DEVELOPMENT OF A MECHANISED PLANTAIN SLICER

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ABSTRACT

Cutting of bulk plantains into chips for local and foreign markets is a processing method, which reduces post-harvest losses of green or ripening plantain. The traditional method of slicing plantain with a kitchen knife is laborious, time-consuming and prone to injury, and can only be practiced on a very small scale of production. The mechanised slicer seeks to reduce the drudgery associated with traditional cutting of large-scale plantains into chips. The machine takes 5-7 seconds to slice a finger of an average-size plantain into chips of 2-3mm in thickness compared to the 40-80 seconds with a kitchen knife, which gives non-uniform thickness of plantain chips. It was found to be very convenient, and the average thickness of plantain chips produced with the slicer compares favourably with commercial standards.

Keywords: Post-harvest, slicer, processing method and plantain chips

INTRODUCTION

Plantain, a slender starchy fruit is used as a staple food in many tropical countries. The fruit is used in similar ways as potatoes are used in European and North American diets (Turbana, 2001). Matured plantain can be kept longer in the green state and exported by sea-shipment at 12 to 13.5°C and 85 to 95% relative humidity (Fintrac, 2002).

Worldwide, Latin America and the Caribbean export more than US$ 5 billion of bananas and plantains annually (IITA, 2001). In Ghana, most farmers are unable to meet the export requirements for green plantains because of poor post-harvest handling practices and strict quality standards required for the export market. To avoid blackening and fungal decay of harvested plantains, most farmers sell their produce cheaply to middlemen at the farm gate. A method that reduces post harvest losses and even adds value to green or ripening plantain is to slice, fry and package as snack food-plantain chips. The use of a mechanized slicer can facilitate this processing method.

The traditional method of cutting plantains into chips is to use a sharp kitchen knife holding the pulp of the plantain fruit on a table. Above a certain scale of production, this method is laborious, time-consuming and prone to finger injury. Plantain chips produced this way are not of any uniform size. This is why the use of a mechanized slicer is very necessary to reduce the drudgery of continuous cutting of bulk plantains with a knife. The use of the mechanized slicer will facilitate mass production of plantain chips. This can contribute to food security, export earnings and economic growth. The main objective

of the research is to develop low cost equipment that can facilitate slicing of bulk plantains, bananas and similar fruits hygienically into chips. Plantains sliced with the mechanized slicer can be fried into chips that can be preserved longer for local and foreign markets. Preliminary investigations carried out on the developed slicer sought to find out some technical and operational problems associated with the slicer so that modifications could be made to enhance its performance.

Description of the Plantain Slicer

The plantain slicer consists of -a main frame, cutters, bottom plate and a container, all fabricated from 2mm stainless steel sheet, a wooden mesher made from oak wood, bolts and nuts, woodscrews and pins. The cutters of the slicer are parabolic in shape and are arranged at intervals that will enable the required thickness of plantain chips to be attained. The depth as well as the curvature of the cutters is designed to accommodate the curvature of the various plantain varieties found on the market. The wooden mesher is curved underneath to mesh with the parabolic-shaped cutters so as to provide an effective cutting force when the mesher presses down a plantain finger against the cutters. The slicer has a container volume of approximately 6 litres and weighs 13 kg when empty. Figure 1 is a pictorial view of the developed plantain slicer.

To operate, a peeled plantain is placed on the cutters. The wooden mesher, which is hinged in place at one end and free to swing at the other end, is pressed against the plantain in such a manner that the reaction forces of the cutters facilitate the cutting. The sliced plantain pieces pass through the cutter spaces down into a container. After several cycles of cutting, when the container is full, it is drawn out to empty the contents. The container is then pushed back to its position for another cycle of cutting. The slicer is designed to cut plantains to 3mm circular thickness. Plantains cut with the machine can be fried and flavoured into chips. The slicer design is simple, and does not require a skilled person to operate. It consists of a few parts and therefore has low probability of failure.

MATERIALS AND METHODS

After construction, the slicer was tested with two confectioners and two domestic users in Kumasi. Randomly selected green to yellow *Apem, Apentu, Oniaba and Ekaamenko* plantain varieties of different finger sizes were used in the trials. Table 1 presents some characteristics of peeled plantain varieties used in the trial run. For the purpose of this work, less attention was paid to the specific quantity of each plantain variety used in the trials. The justification for this is that in real life situation, entrepreneurs do not sort out the plantains into varieties before slicing them into chips. In all the trials women prepared and sliced the plantains in their kitchens. A sharp kitchen knife was used to peel and trim each plantain, which was then sliced with the mechanized slicer. Using the slicer one plantain was cut at a time and some measurements were taken. The specific set of variables measured includes slice sizes, force required for cutting and slicing time per finger of plantain.

For primary level analysis, graphical representation in the form of a bar chart was used to show the distribution of data from the mechanised slicer. To carry out some analyses of the characteristics of the data distribution and the extent to which the measured values scatter, statistical methods of central tendency and dispersion were used. For comparative analysis of variations, samples of plantains were sliced using the mechanized slicer and the traditional kitchen knife method. A stopwatch was used to record each slicing time, and a vernier caliper was used to measure the sizes (thickness).

RESULTS AND DISCUSSIONS

To identify and correct initial defects and deviations of parts from design specifications, several fingers of plantain were cut in the workshop during the initial stages of the slicer development.

After taking series of remedial actions to ensure the machine's functional requirements for its intended use. 12 additional trials were carried out to ascertain the performance of the slicer under kitchen conditions. Since the results of the individual trials were very similar it was decided that the 12 plantain fingers, which gave 720 pieces of chips were representative of the preliminary data set required for analysis. Although the number of plantains used in the trials cannot be used to evaluate the performance of the slicer on a commercial scale, it was useful for suggesting how a mechanised system and a traditional method differ.

Results from design calculations showed that on average 33.15N force is required to slice plantains of 30-70mm diameters. As a finger of plantain ripens and softens so the force required for slicing reduces. Under kitchen conditions, the women who sliced the plantains found the swing of the wooden mesher quite convenient since they did not exert much force during the slicing operation. Such micro-level data is required to improve upon the design and the development of the slicer. The implication here is that any labour-intensive mechanism, which would require less human-energy, could be productive.

Mechanised Slicer

Figure 2 shows a bar chart of slice thickness versus frequency of 361 plantain slices (six plantain fingers) processed with the mechanized slicer. The results showed that 74 out of the 361 slices (20%) indicated uniform slice thickness of 3.1mm as the most frequently occurring thickness. The next most frequently occurring uniform slice thickness is 3.2mm, which occurred in 43 out of the 361 slices (12%), and 3.0mm occurred in 38 out of the 361 slices (10%). The values indicating the frequency of occurrence tell where the most occurring thickness is grouped (i.e. about the slice thickness of 3.1mm). The difference between the largest measured slice thickness (3.5mm) and the smallest thickness (2.5mm) gives a thickness range of R=1.0mm. This value indicates the variation that exists in the slice sizes (plantain chips). Assuming that the minimum and the maximum target thicknesses of the slicing process were 2.5mm and 3.5mm respectively, from Figure 2, it is observed that none of the plantain slices from the mechanized slicer would fall outside these limits. This is an indication that the slices obtained from the mechanized slicer were within some limits or tolerances. From the distribution, the calculated mean of the plantain slices is μ=3.07mm, which is very close to the 3mm slice thickness (1/8 inch slices) recommended for commercial plantain chips. Such chips taste better and crispier, as a dessert, than those bigger in size (Sharon, 2003).

Traditional Knife Method

Using the traditional method of cutting with a knife, 364 plantain slices (6 fingers of plantain) were cut for analysis. The results showed that almost all the 364 plantain slices were of non-uniform circular thickness. From this observation, it became more interesting to measure the extent of variation, which obviously resulted from random variations in the operating characteristics of using a kitchen knife to slice bulk plantains.

Owing to the considerable amount of highly variable slice thickness and variations among the slices, the thickness values were grouped into a table to provide a detailed analysis. Table 2 presents data on 40 of the 364 plantain slices measured for analysis. For each plantain slice, the table shows three different measurements taken around the circular thickness of the slices. For example, slice samples 15, 29 and 26 were (1.0, 2.0 and 2.6mm), (3.0, 3.0 and 2.8mm) and (1.0, 1.8 and 4.0mm) respectively. Although the range values R=0.2 to 3.0mm, represent a simple measure of the dispersion, it can be seen that significantly there were some variations around the circular thickness of the plantain slices from the traditional knife method. The standard deviation σ=0.47mm, is the most useful measure of

the spread or dispersion of the values. The smaller value obtained suggests that most of the slice thickness tend to concentrate around the mean μ=2.51mm.

Suppose the expected thickness from the knife cutting process lies between a minimum thickness X_1=2.50mm and a maximum thickness X_2=3.50mm (cf. Figure 2), with a mean μ= 2.51mm, and a standard deviation, σ=0.47mm (Table 2). If we assume that the slice thicknesses are normally distributed, then the expected proportion of plantain slices that would lie between 2.50mm and 3.50mm could be computed from the standardized deviate Z_1-Z_2, where $Z_1=(X_1-\mu)/\sigma$ and $Z_2=(X_2-\mu)/\sigma$ (Mahajan, 1999). From the computation, Z_1 becomes (2.50-2.51)/0.47, which gives a negative value -0.021, and Z_2 becomes (3.50-2.51)/0.47, which gives a positive value +2.11. From tables, the area under the normal curve gives 0.9826-0.4721 being 0.511 or 51%. This is the proportion of the slices expected to lie between 2.50 and 3.50mm thickness. The converse is that, nearly 49% of the plantain slices would fall outside the specified limits of 2.50-3.50mm. This is certainly a significant measure of the extent of non-uniformity in the thickness of the slices from the traditional knife method. Lastly, comparing the two mean values, the mean μ=2.51mm, obtained for slices from the traditional knife method, is not sufficiently close to the 3mm slice thickness (1/8 inch slices) recommended for commercial plantain chips.

Advantage of Mechanised Slicer over Traditional Knife Method

The preceding results revealed that compared to the mechanised slicer, the traditional kitchen knife method showed large random variations and dispersion in slice thickness. This pattern therefore suggests that the traditional knife method does not possess the characteristics of conformity (Mahajan, 1999). The considerable variation in slice sizes and non-uniformity around the circular thickness of the plantain chips from the traditional knife method could result from the following factors – difficulty in judging precisely without marked out lines for cutting, and knives are not guided when being used for cutting.

In the case of the mechanized slicer the arrangement of the cutters at equal intervals served as a guide to ensure uniform thickness. Although there was small variation in size among the plantain slices, when compared to the traditional method of cutting with a knife, the output of the mechanized slicer was quite encouraging. The low spread or dispersion of the measured thicknesses around the mean of 3.07mm suggests that the sizes of the plantain chips produced by the mechanized slicer were generally very close. The usual aim in the development of such a device is not to achieve every piece with the same thickness, but to obtain plantain chip thickness within specified limits or tolerances (Lockyer et al., 1989).

Considering the slicing time, whereas the mechanized slicer took 5-7 seconds to slice a finger of plantain, the traditional method of cutting with a very sharp knife took 40-80 seconds per finger of plantain. Because of the less cutting time and uniformity of chip sizes produced, it can be said that the mechanized slicer has technological edge over traditional cutting with a knife. To achieve uniform thickness of the plantain chips is not the only point of interest in this trial, the time spent in cutting bulk quantity of plantains, reduction in drudgery and reduction in injury rates also count.

Capacity and Marketing

Using the 6-litre container to measure the number of slices that will fill it up, the following information emerged: depending on the diameter and length of a finger of plantain, the container capacity was known by calculating the number of slices it could take. Considering the two ex-

treme plantain diameters of 30 and 70mm- the container could take about 2800 plantain chips of the 30mm diameter, while it could only take about 520 plantain chips of the 70mm diameter.

Investigations into packaged plantain chips sold in supermarkets in Kumasi revealed that most packaged plantain chips contain 35-45 slices of average diameter 30mm (approximately half *Apem* finger size) and 20-30 slices of 40-70mm diameter (approximately quarter *Apentu* finger size). Such plantain chips are sold for 2000 cedis (23 US cents). This means that the mechanised slicer can produce 26-70 packets per batch with selling values of 52,000 to 140,000 cedis (US$ 6-16) when the container is full. When the costs of ingredients (plantain, water, salt and vegetable oil), plastic bags, labour and overheads are estimated, some profit would be realized. According to Fellows and Hampton (1992) adding value to basic raw materials by processing them into snack foods is often a profitable form of employment for small-scale producers. The domestic market for plantain chips is picking up steadily; however, it is mostly concentrated in the urban centres, where snack foods, in general, are sold in supermarkets and shops. In the Fellows and Hampton (1992) study, it was found that the largest consumer groups of snack foods in the urban areas are workers and school children.

Figure 1: Pictorial View of Plantain Slicer

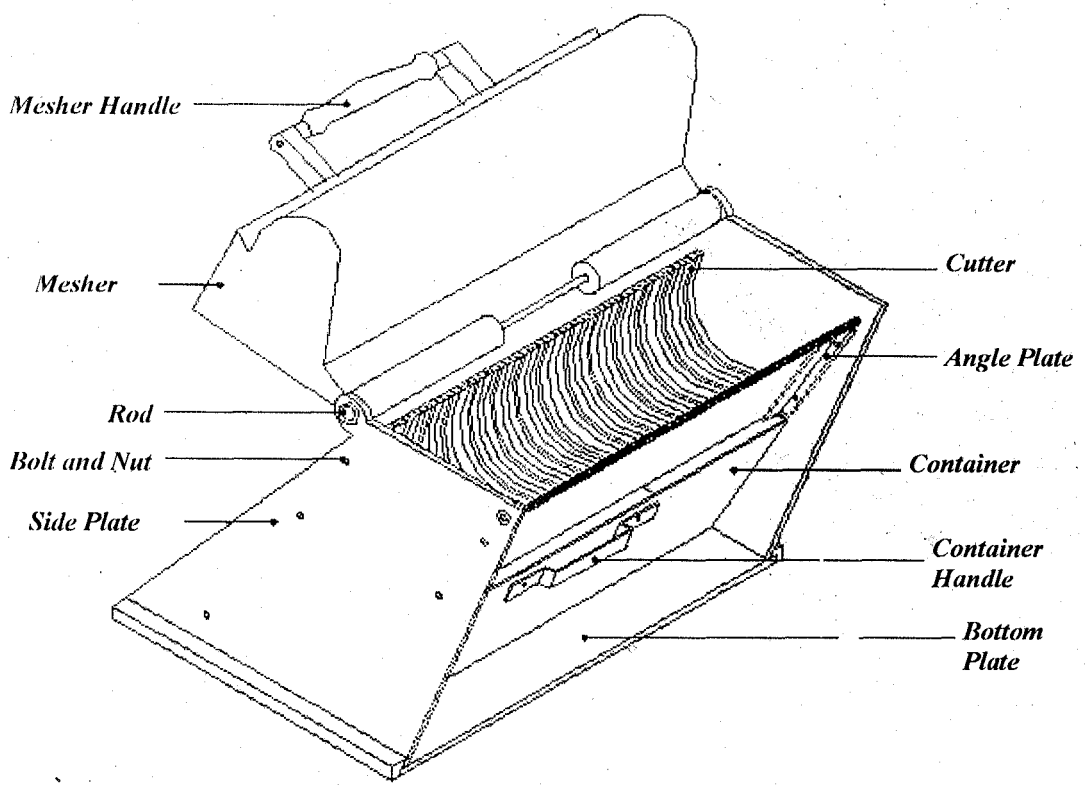

Figure 2: Thickness of Plantain Slices from Mechanised Slicer vrs Frequency

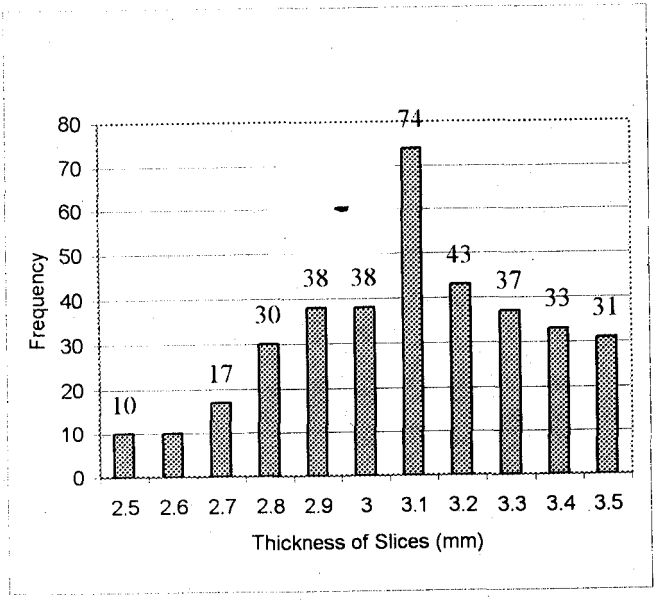

Table 1: Some Characteristics of Peeled Plantain Varieties Used in the Trials

Variety	Diameter of Peeled Plantain (mm)	Length of Peeled Plantain (mm)	Description
Apem	30 – 50	200 – 260	Maiden plantain (*French* or *Apem*). It is small in diameter and curved at the mid-section.
Apentu	40 – 70	250 – 300	Name as known by the Akans of Ghana. It is relatively bigger in diameter and curved at the mid-section.
Oniaba	30 – 50	200 – 260	Name as known by the Akans of Ghana. It contains no seed. The head of each hand (where plantain fingers are attached) is firmly attached to the bunch making dehanding difficult.
Ekaamenko	40 – 65	250 – 300	As known by the Akans of Ghana. It is similar in length and diameter to Apentu, but with relatively smaller bunch size. It normally yields two or three hands as compared to the number of hands on the *Apentu*.

Table 2: Thickness of Plantain Slices from Traditional Method

Slice Sample (mm)	Thickness (mm)			Mean (mm)	Range (mm)	Slice Sample (mm)	Thickness (mm)			Mean (mm)	Range (mm)
1	2.0	2.0	2.5	2.17	0.5	21	3.3	3.0	2.5	2.93	0.8
2	2.0	2.5	3.5	2.67	1.5	22	3.0	3.0	1.5	2.50	1.5
3	1.7	2.0	1.9	1.87	0.3	23	1.0	2.0	2.6	1.87	1.6
4	1.7	1.8	2.0	1.83	0.3	24	4.0	3.8	2.8	3.53	1.2
5	2.6	2.6	2.0	2.40	0.6	25	4.0	3.0	2.5	3.17	1.5
6	2.0	2.5	2.7	2.40	0.7	26	1.0	1.8	4.0	2.27	3.0
7	2.5	3.0	2.6	2.70	0.5	27	3.0	2.2	2.0	2.40	1.0
8	3.0	2.6	3.2	2.93	0.6	28	2.0	3.2	3.4	2.87	1.4
9	3.2	3.3	3.0	3.17	0.3	29	3.0	3.0	2.8	2.93	0.2
10	1.5	1.5	2.0	1.67	0.5	30	1.7	2.8	3.4	2.63	1.7
11	4.0	3.8	2.8	3.53	1.2	31	1.3	3.0	2.4	2.23	1.7
12	4.0	3.0	2.5	3.17	1.5	32	2.0	2.6	2.0	2.20	0.6
13	3.3	2.8	2.0	2.70	1.3	33	3.0	3.0	2.0	2.67	1.0
14	2.8	2.3	1.8	2.30	1.0	34	2.7	2.0	2.4	2.37	0.7
15	1.0	2.0	2.6	1.87	1.6	35	2.5	3.2	2.0	2.57	1.2
16	3.3	3.0	2.0	2.77	1.3	36	2.5	2.5	2.0	2.33	0.5
17	2.2	1.8	1.2	1.73	1.0	37	2.3	1.4	2.0	1.90	0.9
18	2.8	2.3	1.8	2.30	1.0	38	3.5	2.5	2.3	2.77	1.2
19	2.5	2.6	3.0	2.70	0.5	39	2.2	2.3	1.2	1.90	1.1
20	3.3	2.8	2.0	2.70	1.3	40	2.5	3.0	2.5	2.67	0.5

Summary of Data

Mean thickness, μ (mm)	2.51
Range, R (mm)	0.2-3.0
Standard deviation, σ (mm)	0.47

rtainly such pieces of information will go a ıg way to scale-up small-scale production of ınta ı chips and other snack foods in Ghana.

ı .SERVATIONS

Analysing the data obtained from the mechanized slicer, some important factors have been identified for further improvement, namely, size variation among the plantain chips obtained, sticking of chips of yellow and black plantains on the edge of the cutters and firmness and sharpness of the cutters. The observed size variation among the plantain chips resulted from two important factors, namely, unstable nature of the cutters- because during slicing they moved slightly and hence altered the interval between them; the size of the stainless steel material (2mm) used for the cutters- because it was observed that some cutters were thinner and sharper than others.

RECOMMENDATIONS

In subsequent developments there is the need to reinforce the cutters to make them very firm and stable. It is also suggested that a smaller gauge engineering material, preferably 1mm stainless steel be used to make the cutters. Thin, firm, sharp and uniform cutter-edges would be needed to improve on the machine.

CONCLUSIONS

Developing a prototype plantain slicer as well as carrying out trials on it to analyse its output has been a really rewarding exercise. Results from the trials have provided some data required to improve upon the design for efficient performance. Literature and empirical evidence have revealed that plantain chips of sizes up to 3mm (1/8 inch size) taste better and crispier, as a dessert, than those bigger in size. Although the results obtained from the trials of the slicer showed slightly bigger plantain chip sizes than recommended, when compared to the traditional knife method, the slicer produced more uniform-sized plantain chips. Again, the use of the mechanised slicer saves time and reduces the drudgery associated with the traditional method of cutting bulk quantity of plantains into chips. The preceding results are obviously the outcome of interest in the development of the mechanised slicer.

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