Field and post-harvest requirements for optimizing *Carica papaya* L fruit yields

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***Abstract*—*Carica papaya* L fruit (pawpaw) is a growing export crop due to its high demand. Success of this crop in the global market requires extended shelf-life of the fruit. This study assessed fruit firmness and colour change as time-related factors for harvesting in conjunction with the effects of pre-treatment with heat, chlorine or salt solution and storage conditions on the shelf-life of pawpaw. Two hundred and fifty pawpaw trees were studied from bloom to harvest in two fruiting seasons. Number of fruits per tree at peak fruiting, proportion of matured to immature fruits and number of harvest visits were recorded. Fruits were handpicked and only certified healthy fruits were studied for quality and acceptability. Range of matured fruits on trees was 8-25 with average per harvest of 5 fruits per tree. The proportion of matured to immature fruits at each harvest visit was 2:3. Harvested fruits that have not attained full maturity indicated by first colour break either failed to ripe or ripen unevenly. Matured fruits with early sign of ripening preserved for 3-7 and 9-12 days at 27-32^o C and 19-23^o C respectively. Treatments with salt solution prior storage produced poorly ripe and disfigured fruits and encouraged the growth of moulds (*Aspergillus* spp., *Penicillium* spp., *Mucor* spp., *Colletotrichum gloeosporoides*, *Alternaria* spp., *Rhizopus stolonifer*). Heat treatment and dip in chlorine water gave the upper range of shelf-life. Timing of harvest, post-harvest handling and storage at low temperature are critical in determining the post-harvest shelf-life of *C. papaya* fruits.**

***Index Terms*— Carica papaya, pawpaw, fruit maturity, shelf-life, post-harvest spoilage**

I. Introduction

Carica papaya L fruits are widely consumed in Nigeria but its cultivation for export and industrial use is low presumably due to disease incidence both in the field and post-harvest [1]. Aside grappling with papaya fruit, leaf and stem diseases in the field which have caused serious economic loss to farmers, post-harvest deterioration of fruit has been reported to further compound the scenario with additional 20-80% losses [2, 3]. This invariably has hindered both the domestic and export markets of papaya. *C. papaya* is climacteric and ethylene and respiratory peaks associated with fruit softening have been reported to occur 3 days after harvest [4, 5] and fruits that have started ripening on the tree have shorter shelf-life. Therefore timing of harvest have been suggested an important factor in extending papaya shelf-life [6]. A number of studies have attempted to address post-harvest deterioration of pawpaw and assess success rate of different treatment and handling measures in the extension of fruit shelf-life. These range from heat treatment of fruit to destroy insect and microorganisms [7] to low temperature storage [8], control atmosphere [9], physical and chemical treatment [10]. No single or combined measures to date is generally preferred thus necessitating continuous search for better methods or strategy for harnessing optimally harvest of pawpaw fruit for both domestic and export purposes. Consequent to the above, this study assessed fruit firmness and colour change as time-related factors for harvesting in conjunction with the effects of post-harvest handling on the shelf-life of *Carica papaya* L fruits.

II. Materials and Methods

A. The Pawpaw Research Farm

The farm is located in Covenant University on a 3 ½ plot. The half plot served for nursery from which seedlings are transplanted to the Research Farm. The proximity of the Farm allows for frequent visit usually not less than three times per week. From flower bloom to fruiting, records on number of fruiting trees in the Farm with 250 stands of pawpaw were taken. In addition, during harvest the numbers of matured to immature fruits were recorded and each harvest visit documented with details on yield and fruit quality.

B. Sampling

Fruits were harvested by hand picking and only fruits certified as healthy (no skin break, discolouration, and absence of visible symptoms of disease) were used in this study. Fruits harvested by visual inspection were considered matured and were grouped into two; fruits with no visible sign of colour break (army green fruit) and fruits with first colour break (first stripes of yellow). Ripe fruits or fruits with multiple yellow stripes were excluded from this study. Fruits with colour breaks that ripen within 2 days of harvest were removed from study. In all cases, fruits were washed at the farm with soft foam and running water from the tap, drained and surface dried with soft clean cloth. Fruits were transported singly in plastic tray to the storage rooms.

C. Experimental

Fruits were sorted into two groups; colour break and no colour break. Under each category, further subgroupings were made. These include washed fruits only, salt (NaCl solution; 1%-5%) solution bath, heat-treated fruits, chlorine dip fruits and fruits that received heat and chlorine treatment. Heat treatment was done by dipping each fruit into a water bath at 50° C for 20 min. For chlorine treatment, fruits were dipped in 15% chlorinated water for 15 min. Treatment requiring heat and chlorine was done with the heat treatment first followed with the chlorine dip 10 min after. In each group were 20 fruits further divided into two set for storage at two different temperature ranges; room temperature (27-30°C) and air conditioned room (19-23°C). The rooms' temperatures were monitored with a thermometer. Spoilage or ripening during storage was monitored and 10 volunteers were independently asked to assess the quality of the fruits by asking whether they will accept and eat the fruits under each category of treatment and storage based on physical appearance of the fruits.

D. Microbiological study

Where spoilage occurred, samples were taken aseptically for both bacterial and fungal cultures. Media used for bacterial cultivation include Kings agar, MacConkey agar, Nutrient agar and MRS agar. Media used for fungi cultivation were malt extract agar, potato dextrose agar (PDA) and PDA with chloramphenicol. Standard culture techniques for bacteria and moulds were done and isolates were identified using their colonial, microscopic and biochemical characteristics as appropriate.

III. RESULTS

TABLE I. shows the effect of timing of harvest on the post-harvest quality of pawpaw fruit. It also showed respondents acceptability of fruits quality under each category. Range of matured fruits on trees was 8-25 with average per harvest of 5 fruits per tree. The proportion of matured to immature fruits at each harvest visit was 2:3. Matured army green fruits without early signs of ripening before harvest (15% of total) failed to ripen or ripened unevenly stored at 27-30° C. Ninety percent of matured green fruits with early signs of ripening indicated by first colour break preserved from 3-7 days at 27-30° C, the remaining 10% showed symptoms of spoilage between 3-5 days. The 90% of fruits in this category were adjudged suitable for consumption by all respondents. The parallel experiment with storage temperature at 19-23° C extended shelf-life to 9-12 days.

TABLE II. shows the effect of pre-treatment with different agents on the shelf-life and quality of stored fruits at the two ranges of temperature studied. A combination of hot water treatment and chlorine dip gave 98% preserved fruits though with no added extension to shelf-life. Pre-treatment with salt solution resulted in rapid deterioration of the fruits as evident by shrinking, oozing out of fluid from fruit and profuse fungal growth (Figure 1). Fungi isolated from salt treated fruits include *Aspergillus niger*, *A. flavus*, *A fumigates*, *Penicillium* spp., *Mucor* spp., *Colletotrichum gloeosporoides*, *Alternaria* spp. and *Rhizopus stolonifer*.

TABLE I. EFFECT OF TIMING OF HARVEST ON POST-HARVEST FRUIT CONDITION AND RESPONDENTS OPINION ON QUALITY

Features	No of colour break	colour break
Shelf-life at 27-30° C:*	1-5 days	3-7 days
• Percentage spoilage/uneven ripening	15	0
• Percentage ripen fruits with spoilt region	25	10
Respondents perception:		
• Percentage acceptability (uneven ripe fruits)	5	-
• Percentage acceptability (ripe fruits with spoilt region)	20	90

- Not applicable

*at 19-23° C shelf-life was extended to 9-12 days

TABLE II. EFFECT OF PRE-TREATMENT ON SHELF-LIFE OF STORED FRUITS

Pre-treatment	Shelf-life (% increase in preserved fruits at upper range) at 19-23°C	Shelf-life (% increase in preserved fruits at upper range) at 27-30°C
Wash with water only	10 days (90)	3 days (90)
Hot water dip	11 days (95)	5 days (95)
Chlorine dip	11 days (95)	5 days (95)
Hot water and chlorine dips	12 days (98)	7 days (98)
Salt solution	< 3 days (0) [a.]	< 3 days (0) [a.]

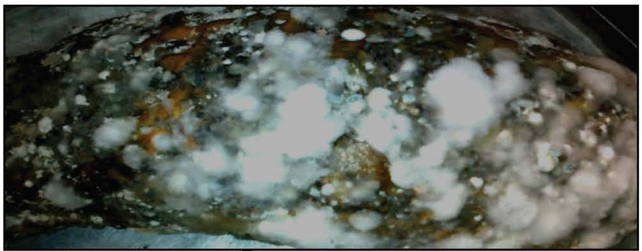
[a.] Growth of moulds identified as Aspergillus niger, A. flavus, A fumigates, Penicillium spp., Mucor spp., Colletotrichum gloeosporoides, Alternaria spp. and Rhizopus stolonifer.

IV. DISCUSSION

Amongst the pre-harvest factors determining the availability of fruits for both domestic and export market is ability to stock-pile harvest. Since all fruits do not mature at approximately the same time both on the same tree or in an orchard cultivated at the same time due to differences in bloom time, measures to preserve harvested fruits within the same proximity of harvest become imperative. Though this feature of the papaya plant may put much pressure on preservation technologies for export shipment, it may be advantageous to the domestic market as this staggering harvest makes fruits available over extended period of time. This is in conformity with the result of the present study that established a ratio of 2:3 for mature to immature fruits at each harvest visit that span 3 months. Ready to harvest described as ¼ colour breaks has been adopted as standard for determining best time to harvest [6]; but this however remains subjective. Ability to critically determine what time to harvest may be a factor of experience as a number of fruits in this study adjudged as belonging to the ¼ category ripen within 2 days post-harvest and were removed from the study. Also, 15% of harvested fruits were mistaken to be matured in this study. This set of fruits failed to ripen or produced unacceptable features by sensory evaluation. It is therefore important to consider these two parameters in devising strategies for extending the shelf-life of *C. papaya* fruit.

A number of studies have reported the shelf-life of papaya fruit at ambient temperature to be less than 1 week [11, 12] and this is in agreement with the range of 3-7 days reported in the present study at 27-30^{o} C. This was further extended to 9-12 days at 19-23^{o} C. Another study [13] achieved a shelf-life for papaya fruit for 10-16 days at 22.5-27.5^{o} C. The storage temperatures used in this present study is to simulate temperatures achievable in retail outlets for domestic market and the extension is of added economic value to retailers.

Pretreatment with hot water and followed with chlorine extended the percentage of fruits successfully preserved by 8% over untreated fruits. These agents have been reported to kill insects and inhibit microbial growth [7]. However, salt treatment with sodium chloride resulted both in physical and microbial deterioration of the fruits, though other reports using calcium based salts have yielded encouraging results [14, 15]. Calcium chloride was reported to inhibit conidia germination and extend papaya storage life by 15 days and reduced the incidence of weight and firmness loss. The role of calcium in maintaining cell wall integrity may account for its protective role against microbial invasion. In conclusion, the data presented in this study has shown that pre-harvest activities and farm management that will produce healthy fruits are major steps in achieving good preservation outcomes for papaya fruits irrespective of the postharvest measures applied.



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