and 2012 (7%), but increased considerably in 2013 (14%) and 2014 (30%). This co-related with the number of infected tree in the farm (Table 3).

Table 2. Effect of plant age on fruit keeping quality post-harvest

Year	Percentage shelf-life to:			
	Ripeness		Spoilage	
	3-5days	6-8days	3-5days	6-8days
2011	70a	20	7c	3
2012	67a	15	13c	10d
2013	59	12b	22	7d
2014	45	10b	35	10d

Letter per column indicates where significant difference do not exist at $P \leq 0.01$

Table 3. Disease incidence from 2011-2014

Year	Disease incidence (%):	
	Overall*	Infected tree#
2011	2a	15a
2012	7a	22ab
2013	14b	35b
2014	30c	48c

*Overall is defined as trees with symptoms of stem or and leaf diseases bearing one or more spoilt fruits

#Trees with stem or and leaf diseases without spoilt fruits on tree at harvest

Same letter on column indicates where significant differences do not exist.

Fruits with blemishes or scratches due to activities of arthropods or mollusc were more prone to post-harvest deterioration and yielded higher percentage spoilage within the study conditions. Regular weeding of farm at least twice monthly from fruit setting to harvest produced fruits with higher shelf-life compared with fruits from farm with less frequent weeding. More trees were infected 15% over trees in farm with weed control management plan (Table 5). Heavy vegetation resulted in 3-5 spoilt fruits on stands on each harvest visit. Hand picked fruits preserved longer than pole harvested fruits. Spoilage set in from areas with multiple contacts with the pole which usually showed exudation of latex during harvest. Second the impact when the fruit make contact with the earth facilitated onset of soft rot. Method of harvest resulted in 38% reduction in shelf-life. This will compound the effect of losses incurred as a result of further mechanical injury in transit. Cappellini et al. (1988) reported 14.8% shipment disorders as mechanical injury while the packing and shipment containers and nature was described to influence the degree of damage (Quintana and Paull, 1993). Immediate washing at Farm site help remove latex from fruit skin and also soil and debris.

Table 4. Effect of harvest timing, and fruit quality on the shelf-life of *C. papaya* fruit under different storage conditions

Features	Shelf-life (days) at storage conditions‡					
	Dry Floor in groups		Plastic container in groups		Separate in foam cushion baskets	
	19-22^{o}C	30-35^{o}C	19-22^{o}C	30-35^{o}C	19-22^{o}C	30-35^{o}C
Timing of harvest						
CLA						
1	7	4	8	5	10	6
2	5	3	6	3	7	4
3	3	-	4	-	5	3
CLB						
1	5	3	6	4	7	4
2	3	-	4	-	5	3
3	3	-	4	-	5	-
CLC						
1	3	-	4	-	4	-
2	-	-	3	-	3	-
3	-	-	-	-	-	-

-; fruits that ripen or got spoilt within 2 days of study and were not considered further in the study

‡; values in Tables are mean of records from 10 fruits per group

Indices for timing of matured fruit ready for harvest were not clear cut. Fruits that showed first colour break produced the best threshold for timely harvest. These fruits under each storage conditions have a longer shelf-life. However, fruits that belonged to the second colour break category ripen more evenly and produced more acceptable sensory properties. These latter fruits ripened 2-3 days earlier than fruits with first colour break. Fruits classified as matured but with no sign of colour break gave very inconsistent results. 1/3rd got spoilt and did not ripen. 2/3rd ripened very irregularly and with poor fruit quality (Table 4). The data in Table 4 uniformly indicated that fruits stored separately and at temperature between 19 and 22^{o} C have a prolonged shelf-life of up to 5-10 days. Relative humidity of 60-65% and temperature above 24^{o} C are generally favourable to microbial growth (Ritzenthaler, 2010) and this may be responsible for the low preservation of fruits stored at 30-35^{o} C. Fruits with first colour break and no bruises preserved longer.

4. CONCLUSION

This study has shown that multiple factors are at play in determining the yield and quality of harvest. The health of the orchard will generally impact on the yield and post-harvest keeping quality of fruits. It is therefore important that more attention is given to farm management and this will include measures aimed at weed and pest control, and regular checks on farm for early detection of disease. Further, method of harvesting should be considered as inappropriate methods may inflict damages on fruit and predispose to microbial invasion and subsequently degradation.

Table 5. Other contributing factor to papaya postharvest shelf-life

Factors	Percentage contribution/description
1. Hand picking of fruits vs. Harvesting pole	38; pole inflicted multiple bruises
2. Weeding vs. herbicides	15; reduce pest population
3. Pest/vector prevalence	Molluscs, millipedes, arthropods; preponderance in rainy season
4. Prompt fruit washing	Reduce bruises, and microbial attack

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