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# DETERMINATION OF HARVEST MATURITY WINDOW FOR COMMERCIAL PROCESSING OF BANANAS (*Matooke - Musa* sp.)

John Bosco KAWONGOLO[1,2&3], Florence I. MURANGA[2], Oliver HENSEL[1]

[1]University of Kassel, Department of Agricultural Engineering, Germany
[2]Presidential Initiative on Banana Industrial Development (PIBID), Uganda
[3]Makerere University, Department of Agricultural & Biosystems Engineering, Uganda.

## ABSTRACT

Banana, (*matooke*) Musa spp. triploid *acuminate* genome group (AAA-EAHB) is an important crop in Uganda. *Matooke* flour contains more than 80% starch (db) which is good for both food and nonfood industrial application, thus it require commercial processing to tap its potential. However, commercial processing of *matooke* requires consistent product quality, which is directly affected by degree of maturity. The main objective of this study was to determine the optimum maturity window for commercial processing of *matooke*. This was objective was achieved by establishing the effect of maturity age on maturity indices that can be potentially used as a measure to estimate the maturity window; and also by establishing the effect of maturity age at harvest on starch content (%db) of *matooke* flour. *Matooke* within maturity window between 13 – 18 weeks, with starch content above 82% (db), is suitable for commercial processing. The Combined Model: $Y = 0.387 + 0.031X_1 + 7.27X_2$ ($R^2 = 0.94$, $p < 0.01$) was the best model for estimating the maturity age at harvest. The Starch Model $Y = 1.76 = 10.6X – 0.34X^2$ (R2 = 99, $p < 0.01$) can be used to estimate the starch content of *matooke* flour at any given maturity age.

**Keywords:** *Matooke*, maturity window, flour, processing, starch content.

## INTRODUCTION

Bananas and plantains (*Musa* spp.) are grown worldwide in tropical countries (Stover *et al*., 1987) and the fourth most important food crop after rice, wheat and maize (Nelson *et al*., 2006; Nyombi, 2010; Akcoaz, 2011). Banana is an important crop in Uganda; it is a staple food for more than 70% of Uganda's population and contributes to about 42% of household income in rural areas (Karugaba & Kimaru, 1999). According to FAOSTAT (2011), Uganda is the second largest producer of bananas and plantains to India, with a production of 10.5 million metric tons

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of plantains and 0.5 million metric tons of dessert bananas, giving a total production of 11 million metric tons. The most common of these plantains is the cooking type locally called *matooke,* a *Musa* spp. triploid *acuminate* genome group (AAA-EAHB), is steamed and served as a main course (Karamura *at el*., 1998; Nyombi *et al*., 2009).

*Matooke* are perishable and are traded in fresh form (Vinzenz, 2011), the latter leads to high postharvest losses ranging from 22-45% (Muranga *et al*., 2010). These high postharvest losses are attributed to non-uniform level of maturity at harvest, poor handling and bulk transportation among others. This is evidenced by the fact that: even if Uganda is the second world producer of bananas and plantains, it does not appear anywhere among the world exporters of bananas (Robinson & Saúco, 2010).

Due to increased market demand of quality products (Sablani, 2006) and consistency of product quality on the market, therefore, commercial processing of fruits should comply with certain specifications like degree of maturity and use of healthy fruits (Leite *et al*., 2007). *Matooke*, like any other fruit, undergoes a developmental process by which the fruit attains maturity. During the fruit development, starch grains are deposited initially in the pulp cells which form in the vicinity of the vascular bundles, and thereafter starch deposition moves centripetally and continues until maximum fruit maturity (Robinson & Saúco, 2010). This indicates that maturity directly affects the quality of the final product as Kader, (1999) reported maturity at harvest is the most important factor that determines storage-life and final fruit quality. Traditionally, *matooke* maturity is judged by the visual appearance of the fingers particularly the angularity (the fingers being full and rounded), the color (the color of the fingers being lighter) and the finger tips turning black (Dadzie, 1998). At present there is lack of information on estimating the maturity window, within which *matooke* flour of consistent quality at all times on the market can be processed.

Harvest maturity also referred to as horticultural maturity or commercial maturity is defined as stage of development when a plant or part of plant possesses the prerequisites for utilization by consumers for a particular purpose (Kader, 1999). The harvest maturity in this study refers to the time from when inflorescence emerges from the stem to the time when the sample is harvested. It has been reported that *matooke* and bananas are generally harvested between three-quarters to full maturity (Muranga *et al*., 2007; Robinson & Saúco, 2010).

In the event of commercial processing of *matooke* into flour, it requires the *matooke* flour to have a consistent quality on the market at all times. To this end it was imperative to establish the harvest maturity window for *matooke* with which a consistent quality of flour could be obtained. Therefore the objective of this study was to establish the optimum harvest maturity window for

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*matooke*. This was achieved by monitoring the relationship between harvest maturity and maturity indices, pasting properties of *matooke* flour and starch content.

## MATERIALS AND METHODS

Samples were obtained from a banana plantation at Presidential Initiative on Banana Industrial Development (PIBID), Bushenyi, Western Uganda. The study area in Bushenyi is located at the Latitude: 0.59°S, Longitude: 30.21° E and Altitude: 1570 m. A completely randomized design (CRD) was employed in selecting the banana stools from which samples for the experiments were picked. The banana stools were monitored and coded as soon as the flower shots up (inflorescence emerges from the stem), in order to establish harvest maturity at the time of picking samples of the banana fruit. The cultivar *Mbwazirume* (Musa *sp* triploid *acuminate* genome group AAA-EAHB) which is soft cooking and commonly grown was selected for the study.

### *Investigation of Maturity Indices*

The maturity indices considered in these investigations were: finger circumference, finger weight, pulp weight, peel weight, pulp/peel ratio and moisture content of the fingers for *matooke* at different harvest maturity (10 - 23 weeks) were determined. A total of five fingers were picked at random from a bunch from middle to top, because fingers from the bottom are 30 – 40% smaller than those from top (Robinson & Saúco, 2010). The fruit circumference was measured by use of a tape measure around the middle of the fruit. The fruit weights were measured on electronic balance. The fingers were hand peeled, and then the pulp and peel were weighed separately on electronic balance. The same data was used to calculate the pulp/peel ratio.

### *Determination of Starch Content*

The samples for determining starch content of *matooke* flour were harvested at harvest maturity from week 10 – 23, washed, peeled and sliced to uniform thickness of 3 mm, using slicing machine. The sliced samples were prepared as per patent No. AP/P/2005/003308 (Muranga *et al*., 2010) and dried at 55ºC in a cabinet dryer. The dry *matooke* chips were milled to flour using the starch mill with double-walled grinding chamber cooled with running water. The starch content was determined using a polarimeter by employing the general polarimeter method (Kirk & Sawyer, 1991), in two parts: total optical rotation (P) and optical rotation (P') in duplicates plus the blank samples.

### *Statistical Analysis*

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The data was analyzed using MINTAB Software (Release 14 for Windows (2003) Minitab Inc., Pennsylvania, USA). The Pearson Correlation was used to determine the significant correlation between harvest maturity and maturity indices.

## RESULTS AND DISCUSSION

### *Effect of harvest maturity on maturity indices*

**Table 1: Pearson correlation for maturity indices**

| | Harvest Maturity (weeks) | Finger Weight (g) | Finger Length (mm) | Finger Circum[1] (mm) | Peel Weight (g) | Pulp Weight (g) | Pulp/ Peel Ratio |
|---|---|---|---|---|---|---|---|
| Finger Weight (g) | 0.939*<br>0.000** | | | | | | |
| Finger Length (mm) | 0.276<br>0.055 | 0.199<br>0.170 | | | | | |
| Finger Circm[1] (mm) | 0.881<br>0.000 | 0.916<br>0.000 | -0.006<br>0.965 | | | | |
| Peel Weight (g) | 0.808<br>0.000 | 0.896<br>0.000 | 0.060<br>0.649 | 0.834<br>0.000 | | | |
| Pulp Weight (g) | 0.958<br>0.000 | 0.978<br>0.000 | 0.121<br>0.143 | 0.919<br>0.000 | 0.897<br>0.000 | | |
| Pulp/ Peel Ratio | 0.953<br>0.000 | 0.900<br>0.000 | 0.332<br>0.021 | 0.847<br>0.000 | 0.691<br>0.000 | 0.933<br>0.000 | |
| Moisture Content (%wb) | 0.794<br>0.000 | 0.727<br>0.000 | 0.186<br>0.201 | 0.694<br>0.000 | 0.599<br>0.000 | 0.774<br>0.000 | 0.766<br>0.000 |

Key: Cell Contents - * Pearson correlation
** p - value (p = 0.000 => $p < 0.0001$)
[1]Circumference

Table 1 shows the Pearson correlation for maturity indices. From the Table 1, the maturity indices with the highest Pearson correlation above 0.90 were selected as the best maturity indices for estimating the harvest maturity and these include: finger weight, pulp weight and pulp/peel ratio. However, comparing the level of significance, finger length had the lowest which indicated that the finger had almost the maximum length before week 10; implying that there was slow development in finger length after week 10. This was in agreement with Robinson & Saúco

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(2010), who reported that the finger length increases rapidly for 30 days after which growth in length slows down and is completed in 40 – 80 days after emergence depending on the area and climate.

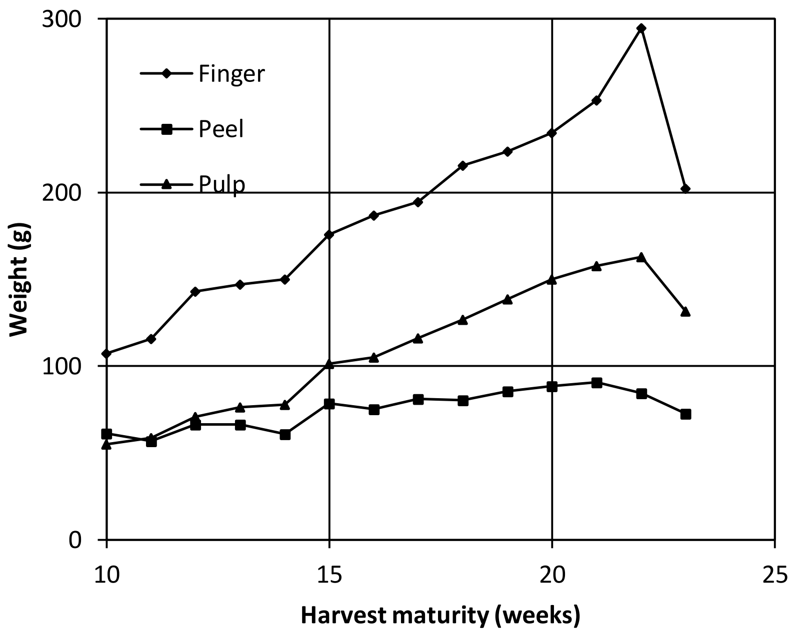


**Figure 1: Effect of harvest maturity on finger, pulp and peel weights**

Figure 1 shows the effect of harvest maturity on finger, pulp and peel weights. It was observed from figure 1 that both finger and pulp weight increased with increase in time until week 22 then decreased. This indicated that *matooke* at week 22 had reached its maximum harvest maturity. The peel weight also increased with increasing time until week 21 and then decreased to week 22. This reduction in peel weights after week 21 could be attributed to cell wall degradation which starts underneath the peel (Robinson & Saúco, 2010). After week 22, *matooke*, being a climacteric fruit, dramatic changes occur during ripening; these include the peel color and pulp texture among others. In advanced stages of maturity, slight peel color change occurs to the initial stages of ripening. The reduction in finger and pulp weight is attributed to loss of starch which plays a major role in textural changes in ripening.

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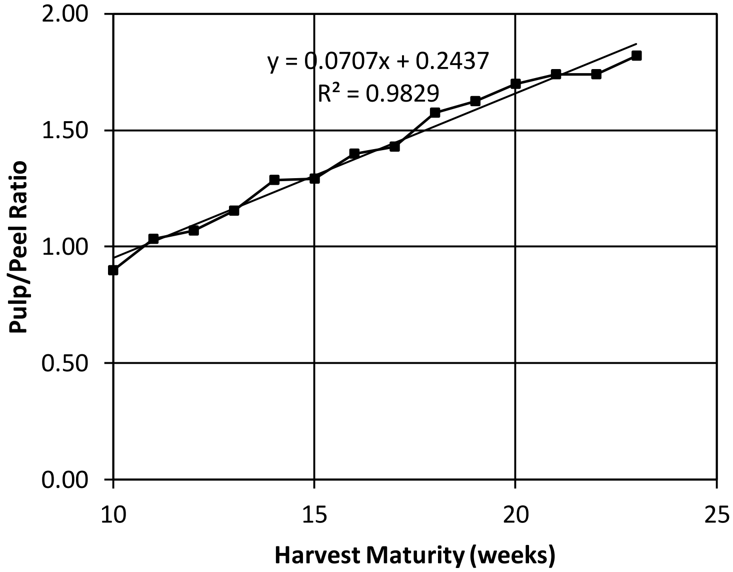


**Figure 2: Effect of harvest maturity on pulp/peel ratio.**

Figure 2, shows the effect of the pulp/peel ratio on harvest maturity. From figure 2 it was observed that the pulp/peel ratio increased with time from week 10 to week 22 and then decreased. It was further observed that *matooke* attains maximum maturity at the harvest maturity at 21 weeks and if it is not harvested it starts going through the post-climacteric stage (Muchui et al., 2010, Tapre & Jain, 2012). These results are within comparable range to those reported by Robinson & Saúco (2010), that the pulp/peel ratio of 1.0 was achieved at about 70 days, in this study was about 77 days (11 weeks).

***Effect of harvest maturity on the starch content of matooke flour***

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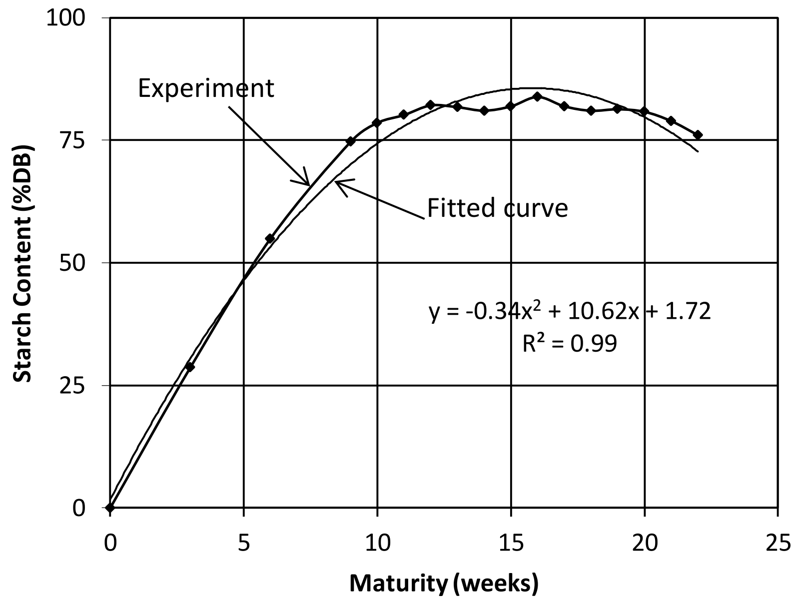


**Figure 3: Effect of harvest maturity on starch content (%db) of *matooke* flour.**

Figure 3, shows the effect of harvest maturity on starch content of *matooke* flour. Figure 3, shows that the starch content increases with time up to maximum and then decreases taking a form of an inverted quadratic curve. This is an indication that the starch accumulates in the pulp as the fruit continues to grow until maximum maturity and beyond which the banana enters the post-climacteric phase which leads to increasing decline in starch. This indicates that *matooke* can be harvested from 13 – 18 weeks because starch content of *matooke* flour was above 82% (db).

***Prediction Models***

Table 2 shows the models which could be used to predict harvest maturity (weeks) given the finger weight (g), or pulp/peel ratio, or a combination of finger weight and pulp/peel ratio. However, it was observed that, the model of a combination was the best followed by the pulp/peel model.

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**Table 2 Models for predicting harvest maturity**

| Model Parameters | Model | $R^2$ | r | P< |
|---|---|---|---|---|
| Harvest maturity (weeks) & Finger weight (g) | $Y = 3.29 + 0.07X_1$ | 0.87 | 0.939 | 0.01 |
| Harvest maturity (weeks) & Pulp/Peel ratio | $Y = 11.9X_2 – 0.298$ | 0.91 | 0.958 | 0.01 |
| Harvest maturity (weeks) & Finger weight (g) + Pulp/Peel ratio (Combined) | $Y = 0.387 + 0.031X_1 + 7.27X_2$ | 0.94 | | 0.01 |

`Where:

$Y$ = Harvest maturity (weeks)

$X_1$ = Finger Weight (g)

$X_2$ = Pulp/Peel Ratio

The model equation given in Table 3 can be used to predict the amount of starch at a given harvest maturity (weeks) of *matooke* after inflorescence emergence.

**Table 3: Models for predicting starch content**

| Model Parameters | Model | $R^2$ | p< |
|---|---|---|---|
| Starch content (%db) & Harvest maturity (weeks) | $Y = 1.72 + 10.62X – 0.34X^2$ | 0.99 | 0.016 |

Where:

$Y$ = Starch content in floor (%db)

$X$ = Harvest maturity of *matooke* (weeks)

***Validation of prediction models***

The above models given in Table 2 were validated by using a new set of experiments to determine the actual values for sleeted maturity indices (finger weight, pulp/peel ratio) at different harvest maturity from week 10 - 22. The analysis of variance (ANOVA) was employed to determine the significance of the relationship between the actual experimental data and the model predicted values (Table 4).

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**Table 4: Significance of prediction model for estimating harvest maturity**

| Model | $R^2$ | p< |
|---|---|---|
| Finger weight model | 0.87 | 0.01 |
| Pulp/peel ratio model | 0.91 | 0.01 |
| Combined finger weight and pulp/peel ratio model | 0.94 | 0.01 |

It was observed that the selected models were significant ($p<0.01$), it indicated that the relationship was statistically significant at α-level of 0.01(99% confident of the estimated harvest maturity). The combined Finger weight with Pulp/peel ratio model was the best followed by the Pulp/peel ratio model. Therefore, the models in Table 2 and 3, can be adapted for estimating the harvest maturity and starch content respectively of *matooke* at Bushenyi.

## CONCLUSIONS AND RECOMMENDATIONS

Considering the results of starch content, the optimum harvest maturity window for commercial processing of raw matooke flour at Bushenyi is between 15-18 weeks for which the starch content above 82%(db). This type of matooke flour can be used to process Extruded, Bakery and Confectionary products (Muranga, 1998). However, in case of natural disaster like storm, matooke from the harvest maturity from week 12-15 weeks can be processed into matooke flour since at that harvest maturity already has starch content above 80% (db) (Muranga, 1998). The ones from age between 3 – 12 weeks can be processed into flour for people who require less starch in their diet. Similarly, matooke from harvest maturity between 18 – 22 weeks can be used to process instant matooke flour (Muranga, 1998). Theoretically the results of the study can be used elsewhere, nevertheless, it is recommended that similar be carried out in the matooke growing areas to determine the applicable models for those particular regions since development of matooke and bananas in general is affected location (Robinson & Saúco, 2010). Further research is recommended to employ the Starch Model and use of a non-destructive method for determining maturity which can relate the starch content to electrical/ magnetic signal.

The finger weight model is recommended for farmers to estimate harvest maturity for matooke and the combined model of finger weight and pulp peel ratio is recommended for commercial processors. Matooke cv mbwazirume (Musa sp. AAA-EAHB) at Bushenyi, harvested within the optimum harvest maturity window from week 15 – 18, should have the following characteristics given in Table 5 and expected starch content above 82 % (db).


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**Table 5 Characteristics of *matooke* cv *mbwazirume* (*Musa* sp. AAA-EAHB)**

| Characteristics | Range |
|---|---|
| Harvest maturity (weeks) | 15 – 18 |
| Finger weight (g) | 175 - 215 |
| Pulp/peel ratio | 1.4 - 1.5 |

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