Int. Agrophysics, 1996, 10, 37-41

FIRMNESS AND STABILITY OF PLANTAIN FRUITS UNDER AMBIENT TEMPERATURES

S.N. Asoegwu

Department of Agricultural Engineering, Federal University of Technology, P.M.B. 1526, Owerri, Imo State, Nigeria

Accepted November 23, 1995

A b s t r a c t. Plantain (*Musa* spp) fruit physical properties of finger diameter, pulp/peel ratio, fruit water content and firmness were measured using standard procedures. Fruits with high firmness had low water content, reduced pulp/peel ratio, small finger diameter, and high fruit weight. It was observed that if 50 % of the fingers in the bunch have a firmness between 45-55 N for a finger diameter above 40 mm, the plantain fruits may be said to have matured for harvest. In 15-d storage at ambient temperature (21-24 °C) fruit firmness and water content decreased from 56.1 to 30.6 N and from 66.8 to 45.3 %, respectively, while fruit weight loss and pulp/peel ratio increased from 0 to 7.66 % and from 1.59 to 2.35 %, respectively. Firmness was used to classify plantain fruits into 'soft' (<N), 'hard' (>55 N) and 'firm' (40-55 N). The fruit can store for 6-d under ambient conditions and still remain 'firm'. After 6-d storage, the fruit ripens and become soft.

K e y w o r d s: fruit firmness, fruit water content, plantain, pulp/peel ratio, storability

INTRODUCTION

Plantain (*Musa* spp) is an extremely important food crop in Sub-saharan Africa, producing nutrition (25 % of carbohydrates, 10 % of calories intake) for many millions of consumers [10]. It is an important source of income for small holder farmers, who produce them in compound or home gardens. There is high demand for plantain fruits for local consumption as a starchy staple and as an industrial raw material for products such as plantain chips, flour purees, etc. [1,14]. It has a great export potential [16]. Because the fruit can not be consumed in its fresh form and can not be allowed to ripen on the pseudostem, it is harvested at a mature green unripe stage and left in storage for postharvest ripening. Many fruits destined for the fresh market must be harvested at a stage of maturity to minimise damage during packing and shipping, yet must also ripen to aceptable quality at the terminal market [4].

Firmness and hardness, the most commonly used engineering terms in quality evaluation of fruits and vegetables [12], are measures of the pressure required to penetrate the fruit, or the deformation caused by exerting pressure on the fruit. Firmness is an important textural attribute in fruits and vegetables in connection with the readiness of crops for harvest, quality evaluation during storage for the fresh market as well as prior to processing. This quality is also important in loading, unloding and transport of the fruits to storage in order to reduce fruit defects (blemishes that affect peel and pulp) and the amount of broken fruits, which reduce the market value. For mechanical processing of fruits and vegetables firmness is significant in ensuring acceptable quality and efficiency [4].

From the engineering standpoint, firmness is associated with tissue stiffness, modulus of elasticity etc., as related to the design of containers for bulk transportation [1,3]. Many changes in physical, chemical and structural properties of fruits and vegetables are reflected in changes in firmness of the material [5,6,17]. Some growers say that 'hard' fruits store better than 'soft' ones, and that a large part of the storage loss may be attributed to shrinkage caused by fruit water loss, or rotting caused by mechanical injury. It has been suggested that fruit sorting machines can be developed based on flesh firmness [4,15].

The peel is like a protective covering for the plantain fruit. As its thickness increases, its cushioning ability becomes more pronounced because of higher firmness. The high pulp/peel ratio has been described as a criterium which help to explain why people prefer the False Horn bunch type of plantain, especially for food processing [13]. The pulp/peel ratio is also a measure of fruit maturity of banana [16]. High pulp/peel ratio in plantain means deeper pulp penetration into the fruit and means low firmness [2].

The objectives of this study were to (i) determine some of the properties that affect plantain fruit firmness and how they influence each other, and (ii) determine how these properties are affected by storage time.

MATERIALS AND METHOD

Fresh bunches of False Horn plantain cv AGBAGBA were hand-harvested from research orchards at the National Horticultural Research Institute, Ibadan and Okigwe Stations at various times during two years. The fruits were brought to the laboratory at a green unripe stage. Straight fruits with uniform cros-section were selected and used in this study in which fruit weight (FW), fruit diameter (FD), pulp/peel ratio (PP), fruit water content (FWC), and fruit firmness (FF) were measured using standard procedures.

Each individual fruit was weighed using an EL 22-5480 electronic balance to determine FW. It was then measured at several points at its mid-section using a vernier calliper. These measurements were averaged and recorded as the FD, and used to categorise the fruits into five class ranges: 30-34, 35-39, 40-44, 45-49 and 50-54 mm. The smallest and largest fruits in each class were selected, the peels removed, both pulp and peel reweighed on weight basis and averaged.

Fruit firmness (FF) was measured by an automatic penetrometer with a 7.9 mm diameter tip (model FT-327) [7-9] at six different random points on each of twenty randomly selected fruits from each class, because as with tomato fruit, there was no homogeneity of firmness along the plantain fruit [11]. Fruits used for the firmness test were weighed, cut into bits, oven-dried to a constant weight at 103 °C, cooled inside a dessicator and re-weighed to determine the FWC on dry weight basis (db).

The remaining fruits from all the classes were mixed together and randomly divided into six groups. Then at 0, 3, 6, 9, 12, and 15 d in storage (DS) fruits from groups 1, 2, 3, 4, 5 and 6 were individually re-weighed and weight loss calculated. Measurement of fruit firmness, pulp/peel ratio,and fruit water content were done in that order on each fruit. Fruit weight loss (FWL) was taken as the decrease in weight with time divided by the initial weight at zero DS.

These data were used to establish equations for predicting plantain fruit texture, since standard industry practice is to quantify texture by penetrometer measurement of flesh firmness.

RESULTS AND DISCUSSION

The frequency of distribution of FD, given in Table 1 shows that 85 % of the fruits had a diameter between 35-49 mm and 52 % between 40-44 mm. Only 10 % of the fruits were extra large (50-54 mm) and 5 % extra small (30-34 mm). For engineering design, therefore, plantain fruit diameter (peel included) may be taken to be between 35-49 mm. Table 1 also shows the distribution of the other measured parameters according to fruit diameter class.

Finger diameter PP and FWC significantly correlated negatively with FF (Eqs 1-3). Large

Table 1. Distribution of plantain finger diameter, firmness pulp/peel ratio, fruit weight, fruit water content at ambient temperature (21-24 °C)

Parameter	Diameter distribution (mm)				
	30-34	35-39	40-44	44-49	50-54
Frequency	5	13	52	20	10
Firmness (N)	59.1* (0.58)	60.8 (1.30)	56.9 (2.19)	44.7 (1.85)	39.6 (1.24)
Pulp/peel ratio (g/g)	1.32 (0.09)	1.47 (0.21)	1.71 (0.26)	2.09 (0.10)	2.21 (0.15)
Fruit weight (g)	240.5 (3.97)	235.9 (4.32)	229.2 (3.29)	219.6 (4.17)	216.1 (2.46)
Fruit water content (%) (db)	58.9 (1.22)	60.8 (0.95)	64.4 (2.35)	71.2 (3.65)	73.5 (1.87)

*Figure in bracket are standard deviations.

diameter fruits with high PP were found to have low FF because of low peel content. Penetration resistance has been found to be more in peel than in pulp [2,8]. Heavy fruits with low moisture content had high FF (Eq. 4), showing that plantain FWC influence FF considerably:

$$FF = 98.504 - 1.102\ FD \quad (r = -0.920) \qquad (1)$$

$$FF = 93.602 - 23.513\ PP \quad (r = -0.955) \qquad (2)$$

Since firmness, like hardness, may be defined as resistance to deformation, then it follows that, for plantain fruit, more water content will reduce firmness as has been reported by Zoerb and Hall [18]:

$$FF = 146.902 - 1.440\ FWC \quad (r = -0.971) \qquad (3)$$

$$FWC = 205.468 - 0.612\ FW \quad (r = -0.996) \qquad (4)$$

The low FWC in heavy fruits may be due to their low PP. This is so because while FWC increased with increase in PP (Eq. 5) those fruits with high PP had low weights (Eq. 6):

$$FWC = 36.596 + 16.570\ PP \quad (r = 0.998) \qquad (5)$$

$$PP = 10.204 - 0.037\ FW \quad (r = -0.999) \qquad (6)$$

It was interesting to observe that large diameter fruits correlated negatively with FW (Eq. 7) and the larger the fruits, the larger the PP (Eq. 8); showing fruits that have filled completely:

$$FW = 282.944 - 1.302\ FD \quad (r = -0.991) \qquad (7)$$

$$PP = -0.256 + 0.048\ FD \quad (r = 0.987) \qquad (8)$$

However, large diameter fruits were found to contain high water content (Eq. (9)) and low FF (Eq. (1)), thus making heavy fruits to have high FF (Eq. (10)) because of the high proportion of peel they contain:

$$FWC = 32.496 + 0.792\ FD \quad (r = 0.984) \qquad (9)$$

$$FF = -144.761 + 0.863\ FW \quad (r = 0.947) \qquad (10)$$

Holder and Gumbs [8] found that the penetration resistance of the banana peel is about twice that of the pulp. The more the pulp in a fruit the less the overall FF because of its FWC. However, during the transportation of the fruit, firmness plays an important role in withstaning mechanical damage. For PP above 1.6, FF is generally less than 50 N and FWC above 60 %. So it may be advantageous to transport firm green fruits with moderate PP.

Again, the distribution of the FD showed that in the design of containers for truck transport of the plantain fruit, FD of 35-49 mm, FF of over 50 N and PP of below 1.6 should be used. Also FF and FD may help one assess with ease, the maturity of the plantain at harvest. Once over 50 % of the fingers in a bunch have attained FF of 45-55 N and FD of above 40 mm, the bunch may be said to have matured enough to withstand an appreciable amount of mechanical damage and should be harvested.

In storage FF and FWC decreased with DS. At the end of 15-d storage FF decreased from 56.1 to 30.6 N (54.5 % reduction) while FWC was reduced by 32.2 % from 66.8 to 45.3 % (Table 2). At 6-DS, FF is above 50 N, PP is 1.82 meaning that the fruits were still hard enough to withstand packing load and mechanical damage. Since high PP is associated with low firmness, the peel is a major component of the fruit that could be advantageous for resisting applied load [1]. At 9-DS, FF had dropped to below 40 N with PP above 2.0 because the plantain fruits had shown signs of ripenning. The low FF and PP associated with the plantain fruit ripeness are in agreement with findings of Peleg and Gomez Brito [14] that the ripenning of plantain fruit is accompanied with considerable decrease in the apparent compressive strength, equivalent to FF (a drop from 50.8 N at 6-DS to 39.6 N at 9-DS when most of the fruits had ripened). The relationship betweeen fruit parameters and DS under an ambient temperature of 21-24 °C are given in Eqs. 11-14. There was a steady increase in fruit weight loss (FWL) as storage progressed.

Table 2. Changes in mechanical properties of plantain in storage

Parameter	Days in storage					
	0	3	6	9	12	15
Firmness (N)	56.1* (2.32)	54.0 (2.06)	50.8 (2.77)	39.6 (1.91)	34.1 (1.28)	30.6 (2.89)
Fruit weight loss (%)	0 (0)	3.53 (0.88)	40.95 (0.40)	6.73 (0.22)	7.37 (0.38)	2.66 (0.95)
Fruit water content (%) (db)	66.8 (2.48)	62.6 (1.80)	58.1 (3.59)	54.3 (2.32)	49.7 (2.50)	45.3 (2.68)
Pulp/peel ratio (g/g)	1.59 (0.025)	1.67 (0.082)	1.82 (0.046)	2.19 (0.072)	2.31 (0.051)	2.35 (0.066)

*Figure in bracket are standard deviations.

$$FF = 58.371-1.890\ DS \quad (r= -0.977) \quad (11)$$

$$FWC = 66.848-1.429\ DS \quad (r= -0.999) \quad (12)$$

$$PP = 1.553+0.058\ DS \quad (r= 0.970) \quad (13)$$

$$FWL = 1.354+0.491\ DS \quad (r= 0.942) \quad (14)$$

As PP and FWL increased with DS both FF and FWC decreased. Considering the value of FWL, FF and PP at 6-DS, it is evident that there was a sharp textural variation characterized by both softness and the development of the peel's yellow coloration. It may be possible to classify plantain fruits with FF less than 40N as 'soft', those with FF greater than 55N as 'hard' and those with FF between these two limits as 'firm'. One may conclude from this study that under an ambient temperature (21-24 °C) of plantain fruits may store for up to 6-DS and still remain 'firm' enough to withstand packing and transportation loads. Beyond 6-DS, plantain fruits must have started ripening; packing and transporting them at this stage requires extra care to minimize mechanical injury.

CONCLUSIONS

1. For engineering desing, plantain fruit diameter (peel included) may be taken to be between 35-49 mm.

2. Fruit firmness decreased as finger diameter, pulp/peel ratio, fruit water content and days in storage increased. Only fruit weight correlated positively with firmness, at harvest.

3. Large diameter fruits have low fruit weight with higher pulp/peel ratio than small diameter fruits, because they contain higher fruit water content.

4. Pulp/peel ratio, an important parameter in fruit transportation that affect fruit firmness,

has a negative correlation with fruit weight, but a positive one with fruit diameter and days in storage.

5. If over 50 % of the fingers in a bunch have a firmenss between 45-55 N for finger diameter above 40 mm, plantaint fruits may be said to have matured and the bunch harvested.

6. Plantain fruits lose firmness and water content as they ripen in storage, though their pulp/peel ratio and weight loss increase.

7. Plantain fruit of firmness less than 40N may be termed 'soft' more than 55N termed 'hard' and between these two limits termed 'firm'.

8. Plantain fruit can store up to 6-d under ambient conditions and still remain 'firm'. Beyond this storage time ripeness may set in and the fruit softens.

ACKNOWLEDGEMENT

The author acknowledges with thanks the facilities for this work which were provided by the Director, National Horticultural Research Institute (NIHORT), Ibadan and the technical assistance of B. Adelaja and P.O. Onyele.

REFERENCES

1. **Ajibola O.O.**: Some viscoelastic properties of plantain (*Musa paradiasca*). Nigerian J. Eng. and Technol., 9(1), 91-104, 1986.
2. **Asoegwu S.N.**: Yield response of late season plantain to frequently irrigation. The Nigerian Eng., 26(2), 1-12, 1991.
3. **Chuma Y., Shiga T., Iwamoto M.**: Mechanical properties of Satauma orange as related to design of containers for bulk transportation. J. Texture Studies, 9, 461-479, 1978.
4. **Delwiche M.J., Tang S., Mehlschau J.J.**: An impact force response fruit firmenss sorter. Trans. ASAE, 32(1), 321-326, 1989.
5. **Diener R.G., Elliot K.C., Nesselroad P.E., Ingle M., Adams R.E., Blizzard S.H.**: Bruise energy of peaches and apples. Trans. ASAE, 22(2), 287-290, 1979.
6. **Garrett R.E., Zahara M., Griffing R.E.**: Mechanical harvest of crisphead lettuce. Agricultural Eng., 45(11), 611-613, 1964.
7. **Hipps N.A., Perring M.A.**: Efffects of soil management systems and nitrogen fertilizer on the firmness and meanfruit weight of Cox's orange and pippin apples at harvest. J. Sci., Food and Agriculture, 48, 507-510, 1989.
8. **Holder G.D., Gumbs F.A.**: Agronomic assessment of the relative suitability of the banana cultivars 'Robusta' and 'Giant Cavandish' (Williams hybrid) to irrigation. Tropical Agriculture (Trinidad), 60(1), 17-24, 1983.
9. **Holt C.B.**: Measurement of tomato firmness with a universal testing machine. J. Texture Studies, 1, 491-501, 1970.
10. I.I.T.A. (International Institute for Tropical Agriculture), Annual Report, 22, 1993.
11. **Kader A.A., Morris L.L.**: Tomato firmness as a quality attribute. Proc. 2nd Tomato Quality Workshop. Davis California, 30-34, 1976.
12. **Mohsenin N.N.**: Mechanical properties of fruits and vegetables - review of a decade of research applications and future needs. Trans. ASAE, 15(3), 1064-1070, 1972.
13. **Ogazi P., Swennen R.**: Fruit characteristics in plantains. In: I.I.T.A., Annual Report on Root, Tuber and Plantain, 61, 1988.
14. **Peleg M., Gomez Brito L.**: Textural studies in ripening plantains. J. Texture Studies, 7, 457-463, 1977.
15. **Rohrach R.P., Franke J.E., Willits D.H.**: A firmness sorting criterion for blueberries. Trans. ASAE, 25(2), 261-265, 1982.
16. **Stover R.H., Simmonds N.W.**: Bananas. Longman Group, U.K. Ltd., 66-74, 1987.
17. **Tennes B.R., Diener R.G., Levin L.H., Whittenberger R.T.**: Firmness and pitter loss studies on tart cherries. Trans. ASAE, 13(6), 810-813, 1970.
18. **Zoerb G.C., Hall C.W.**: Some mechanical and rheological properties of grains. JAER 5, 83, 1960.