DESIGN AND FABRICATION OF LOCALLY MADE PEELING AND SLICING MACHINE FOR PROCESSING BITTER YAM

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Abstract

A peeling and slicing machine was designed, fabricated and evaluated by using bitter yam as test material. It was fabricated with the objective of solving problems associated with peeling and slicing in order to revamp our indigenous foods for economic development and not contaminate them. This was done using locally sourced materials such as stainless steel, angle ion for main frame and drum. Yam peeling remains a challenge to design engineers involved in the design of yam processing machines. The design was powered by electricity with an electric motor. Bitter yam of three (3) different batch loads (1, 1.5 and 2kg) were used at residence times of 15, 30, 45 and 60s till the end of the operation. The results obtained were used to calculate the peeling efficiencies at 15, 30, 45 and 60s for 1, 1.5 and 2kg batch load were 2.80, 5.40, 33.63 and 67.00% respectively. The mean peeling capacities were 0.058, 0.050, 0.044 and 0.037kg/s respectively while the mean peel weight proportions were 0.66, 1.85, 6.0 and 13.4% respectively. The slicing efficiency for 1, 1.5 and 2kg batch loads range between 67.1-89.5% while slicing capacity ranged between 0.003-0.008kg/s at slicing time between the ranges of 120-186secs. It was concluded from the study that the machine was efficient in peeling and slicing bitter yam and can be done in large capacities to reduce product losses and processing time to boost agricultural technologies in food processing.

Keywords: peeling, fabrication, slicing machine, drudge.

Introduction

Yam (*Dioscorea spp*) is a tuber crop that is widely grown and consumed as a staple diet (Diegbeu, 2009). Yams are important source of carbohydrate for many people and are the third most important root crop after sweet potato and cassava (Onyeka *et al*., 2006). Yam contributes more than 200 dietary calories per capital daily for more than 150 million people in West Africa and serves as an important source of income (Babaleye, 2003). It is a starchy root and tuber which contains 70-80% of moisture, 16-24% of starch and trace quantities of proteins and lipids (Huang *et al*., 2006). In addition to its nutritional role, yam is a food of choice during festive periods and it is indispensable for dowry in some African societies (Akissoe *et al*., 2003).

In many parts of West Africa including Nigeria, yam is processed into various food forms, which include pounded yam, boiled yam, roasted yam, or grilled yam, yam balls, mashed yam, yam chips and flakes and are usually accompanied by protein rich soups and sauces (Ojokoh and Gabriel, 2010). Some yam varieties are widely known and over-exploited as food in some communities in Nigeria, throughout the world, over 150 species are grown (Akissoe *et al*., 2000) and about six species are known as important staples in the tropics and economically important species (Ike and Inoni 2006).

1.2 Bitter Yam

Bitter yam (*Dioscorea dumetorum)* belongs to the genus *Dioscorea* and *Dioscoreacae*. Other common names for bitter yam include African bitter yam, wild yellow yam, trifoliate (three-leaved) yam and cluster yam. Bitter yam is known as "*Ji una*" or "*Ji ona*" in Ojoto and many Igbo speaking area in the south-eastern Nigeria, where it is regarded as food for the adult. Bitter yam serves as food of choice for diabetic patients and as herbs for the treatment of various ailments. In the south-western Nigeria, bitter yam is utilized in the treatment of malaria (Dike *et al*., 2012), suggesting a widespread ethno-medicinal importance of bitter yam. Bitter yam is rich in phytonutrient, including proteins (Alozie *et al*., 2009), yet it remains an underutilized tropical tuber. Even the potential of using bitter yam in bakery and pharmaceuticals industries, it has no industrial application. There is limited use of bitter yam which include high post-harvest hardening of the tubers and the unpalatable bitter taste (Medoua *et al.,* 2005). In order to

minimize losses and improve quality, considerable quantities of roots and tubers are transformed into more durable products like yam flour, due to is highly perishability factor in its natural state, the storage problem is a major concern to other agricultural products in West Africa, and processing them into flour eliminates these shortcomings.

Peeling is an important step for processing of many agricultural commodities or crop need to be peeled in order to remove the inedible portion at the initial stage of food processing (David O'Beirne *et al.*, 2014). High peeling efficiency and low product loss are the important characteristics of ideal peeling system. Over the years, traditional methods of peeling and slicing of bitter yam have evolved which is the use of knife in peeling and slicing freshly harvested tubers of yam species or hand to peel when cooked (Aderoba, 2008). The traditional technique of peeling and slicing bitter yam using kitchen knife exposes the user to the danger of knife cut and contamination. The output of the traditional technique has been found to be low due to the drudgery of the process, hygiene and efficiency (Ilori and Adetan, 2013). Developing yam peeling and slicing machine provides important appropriate technology since the traditional method is tedious, raises hygiene concerns and has high risk of injury. There are different types of peeling, manual peeling, chemical peeling, thermal peeling and mechanical peeling. Among different types of peeling, mechanical methods are preferable because mechanical peeling keeps the edible part (Shirmohammadi *et al.*, 2012).

Slicing is a form of size reduction and the general term size reduction includes slicing, cutting, grinding, chopping, crushing and milling. The reduction in size is brought about by mechanical means without change in chemical properties of the material and uniformity in size and shape of individual units of the end product. Reducing the size of food raw materials is an important operation to achieve a definite size range (Buliaminu and Aderoba, 2008).

2 MATERIALS AND METHOD

2.1 Physical Properties of Bitter Yam

In the selection of bitter yam for this study, it is essential to know and determine the database of physical and engineering properties of the crop because it plays an important role in the design and fabrication of bitter yam peeling and slicing machine.

The tuber was cleaned manually to remove dust, dirt and stone before the mean size of the tuber is determined. Varieties of bitter yam were selected randomly according to their size and it was divided into ten samples. It was statistically analyzed to get the mean values (A.V) by measuring the major, intermediate and minor diameter of the bitter yam using digital caliper of 0.01mm accuracy. Sp was determined as (Mohsenin, 2006)

$$Sp = \frac{(abc)^{⅓}}{a} \times 100 \quad (1)$$

where Sp = mean sphericity of the tuber

a = major diameter of the tuber
b = intermediate diameter of the tuber
c = minor diameter of the tuber

The R(a) was obtained by using Omobuwajo *et al.*, 2009 equation as shown below.

$$R(a) = \frac{b}{c} \times 100\%$$

where R(a)= Aspect ratio
a = major diameter of the tuber
b = intermediate diameter of the tuber
c = minor diameter of the tuber

The Dp (cm) of the tuber was calculated from the following relationship as shown below (Asoegwu, 2006)

$$[\mathrm{Dp} = ((abc)^{⅓}) \quad (3)$$

where

Dp = Mean geometric diameter (mm)
a = Major diameter of the tuber
b = Intermediate diameter of the tuber
c = Minor diameter of the tuber

2.2 Materials for Construction

The materials to be used for the construction of the yam peeling and slicing machine are those that can be locally and easily maintained. The process used in fabrication of the peeling and slicing machine is to make use of locally available materials. The fabrication process involved in this work includes joining of metal parts by welding, sheet metal cutting using sheer cutters, making holes with the use of drilling machine. Each component of the machine is fabricated separately before they are joined or welded together. The components and material used for bitter yam peeling and slicing machine include: stainless sheet, cutting disc, 2 inches angle iron, grinding disc, mild steel sheet, water jet, shaft, peeling drum, bearing, electric motor, pulley, abrasive plate, frame

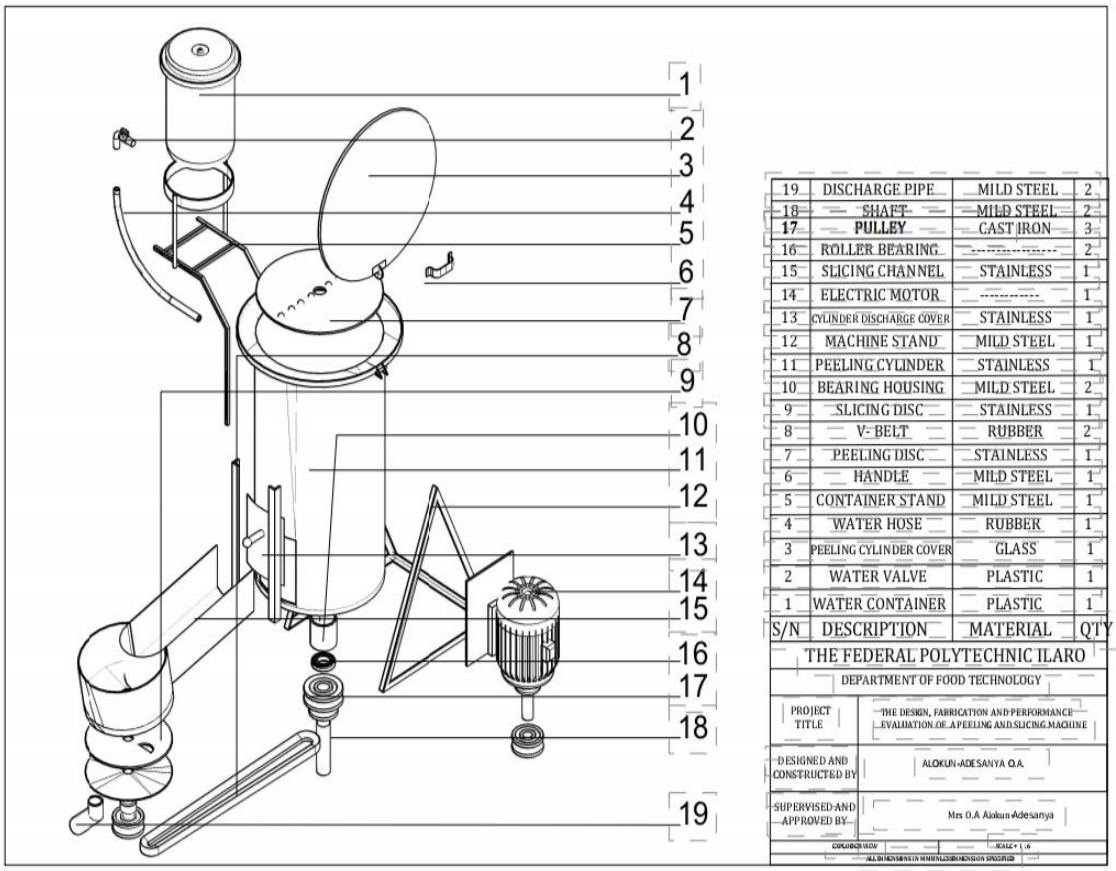
2.3 Design Considerations

The bitter yam peeling and slicing machine is designed based on the following as described by Singh, 2017 with little modification. The materials to be used for the design and fabrication of the machine are those that can be easily maintained, repaired and locally obtained while the cost must be considered with the development budget.

The strength helps to show the toughness and durability of the machine. More consideration must be given because it is very important to achieve the high quality in market today which is an advantage.



Fig. 1: Fabrication of peeling and slicing machine



S/N	DESCRIPTION	MATERIAL	QTY
19	DISCHARGE PIPE	MILD STEEL	2
18	SHAFT	MILD STEEL	2
17	PULLEY	CAST IRON	3
16	ROLLER BEARING	----------	2
15	SLICING CHANNEL	STAINLESS	1
14	ELECTRIC MOTOR	----------	1
13	CYLINDER DISCHARGE COVER	STAINLESS	1
12	MACHINE STAND	MILD STEEL	1
11	PEELING CYLINDER	STAINLESS	1
10	BEARING HOUSING	MILD STEEL	2
9	SLICING DISC	STAINLESS	1
8	V- BELT	RUBBER	2
7	PEELING DISC	STAINLESS	1
6	HANDLE	MILD STEEL	1
5	CONTAINER STAND	MILD STEEL	1
4	WATER HOSE	RUBBER	1
3	PEELING CYLINDER COVER	GLASS	1
2	WATER VALVE	PLASTIC	1
1	WATER CONTAINER	PLASTIC	1

THE FEDERAL POLYTECHNIC ILARO

DEPARTMENT OF FOOD TECHNOLOGY

PROJECT TITLE: THE DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A PEELING AND SLICING MACHINE

DESIGNED AND CONSTRUCTED BY: ALOKUN-ADESANYA O.A

SUPERVISED AND APPROVED BY: Mrs O.A Alokun-Adesanya

EXPLODED VIEW | SCALE: 1 | 6

ALL DIMENSIONS IN MM UNLESS DIMENSION SPECIFIED

Fig.2: Diagram of fabricated peeling and slicing machine

2.4 Performance Test and Evaluation

After fabrication, the peeling and slicing machine's performance evaluation was based on collected data from gotten during the operation cycle such as peeling thickness, capacity, efficiency of the machine etc.

The peel thickness was measured with ruler to void loss of edible tissue, while peeling capacity of the machine is the batch load of the bitter yam divided by the total peeling time (Loading time + peeling residence time + unloading time) in an hour. The capacity of the machine is calculated as follow:

$$Cp = \frac{(Lb)}{(T1+T\,t+Tn)} \times \frac{60}{100} \quad (4)$$

where Cp = Machine peeling capacity (ton / h)
L_b= Batch load (kg)
T_1= Loading time (min)
T_r = Peeling residence time (min)
T_r = Unloading time (min)

2.4.1 Peel Weight Proportion

The peel weight proportion as given above by Balamo *et al.*, 2012

$$Pw = \frac{(MPC)}{Ms} \times 100 \quad (5)$$

where MPC=Weight of peels collected
M_S= Weight of the sample (kg)

2.4.2 Peeling Efficiency

Peeling efficiency is the ratio of the throughput capacity to the theoretical capacity expressed as percentage. Agrawal, 2002 gave peeling efficiency of the machine below.

$$\eta_P = \frac{M_{po} \times 100}{T_{wp}} \quad (6)$$

where η_p= Peeling efficiency (%)
M_{po}= weight of peel collected through the peeling outlet of the machine (kg)
T_{wp} = Total weight of peels collected by manual peeling

2.4.3 Slicing Efficiency

This is the ratio of weight of uniform sliced bitter yam to the weight of the bitter yam fed (Hoque and Saha, 2017)

$$N_{\mu} = \frac{Q_{\mu}}{Q_f} \times 100 \quad (7)$$

where N_S= Slicing efficiency (%)
Q_n = Weight of the uniform sliced bitter yam
Q_f = Weight of bitter yam fed

2.4.4 Slicing Capacity

This is the quantity of bitter yam sliced in a given time (Hoque and Saha, 2017) and was given below as:

$$S_c = \frac{Q_t}{T} \quad (8)$$

where S_C = Slicing capacity
Q_t = Quantity of the bitter yam sliced
T = Slicing Time

2.4.5 Percent Non- Uniformity

This is the ratio of weight of non-uniform sliced bitter yam to the total fed into the machine and was calculated using (Hoque and Saha, 2017) as:

$$\text{Percent non –Uniformity} = \frac{Q_{\mu}}{Q_f} \quad (9)$$

where
Q_n = Weight of non-uniform sliced bitter yam
Q_f = Total fed into the machine

2.5 Data Analysis

All the data collected during the performance evaluation was analyzed using SPSS and Microsoft office.

3.0 RESULTS AND DISCUSSION

3.1 Performance Evaluation of Bitter Yam Peeling and Slicing Machine

The performance evaluation of the fabricated peeling and slicing machine was carried out using bitter yam tubers of 3 different batch loads (1 kg, 1.5 kg & 2 kg). The evaluation was performed using different parameters such as the effect of residence time (15, 30, 45 & 60 sec) on peeling efficiency, capacity, peel weight proportion, slicing capacity, slicing efficiency (at a constant rpm of 1725) and the average values obtained were recorded.

3.2 Physical Properties of Bitter Yam Tuber

As shown in Table 3.1, ten (10) samples were randomly taken to measure the physical properties of bitter yam. The ten (10) major, intermediate and minor diameters were measured and recorded. Table 3.1 shows the values of the geometric mean, volume, aspect ratio and sphericity of ten bitter yam tubers. The average values obtained for volume, geometric mean diameter, sphericity and aspect ratio of the selected bitter yam tubers were 65353.6 mm^3, 37.04 mm, 48.76%, 63.75% respectively. The geometric mean can be used to determine the average diameter of bitter yam. This was useful in designing the diameter of abrasive plate and sphericity of bitter yam was used to determine the shape and thickness of the plate. This is similar to the report of Mohammed (2017), although there were little variations in the results which could be a result of the number of samples, shapes and sizes that were randomly selected for the experiment.

Table 3.1: Physical Properties of Bitter Yam

Description	a (mm)	b(mm)	c(mm)	v(mm^3)	D_p	S_p (%)	R_a(%)
Sample size	10	10	10				
Mean	79	64	24	65353.6	37.04a	48.76	63.75
S.D	11.80	11.34	6.30				
CV	0.14	0.17	0.26				

KEY

a = minor diameter
b = intermediate diameter
c = major diameter
V = volume
D_p = mean geometric diameter
S_p = the sphericity
R_a = aspect ratio

3.3 Effect of Residence Time on Peeling Capacity

The relationship between residence times and peeling capacity of bitter yam during peeling was different from one batch load to another. As shown in Figure 3.1, for 1 kg batch load, the peeling capacity at 15, 30, 45 and 60 s were 0.050, 0.042, 0.035 and 0.031 kg/s respectively. For 1.5 kg, it was observed that there was an increase in peeling capacity as the values obtained for 15, 30, 45 and 60 s were 0.055, 0.050, 0.042, 0.035 kg/s respectively. For 2 kg batch load, the peeling capacity obtained at 15, 30, 45 and 60 s were 0.070, 0.060, 0.057, 0.047 kg/s respectively. These results indicated that that as batch load increased, the peeling capacity increased. However, it was observed that as residence time increased, there was a decrease in peeling capacity. The results correspond to those reported by Balamo *et al*. (2012) on a potato peeling and slicing machine. Also, small batch loads resulted in an equally low capacity and when the batch load increased, peeling capacity increased. The highest capacity was recorded for 2 kg batch load.

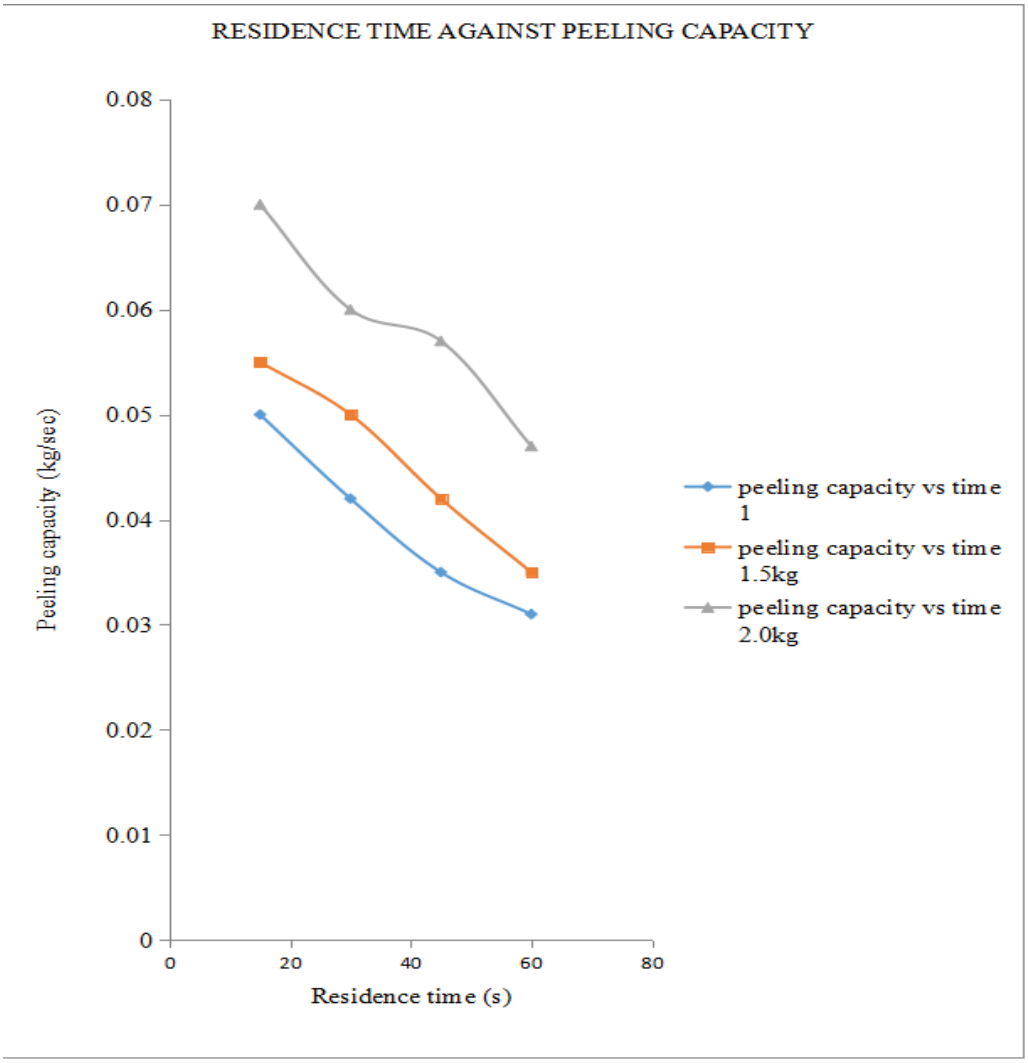


Fig. 3: Effect of Residence Time on Peeling Capacity

3.4 Effect of Residence Time on Peel Weight Proportion

As shown in Figure 3, for 1kg batch load of bitter yam, the peel weight proportions of bitter yam at 15, 30, 45 and 60 s residence times were 0.20, 1.50, 5.20 and 10.80% respectively. For 1.5 kg batch load, the peel weight proportions obtained at 15, 30, 45 and 60s were 0.24, 0.33, 6.10 and 14.4% respectively. Finally, for 2 kg batch load, the peel weight proportions obtained at 15, 30, 45, and 60s were 0.63, 1.73%, 6.80 and 15.00% respectively. The lengths of time the bitter yam tubers spent in the peeling machine would affect the peels detached from the tuber as reported by Oluwole *et al*., (2013). These results indicate that there was a decrease in the weight of the peeled bitter yam for every duration of 15secs. This could also be attributed to the collected peels from the peel outlet of the machine which evidently caused the final weight reduction at the end of the peeling operation. It was observed that the more the tubers, the more peels generated at the end of the peeling operation.

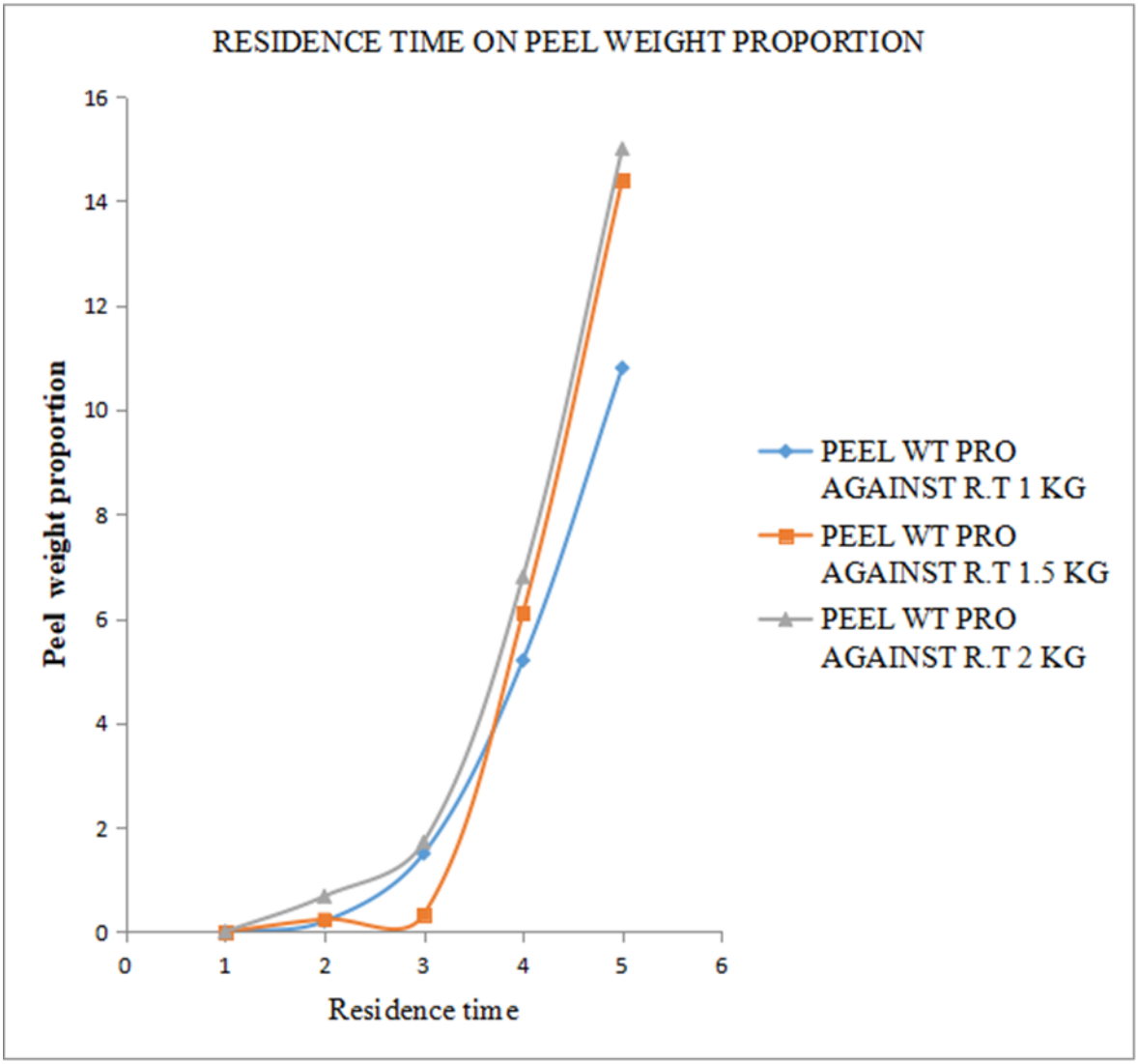


Fig. 4: Effect of Residence Time on Peel Weight Proportion

3.5 Effect of Residence Time on Peeling Efficiency

The relationship between the peeling efficiency and residence time is shown in Fig.4 below, shows that for bitter yam peeled at 15s, 30s, 45s, 60s the results indicated that as residence time increase the peeling efficiency increase. The results are similar to those obtained by Mohammed (2017).

For bitter yams peeled at 15s:1.5 kg:2.58%; 30s:3.50%; 45s:18.53% and shown on the graph to have a higher peeling efficiency compared to bitter yam peeled for the first 30sec. At 60s:62.57%, showing a marked decrease when compared to that of 1 kg. It can be seen from these results that the increase in batch loads from 1 kg to 1.5 kg decreased the peeling efficiency of the machine at 60s.

For 2 kg, the peeling efficiency at 15s:3.28%; 30s:5.10%: 45s:54.86%: 60s:60.44%. These results showed that as the batch load increased from 1 kg to 2 kg for a peeling duration, the peeling efficiency decreased from 78.01% to 60.44% which is similar to the findings obtained by Case (2015) which showed that the peeling efficiency decreased with increase in batch loads.

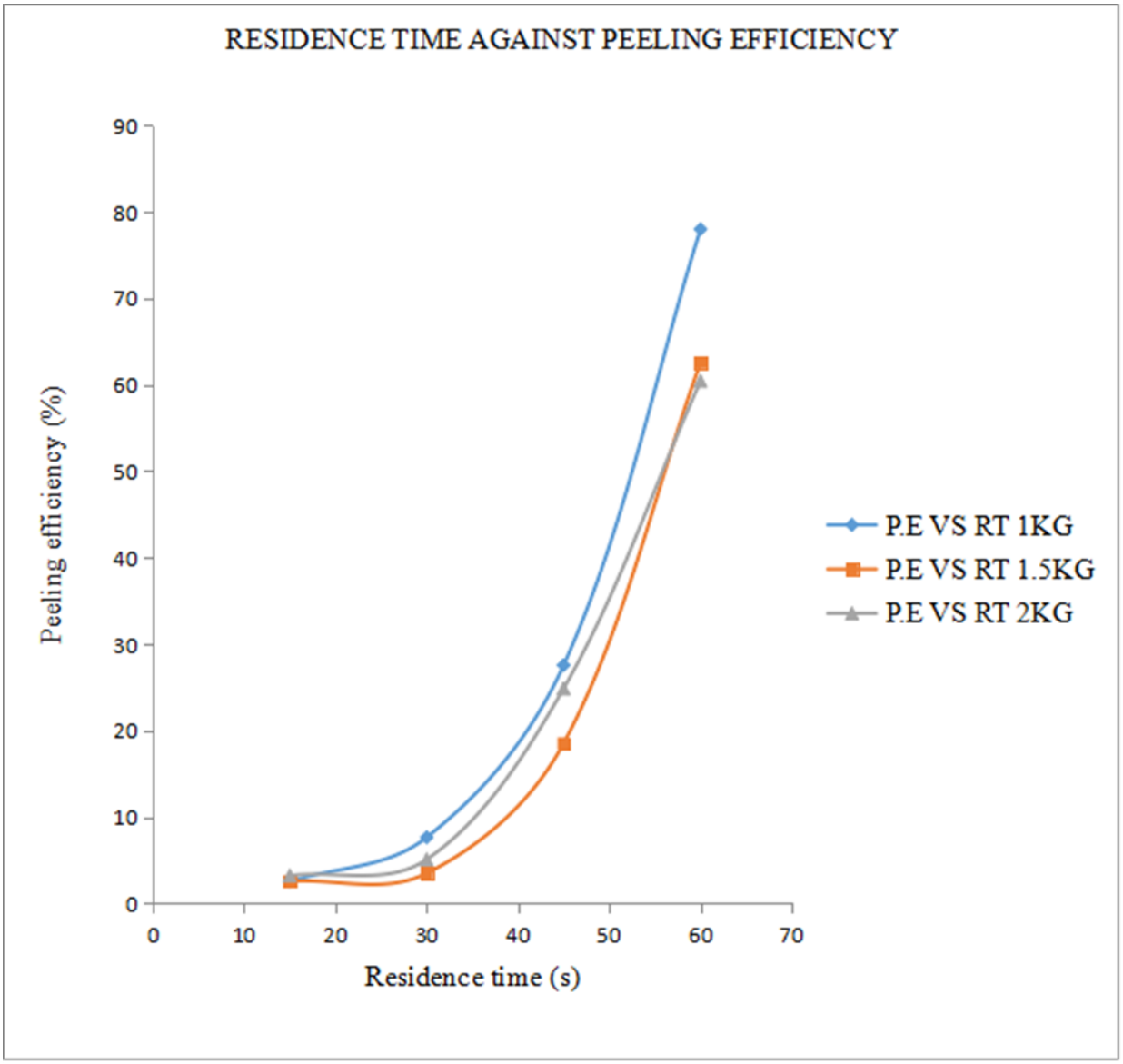


Fig. 5: Effect of Residence Time on Peeling Efficiency

3.6 Effect of Time on Slicing Capacity

The relationship between the residence time and slicing capacity is shown in table 3. It was shown that for 1kg:120s:0.003 kg/s. For 1.5kg:156s:0.006kg/s. For 2kg:186s:0.008 kg/s. The results obtained indicated that increase in batch load increased slicing time and resulted to an increase in slicing capacity.

Table 2: Effect of Residence Time on Slicing Capacity

Batch load (kg)	Residence time (s)	Capacity (kg/s)
1	120	0.003
1.5	156	0.006
2	186	0.008

3.7 Effect of Batch Load on Slicing Efficiency

The relationship between batch load and slicing efficiency is shown in table 3 below. The slicing efficiency for all the batches of samples ranged from 67.1-89.5% from 1-2kg for the batch loads. This result also showed that an increase in batch load resulted in an increase in slicing efficiency, which is similar to the results of Hoque and Saha (2017) who worked on a manual potato slicer.

Table 3.3: Effect of Batch Load on Slicing Efficiency

Batch load (kg)	Initial wgh fed (kg)	Weight of uniform slices (kg)	Slicing efficiency (%)
1	0.87	0.619	67.1
1.5	1.280	1.123	84.4
2	1.704	1.538	89.5

4.1 Conclusion

The peeling and slicing machine was fabricated and performance evaluation was carried out using bitter yam as a test samples. The developed machine will help to enhance quality, hygiene and efficiency in bitter yam processing. The machine was found to be very suitable in increase processing capacity. It also resulted in improved economics of the bitter yam processing; more products were processed in lesser times. The cost of production and maintenance was also relatively cheap.

4.2 Recommendation

After testing the peeling and slicing machine within the specified test parameter, it is recommended that the designed peeling and slicing machine can be used for small scale tuber processing and the machine can be fitted with a conveyor system that will help to transport the product easily from the peeler to the slicer without any human contact.

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