CHAPTER ONE

GENERAL INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Root and tuber crops occupy the same position in the tropics analogous to grains in the temperate regions as the major staple food. The storage potential of the different root and tuber crops differ, but generally, they do not store well in the fresh form and transportation is costly due to their bulkiness. Processing into staple, non-perishable and easily transportable produce offers an alternative to storage in the fresh form. They are best preserved in the dried form by processing into flour, chips and pellets for both human and livestock consumption.

Generally, the size of food materials is often reduced during processing for many reasons chief among which are drying, boiling or steaming and frying or roasting. Slicing of crops before drying reduces the drying time by exposing more surface area to the air. The preservation of almost all processed root and tuber crop products depends on reducing the moisture to a level which prevents the growth of microorganism. Crops are often sliced before cooking and steaming, either for direct consumption or as one step in a processing system. The process of cutting or slicing the crops gives rise to faster cooking. Agbetoye L.A.,(2009)

Slicing equipment consists of rotating or reciprocating blades which cut the food material as it passes beneath. The food is held against the blades by centrifugal force while for slicing meat, the food is held on a carriage as it travels across the blade. The automated potato slicing machine is a fast method commonly used in medium scale industries. The use of motorized slicer will facilitate mass production of the chips. The potato is pressed and moved across the sharp blades of the machine. Potato slicing machine is used for slicing potatoes that are fed across the inlet hopper and sliced chips are guides through the outlet hopper. The machine is a single pulley driven shape of slices with different shapes. It requires low maintenance and easy handling. Rotary cutting knives are usually employed to cut the potato being presented on them, often on a vibrating belt in to parallel sliced of the thickness.

According to World Health Organization (WHO) on world health dated 7th April 2015, “From farm to plate, make food safe”. However before agricultural produce leaves the farm to become edible food, tedious processes are involved in making this possible. This process is the transformation of raw ingredients, by physical means into food. The agricultural produce is usually present in range of sizes, often too large to be handle and must be reduced in size for easy handling to aid processing and storage. Crops such as yam, plantain, and potato are important dietary source of carbohydrate in the humid tropical zones of Africa, Asia and South America. The aforementioned crops are rich in carbohydrate, vitamins A, C and B group as well as minerals such as calcium and iron (Yusuf and Abdullahi, 2007; Akinyemi et al., 2010). The crops are useful as food to be consumed by human either as flour to be used in confectionaries or as jams and jellies; in chips etc. Their peels can be used as animal feed. All parts of the crops have medicinal applications; the flower is uses in bronchitis and dysentery and on ulcers, cooked flowers are given to diabetic patients etc. Their leaves especially plantain is useful for lining cooking pots and for wrapping food materials. Improved processes have also made it possible to utilize plantain fiber for ropes, table mats and handbag. (Adewunmi et al.,2011)

Fruit and vegetable processing main objectives are to supply safe, nutritious and acceptable food to consumers throughout the year. Generally, the size of food materials is often reduced during processing for many unit operations which are drying, boiling or steaming and frying or roasting. Slicing of crops before drying reduces the drying time by exposing more surface area to the air. The preservation of almost all processed root and tuber crop products depends slicing. Crops are often sliced before cooking and steaming, either for direct consumption or as one step in a processing system. The process of cutting or slicing the crops gives rise to faster processing. Crops are commonly sliced and prepared by frying in hot oil or roasting. This practice of roasting food items without slicing the product takes longer time than when they are sliced. Slicing as unit operations helps in preparation of the raw material for further processing like cleaning, trimming, peeling followed by cooking, canning or freezing. Processing (canning, drying, freezing, and preparation of juices, jams, and jellies) increases the shelf life of fruits and vegetables. (Westley. A et al)

Slicing of plantain have been carried out over the ages with the use of manual methods like the domestic knife, chip cutters and graters producing a non-uniform chip which is laborious, time consuming, liable to cause injury, less effective and unhygienic and could only be effective for domestic purpose. Mechanized slicer of higher efficiency was developed to overcome the shortcomings of the manual slicers. The mandolin slicers which are general fruits and vegetable slicers though small and manually operated are very efficient (Mandoline, 2004); the Knott's slicer is a leading international manufacturer of potato and plantain slicer have developed slicers ranging from low speed to high speed and automatic slicers which are quite effective, less laborious, time and cost saving (Knott, 2006).

1.2 STATEMENT OF THE PROBLEM

Tuber peeling is an essential unit operation prior to further processing, they are utilized extensively for human and livestock consumption as well as for industrial purposes. In order to expand the utilization of the tubers and vegetables, there is need to measure the throughput capacity of the machine being used and the slicing efficiency

1.3 AIM AND OBJECTIVE

The aim of this work is to evaluate the performance of a multi-crop slicing machine with the following objective;

i. To design and fabricate a prototype multi-crop slicing machine.
ii. To evaluate the performance of the machine in slicing different vegetables and tubers by determining its slicing efficiency and throughput capacity at different speeds of operation.

1.5 ORGANIZATION OF THE REPORT

Chapter one contains Introduction, statement of the problem, aim and objective, significance of the study, limitations of the study. Chapter two: Literature review and general review. Chapter three: Research methodology and analysis of existing system. Chapter Four: System analysis and design implementation. Chapter five: Conclusion, recommendation and appendix.

1.6 DEFINITION OF TERMS

i. **DESIGN:** A plan or drawing produced to show the look and function of a project.
ii. **PERFORMANCE EVALUATION:** Is a formal and productive procedure to measure a particular work based on the research.
iii. **MULTI-CROP:** Is the practice of growing two or more crops in the same piece of land during one year instead of just one crop.

iv. **SLICING MACHINE:** Is a professional tool created to obtain thin and uniform slices from a wide range of food

v. **THROUGHPUT CAPACITY:** is the total amount of material processed or produced by the system in the given time

vi. **SLICING EFFICIENCY:** Ability to ensure the achievement of high rate of productivity, profitability and product quality.

CHAPTER TWO

LITERATURE REVIEW

2.1 REVIEW OF RELATED WORK

L Agbetoye1 and A Balogun (2009) worked Design and Performance Evaluation of a Multi-Crop Slicing Machine.

They designed A multi-crop slicing machine which was fabricated and evaluated for performance. The major components of the machine include the hopper, mainframe, conveying disc, slicing unit, slicing shaft, idler shaft, pulley, bearing, electric motor base and outlet. The machine is powered by a threephase, 1400 rpm, and 2 kW electric motor. The performance of the machine was evaluated in slicing four selected crops (carrot, potato, onion and yam), grouped into three sizes (small, medium and large) at five machine speeds of 39 rpm, 41 rpm, 43 rpm, 46 rpm and 48 rpm respectively.

The parameters that were investigated were slicing efficiency and throughput capacity. A speed of 46 rpm was found to favor the slicing of large size crops only, while a throughput capacity of 48.9 kg/h and efficiency of 95.4% were obtained for carrot. Medium and large size samples gave good result for potato at a speed of 41 rpm with capacities and efficiencies of 72.8 kg/h, 88.9 kg/h, 97.9% and 94.8% respectively.

Best result for small and medium size grade of onion we achieved at speed of 41 rpm with capacities and efficiencies of 44.6 kg/h, 71.6 kg/h, 91.7% and 96.4% respectively. A throughput capacity of 135.7 kg/h at a speed of 41 rpm and efficiency of 96% was obtained for yam. The machine is therefore observed to perform best at the optimum operating speed of 41 rpm for all the crops selected except carrot. The result of the study shows that the machine can slice root and tuber crops satisfactorily with slices ranging from 8 mm to 9 mm thickness were obtained.

Kaley khan(2017) worked on Performance Evaluation of Manually Operated MultiCrop Planter for Okra.

He discussed that Traditional method of sowing is not suitable for growing the crop. The result is very low production. There are many faults such as not proper seed rate, fertilizer rate, seed spacing, problem in inter cultivation and consume more time.

He further discussed that manually operated multi crop planter was evaluated for its performance in laboratory and field test. The parameters under study in laboratory test was calibration test, seed germination test seed damage test, uniformity of intra-row seed spacing, while the field test examined the field efficiency, field capacity, draft, hills populations, missing hills and average seed spacing within the row. The average amount of seed in fifty revolutions of drive wheel was observed 14.70 g during calibration. The planter metered out one seeds per discharge at average planting depth of 3 cm with minimum seed damage of 2 % during operation. It has a field efficiency of 89.83% and field capacity of 0.11 ha/hr with an average planting depth and spacing of 3 cm and 18.76 cm respectively.

Nagaratna., et al(2017) worked on Performance Evaluation of Aloe Vera Leaf Slicing Machine. They discussed that The Aloe plant belongs to a member of the family Liliaceae, which comprises more than 360 different species. Recently, the family was given the name Aloaceae Aloe Vera can be processed into various products like gel, extract, powder, juice etc. Consumers can use Aloe Vera externally and internally. Aloe Vera is a medicinal plant that has many health benefits for its users. It is commonly used to heal and cleanse wounds. It has the ability to hydrate and soothe the skin and to reduce inflammation. In manufacturing of whole leaf Aloe Vera powder, slicing is one of the important unit operation after trimming. Presently, manual slicing is most commonly followed in Indian Aloe industries, which is time consuming, tedious, unhygienic, expensive and sometimes hazardous. If the leaves are sliced by hand system, the obtained slices are not of uniform size. The processing of the Aloe vera plant for making whole leaf powder involves cleaning, washing, trimming, slicing and drying.

They further discussed that The design and development of Aloe vera leaf slicing machine is to solve the aforementioned problems. This machine mainly consists of belt conveyor, feed and conveyor roller, chain sprockets, knives, power transmission mechanism and frame. The performance evaluation of the machine was evaluated under three belt conveyor speed (0.251, 0.188 and 0.125 m.s-1) and three No. of knives (2, 4 and 8). It was found that 0.2511 conveyor speed with 8 No. of knives was optimized condition. The machine is simple in construction, easy to operate and does not requires special skill. Results of the test carried out showed that the time required to slice equal length of Aloe vera with the machine is 24 times less than the manual process.

Kabir H et al., (2021) worked on Design, Construction and Performance Evaluation of a Motorized Tomato Slicing Machine.

They discussed that One of the major methods of tomato preservation is drying before storage. Tomatoes are best dried when sliced, the manual means of slicing tomato using knife is energy and time consuming and of course prone to injury when not done carefully. To solve the problems encountered in slicing of tomatoes, a motorized tomato slicing machine which is capable of conserving human energy, reducing time spent in slicing, providing safety as well as hygiene to users and serves as a source of income to small and medium scale farmers was designed, constructed and tested. Fully ripped tomato sample was obtained and classified into three (Large, medium and small), evaluation of the machine performance was done based on the classifications and slicing efficiency, output capacity and percentage damage were calculated.

They concluded that the machine was designed to cut tomatoes into slices of 2.45cm thickness. The percentage damage, slicing efficiency and output capacity for large, medium and small tomatoes were 3.33%, 93.33% and 179.25kg/hr, 5%, 88.33% and181kg/hr, 5%, 81.67% and 178kg/hr respectively. The results of the study showed that the motorized machine can slice tomatoes effectively and satisfactorily.

Zakariyah A et al., (2019) worked on Performance Evaluation of a Portable Ginger Slicing Machine. They discussed that Ginger (Zingiber officinale Roscoe) is a root crop grown in many parts of the world (India, China, Indonesia, Nigeria, Brazil, Philippines and Thailand) and reported that, India is the largest producer of ginger in the World with a production of1,109,000 metric tonnes/year and Japan is the largest importer in the World. However, Nigeria is the fourth producer in the world and largest producer in Africa with a production of 522,964 metric tonnes/year. The crop is an important source of foreign exchange for Nigeria. It can be used in pharmaceutical, bakery, culinary, cosmetic preparation and soft drink in beverage industries. As reported, ginger has a moisture content of 80 - 85% wet basis when freshly harvested and 10 - 12% moisture content dry basis for storage. It can be consumed fresh or dried.

They further explained that the study aimed at evaluating the functional performance of a developed portable ginger rhizomes slicing machine. The study was conducted at various levels of impeller speed, impeller gang and slicing compartment in the Department of Agricultural and Bioresources Engineering, Ahmadu Bello University, Zaria, Nigeria between April 2018 and June 2018. A 5 × 4 × 2 factorial experiment in a Completely Randomized Design (CRD) was used. The indices for the performance evaluation were the Slicing Efficiency and

Throughput Capacity. The machine was powered by one horse power petrol engine and ginger moisture content of 77.44%. Data collected were subjected to statistical analysis using Analysis of Variance (ANOVA) to test the significance level of the experimental factors and their interactions; and those found significant were further subjected to Duncan Multiple Range Test (DMRT) for mean separations at ($P = .05$), respectively. The results showed that, the ANOVA for all the factors evaluated and their interactions on Slicing Efficiency.

Adeshina F and Olusola F (2020) worked on Design and Performance Evaluation of a Multi-Tuber Peeling Machine.

They discussed that Root and tuber crops, including cassava (Manihot esculenta, Crantz), yam (Dioscorea spp.), sweet potato (Ipomoea batatas, Linneus) and cocoyam (Colocasia spp. and Xanthosoma sagittifolium), are widely grown and consumed as staple foods in many parts of Africa. According to the report of the International Institute of Tropical Agriculture, the production of the cassava, sweet potato, yam and cocoyam account for about 95% of the total root and tuber crops production in Africa. They are part of the most important energy sources in the human diet as they are highly enriched in carbohydrate. They can be consumed as vegetables or used as raw material for the small-scale industries at a global level, particularly in less-developed tropical countries. In some other places, they serve as cash crops that thrive where most other crops fail.

They further explained that: Tuber peeling is an essential unit operation prior to further processing. In this research, a batch loading tuber-peeling machine, with a capacity of 10 kg/min, was designed, fabricated and tested for cocoyam, sweet potato, yam and cassava tubers. The machine was designed to operate at a speed range of 350–750 rpm and time range of 5–12 min based on the principle of surface scratching. The performance of the machine was determined with respect to the peeling efficiency, percent weight of peel and flesh loss. The results showed that the peeling efficiency increased with an increase in the shaft speed for all the tubers. Also, the flesh loss and percent weight of peel decreased with an increase in the shaft speed for cassava and cocoyam tubers but increased for sweet potato and yam tubers ($p < 0.05$). Effective peeling of the tubers was achieved for sweet potato and yam at all the shaft speeds and time ranges considered.

CHAPTER THREE

3.0 MATERIAL AND METHOD

3.1 MACHINE DESCRIPTION

The assembly and orthogonal drawings of the multi-crop slicing machine is shown in Figure 1. The machine consists of the following components, namely; hopper, upper housing, feed channel, conveying disc, slicer shaft, outlet, slicing unit, frame, idler shaft and idler frame (Figure 2).

The main frame is the unit of the machine on which all other components of the machine are supported. It was fabricated from high strength material so as to withstand vibration. It was fabricated from 50 mm x 50 mm mild steel angle of 6 mm thickness). Idler frame was also fabricated for a 50 x 50 mm mild steel angle to support the idler shaft and was welded directly to the main frame. The hopper serves as a container for holding the crop to be sliced. It was bolted to the top of the main upper housing. It was fabricated for made of 1.5 mm thick stainless-steel sheet which was adequate to sustain the weight of the crops.

The slicing unit, a very important unit of the machine, performs the actual slicing. It has a set of stainless-steel knives (9 in number) arranged horizontally. A collar or spacer was used to separate the knives in order to achieve the desired slice thickness. A long bolt and nut were used to join all the set of knives and spacers together. A conveying disc of 25 mm diameter serves as a picker and a conveying mechanism for the crop to the set of knives for slicing operation.

These conveying discs are 9 in number and they were arranged in such a way that they are separated by spacers between then to achieve the desired thickness of slices (Figure 2). The feed channel is incorporated into the hopper so that smaller crop sizes can be transported to the conveying disc directly without falling off before getting to the conveying disc. The idler shaft was introduced into the machine to reduce the speed coming directly from the prime mover to desired level. The sliced crops are collected at the outlet.

3.2 PERFORMANCE TEST PROCEDURE

Three knives were designed and used to slice three selected crops (vegetables, cassava and plantain (ripe and unripe). Machine performance was evaluated with regards to the machine capacity, roundness index, and efficiency of slicing, slice thickness etc.

3.2.1 MACHINE CAPACITY: The capacity of the machine was determined by feeding peeled material into th machine and weighing the slices produced irrespective of damage. The capacity of machines is expressed as material sliced (kg) per unit time.

$M_c = \frac{w}{t} kg/hr$…………………(1)

Where M_C = Capacity of machine, W=Input weight, kg(t) time/hour

3.2.2 SLICING EFFICIENCY: Slicing efficiency is the inverse term of breaking percentage. The efficiency of slicing was determined by following expression (Balasubramaniam et al. 1993).

$\alpha = \frac{Wt - Wd}{Wt}$ * 100% ……………….(2)

Where:

$\propto$ = slicing efficiency (%)

WT = weight of total slices (kg)

WD = weight of damaged slices (kg)

3.2.3 PERCENTAGE BREAKAGE: The damaged or broken slices are defined as the slices having the area less than 2/3 of its circumscribing circle. Breakage percentage is calculated as the ratio of weight of damaged slices to the total weight of slices.

$B_c = \frac{Wd}{W}$ ………………………………………(3)

3.2.4 SLICING LOSS: is the measurement of effectiveness of the slicing operation of the machine. Slicing loss was calculated by following equation Mishra et al., (2013)

$S_L = -\frac{W1-W2}{W1} * 100$ …………………(4)

Where,

S_L= Slicing loss (%)

W_1= Weight of tubers before slicing (kg)

W_2= Weight of tubers after slicing (kg)

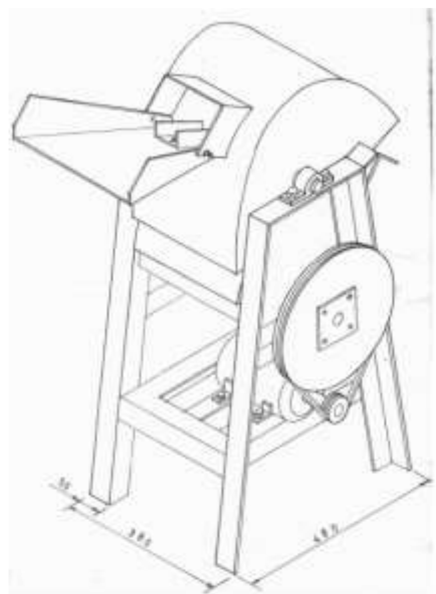

Fig 1: Isometric view of the multi crop slicing machine

Legend: A, Idler shaft; B, bearing; C, Motor (driver) pulley; D, shaft; E, conveying disc; F, idler pulley; G, hopper; H, feed channel; I, upper housing; J, frame; K, outlet; L, motor seat; M, slicing unit

Figure 3: Exploded view of the slicing machine showing the component parts.

CHAPTER FOUR

4.0 RESULT AND CONCLUSION

The chips produced from the tests carried on the machine using different crops under prevailing operational conditions is shown in (Figure 4). The machine performance was satisfactory, in that the machine was capable of slicing tubers and vegetables e.g okro.

Table 1: Physical characteristics of crops sample

Tubers			
Weight (kg)	Length(mm)	Diameter(mm)	
		major	minor
0.5	170.72	30.69	30.69
0.45	190.32	20.98	25.73
0.40	118.09	20.87	25.90
Vegetables			
0.32(0.32)	186.90(196.38)	30.48(30.38)	20.56(20.37)
0.25(0.25)	189.20(193.40)	30.32(30.53)	20.92(20.64)
0.28(0.28)	197.87(192.64)	30.60(30.85)	30.48(30.20)

A tachometer was employed to ensure correctness of operating speeds as determined in the design calculation. It was discovered that the machine cannot be operated beyond 50kg because it pushed samples instead of slicing, which implies that rotational speed less than 50 rpm is adequate for the operation of machine. The sample mass per treatment considered in this study, fell within 300 ± 25 kg. The output materials obtained from the machine outlet was collected and separated into two groups, that is, sliced material and un-sliced material. The mass of each category was determined by an electronic balance. The time taken for each test run was recorded with stopwatch.

The weight was determined using an electronic weighing balance while characteristic sizes of the chips produced were take using a vernier calliper (Table 2).

Table 2: Characteristics of product sample

Cassava			
sample	Length	Diameter	Thickness
1	45.50(42.70)	35.40(35.50)	4.10(4.90)
2	40.50(43.40)	32.70(34.90)	5.00(3.80)
3	41.80(45.40)	35.50(33.58)	4.50(3.30)
4	49.10(42.75)	32.60(32.57)	5.10(4.20)

Tables 3, shows the data obtained from chipping vegetables and, and Table 4 indicate machine performance in chipping cassava. Table 3: Performance test in chipping tubers and vegetables.

*t	W [kg]	W_T[kg]	W_D(Kg)	M_C kg/hr	α(%)	B_C(%)
Slice(unsliced)						
0.016	0.23(0.32)	0.14(0.04)	0.14(0.04)	20.00(20.00)	59.78(85.72)	43.75(12.50)
0.01	0.25(0.25)	0.17(0.22)	0.08(0.03)	25.00(25.00)	47.06(86.36)	32.00(12.00)
0.012	0.28(0.28)	0.18(0.26)	0.10(0.02)	44.8(26.8)	44.44(96.16)	35.71(7.14)
0.008	0.35(0.35)	0.22(0.32)	0.13(0.03)	43.75(43.75)	40.91(90.63)	37.14(8.57)
Mean				53.58	86.15	19.35

*t = time (hr), W = Input weight (kg), WT = weight of total slices (kg), WD = weight of damaged slices (kg) ךּ = ⍰Capacity of machine, α = slicing efficiency (%).

Table 4: Performance test in chipping cassava samples

t [hr]	W [kg]	W_T(kg)	W_D(kg)	M_C kg/hr		B_C (%)
0.009	0.5	0.42	0.08	55.55	80.95	16.00
0.007	0.45	0.38	0.17	64.29	55.26	37.78
0.006	0.40	0.35	0.05	66.67	85.71	12.50
0.007	0.45	0.4	0.05	64.26	87.5	11.11
Mean				53.58	86.15	19.35