DESIGN AND FABRICATION OF A PEDAL OPERATED CASSAVA CHIPPER

BY

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MATRIC NO. 2004/18439EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY, 2010

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

.... 22/02/2010 ....
Esimi, Jimoh Sezno **Date**

CERTIFICATION

This is to certify that "Design and Fabrication of a Pedal Operated Cassava Chipper" by Esimi, Jimoh Sezuo meets the regulations governing the award of the degree of Bachelor of Engineering (B.Eng) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project is dedicated to my late mother, Mrs. Alice Esimi.

ACKNOWLEDGEMENTS

Though words are not enough, my sincere gratitude goes to God Almighty for provision, protection, love, favour, grace and mercies he has bestowed upon my life throughout the period of this programme.

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ABSTRACT

A pedal operated cassava chipper was designed and fabricated using locally available materials, such as mild steel, aluminum, stainless steel and galvanize, sheets. Reducing the size of tubers to be processed into food products which requires fermentation and drying has been recognized as an effective method of reducing processing time and improving the quality of the products. The machine gave a minimum amount of sub-standard chips and the chipping efficiency is 75%. Using the equipment, chipping can be accomplished with relative ease and subsequent operations can be done more quickly. Fermenting time traditionally require 4 – 5 days and has been reduced to 1 – 2 days. Chipped material dried in 8 – 10 hours depending on the loading density and weather condition. The chips dry uniformly, whitish with sweet floury aroma and are friable.

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ABBREVIATIONS, SYMBOLS AND NOTATIONS

W_C	=	Chain width
D_R	=	Roller diameter (standard)
$D_{PW.}$	=	Pitch diameter of wheel
D_{BW}	=	Bottom diameter of wheel
D_{OW}	=	Outside diameter of wheel
Z_W	=	Number of teeth on the wheel
P_{CP}	=	Standard pitch of a bicycle chain
D_{CW}	=	Caliper diameter of wheel
ω_W	=	Angular speed of the wheel in rad/sec
P_{mH}	=	Maximum human power
F_{pd}	=	Maximum pedaling power
R_{wc}	=	Crank radius of wheel (standard)
N_w	=	Speed of wheel in rev/min
V_{cw}	=	Chain pitch line velocity of wheel
τ_w	=	Torque generated at the wheel
D_{PN}	=	Pitch diameter of pinion
D_{BPN}	=	Bottom diameter of pinion
D_{CPN}	=	Caliper diameter of pinion
Z_{PN}	=	Number of teeth on the pinion
D_{OPN}	=	Outside diameter of the pinion
V_{CPN}	=	Chain pitch line velocity of pinion
ω_{PN}	=	Angular speed of the pinion in rad/sec
R_{PN}	=	Pitch radius of the pinion
N_{PN}	=	Speed of the pinion in rev/min
τ_{PN}	=	Torque generated at the pinion

L_p = Length of chain

C = Centre distance between the two sprockets

π = pie (3.142)

T_c = Chain tension

g = Acceleration due to gravity

V_c = Chain pitch line velocity for both wheel and pinion

H.P = Human power in Horse Power

F_R = Tangential force transmitted by the chain

F_g = Tension caused by centrifugal forces

ρ_c = Density of chain

a = Angle between tangent and centre line

R = Radius of the wheel

r = Radius of the pinion

$\sin^{-1}$ = Arc sine

F_{TOT} = Total force on the chain

P_R = Chain bearing pressure per unit hinge area

A_{CH} = Chain hinge area

K_C = Service factor of chain

K_{dyn} = Dynamic load rating

K_y = Rating factor

K_{ten} = Load factor

K_{lub} = Lubrication factor

F_{mt} = Maximum tangential force transmitted without excessive wear of the line hinge

P_{bc} = Chain actual bearing pressure

S = Factor of safety

[S]	=	8.33 (Berezovtsky et al: 1988)
F_b	=	16464N (constant)
B_D	=	Bore diameter of the bearing
L_{10}	=	Rated life of the bearing
P_r	=	Dynamic load on the bearing
F_H	=	Horizontal force on the shaft
C_r	=	Required capacity of the bearing
D	=	Diameter of the chipping wheel
t	=	Thickness of the chipping wheel
R_p	=	Radius of pulley
n	=	Number of arms
W_T	=	Tangential load per arm
M	=	Maximum bending moment on the arm at the hub end
Z	=	Section modulus
a_1	=	Major axis of the arm
b_1	=	Minor axis of the arm
d_h	=	Diameter of the hub
L_h	=	Length of the hub
A_h	=	Area of the hub
R_h	=	Radius of the outside diameter of the hub
r_h	=	Radius of the internal diameter of the hub
V_h	=	Volume of hub
A_r	=	Area of rim
R_r	=	External radius of the rim

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the design

Cassava is a staple food in the Nigerian diet, eaten for its nutritional and stomach filling value, as well as its affordable price by low income earners. Cassava makes up to half of the nutritional requirements in many Nigerian households.

Increased cultivation of cassava has been largely brought about by the newly developed, improved, high yielding, pest and disease resistant varieties from institutions like International Institute of Tropical Agriculture (IITA) and the National Root Crops Research Institute (NRCRI), Umudike.

Cassava, even though can grow in different climates thrives well in drained loamy soils with light or medium rainfall, which is characteristic of a significant part of the middle belt and Southern Nigeria.

Within the Nigerian agriculture economy, a lot of effort are continually being put into cassava production by national government, through the World Bank assisted agricultural projects, e.g IITA and International Agencies such as UNICEF, UNDP, and other special projects aimed at cassava promotion and utilization.

The extremely perishable nature of cassava tubers poses a serious problem to storage. Cassava tubers once detached from the growing plant will not normally keep for than a few days (40-48hours), before deterioration sets-in. The deterioration is caused by microbial infections and physiological factors like loss of moisture.

Drying cassava is necessary to maintain its quality until they are processed into a desired final product. This must be done immediately to prevent discolouration and deterioration.

In the rural areas, cassava is dried either as full size tuber or they are chopped into small pieces 1.5 to 2.0cm long then spread them on floors such as flat rock surfaces, hard soil (clay) grounds or in cemented pavements to sun-dry.

The traditional system of drying cassava is labour intensive and requires 4 to 6 days to about 10% moisture content. The longer the cassava is dried, the more losses are incurred because of repeated handling and direct consumption by animals such as goats and chicken. Quality changes also occur because of prolonged drying time. Losses due to microbial contamination add to the spoilage losses which are normally observed in sun-drying.

A method which was found to be efficient in terms of hastening the drying rate and improving the quality of the product is cutting the cassava still into smaller pieces, called "chips". The development and introduction of new processing technologies offers the potential to improve access to markets for cassava producers and thereby increasing their incomes.

Chips production is relatively simple. It calls for no major investments and provides an effective means for producers to boost the value of their crop. Yam chips are stabilized products with a moisture content of 12% and can be kept for up to a year when stored under insect-proof conditions. The cassava chips produced by the chipping machine dry quickly, are of high quality, reduce labour input involved in processing, easy to transport to the market, contains less cyanide and have improved palatability. The crop has about 69% moisture content and transportation from the rural area to urban area for marketing is usually difficult. The processed products are easier to store than the raw cassava, they need less storage space and can be stored for a longer period of time.

1.1.1 The Pedal Power

Throughout history, human energy has generally been applied through the use of the arms, hands, and back. With minor exceptions, it was only with the invention of the sliding seat rowing shell and particularly of the bicycle, that legs also began to be considered as a "normal" means of developing power from human muscles.

A person can generate four times more power by pedalling than by hand cranking. At the rate of 0.25hp, continuous pedalling can be done for only short periods, about 10minutes. However, pedalling at half this power (0.125hp) can be sustained for around 60minutes. Pedal power enables a person to drive devices at the same rate as that achieved by hand-cranking, but with far less effort and fatigue. Pedal power also lets one drive devices at a faster rate than before or operates devices that require too much power for hand-cranking (Whitt *et al;* 1983).

1.2 Statement of the Problem

In recent years, the consumption of leaven wheat bread has risen enormously in Nigeria as a result of increasing populations, urbanization and changing food habits.

The importation of wheat in sub-Saharan Africa has significantly increased in the past 15 years and the depreciation of African currencies during the same period has made such importation a heavy burden on the local economies. At the same time, cassava production in the region has increased substantially. Many studios have demonstrated the technical feasibility and economic advantages of using cassava as a partial or total replacement for wheat in bread-making.

However, Nigeria for climatic reason cannot grow wheat suitable for bread making and relies on expensive wheat imports, paid for with scarce foreign currency. The first attempts to effectively reduce the outflow of funds towards temperate countries were aimed at the partial substitution of wheat flour with flour from indigenous crops such as cassava and yam.

Cassava chips are also used in the production of pellets for export in many countries. So, there is need for a cheap and efficient cassava chipping machine made from materials considered to be non-toxic to human health.

1.3 Objectives of the Design

1. The specific objectives are to improve the existing slicing of tubers with knives by designing and fabricating a Pedal Operated Cassava Chipper.

2. To carry out performance test.

1.4 Justification of Design

More than 70% of farmers in Nigeria grow cassava as a major crop. One of the products into which cassava roots are processed in this country is flour which is used in baking of different confectionary.

One of the unit operations involved in the production of cassava flour is chipping of cassava tuber into pieces (chips).

There is an urgent need to improve the cassava chipping machine and increase the efficiency, so as to improve market for cassava producers thereby increasing their incomes. This processing technology which was found efficient in hastening drying rate in cutting the tuber into chips, increasing labour productivity and improve product quality, chips produced are of full potential as a source of both food and income.

Rural-urban drift is also counter-balanced by new income perspectives in the villages and to enhance the availability of raw materials to feed the cassava processing industries. This calls for cassava chipper.

1.5 Scope of the Design

The scope of this work covers the Design and Fabrication of a Pedal Operated Cassava Chipper, Effect of Tuber Size on Chipping Capacity.

CHAPTER TWO

2.0 LITERATURE REVIEW

Apart from cassava's importance as a staple food in many tropical developing countries, it is a raw material for the production of animal feed, starch, glucose syrup, dextrose, fructose syrup, alchohol, etc. In the production of many of these commodities, chipping of cassava roots is an intermediate step.

Cassava is consumed, as food, mostly in the form of gari, fufu, lafun and cassavita. Several studies have been undertaken to immprove the processing of cassava into these products, particularly gari. Machines have been developed for many of these processing operations. A recent study revealed that it is possible to produce gari of good quality by fermenting, steaming, drying and milling cassava chips (Ajibola *et al*; 1987). It is expected that this process could be used in producing other agricultural materials. Chipping of cassava can also make fufu production more efficient. Cassava chips are used in the poduction of pellets for export in many countries. So, there is need for a cheap and efficient cassava chipping machine.

2.1 Existing Cassava Chipper

Some designs for chipping machines are already available from Southeast Asia, especially Indonesia, Malaysia and Thailand. Generally, the chipping element is a circular plate carrying sets of blades with corrugated cutting edges. Sometimes, the chipping wheels are mounted on wooden frames. Chips produced from these machines are usually irregular. The demand for chipping machine in Nigeria indicates there is support for local productionof machine

Two ealier attempts to design a chipping machine have provided useful experience and guidelines for the current work. In the first attempt, the chipping mechanism followed the principle of the circular plate with slicing blades. The resultant product was irregular and unsatisfactory. The intention was to amend this defficiency in the second design by incorporating a new element: a set of stationary crisscross blades, to dice the sliced roots produced from the circular plate.

Both machines produced various sizes of irregularly shaped chips and a lot of fine chips, perhaps because the two operations, slicing and chipping, were performed at the same speed in the same chamber. Quayle (1984), has observed that slicing of soft woods (under which cassava roots could be classified) is best accomplished using a circular straight line edger saw at a rim speed of 50-70m/sec, while chipping is best achieved using a plunger reciprocating at about the same speed might have led to crushing of the roots and hence, the production of irregularly shaped chips and fines. Separation of the two operations may provide the solution.

The desired level of uniformity of chips and chip geometry cannot be achieved with the designs described above. Chips can be cut to uniform size by first slicing across the diameter of the root and then dicing with a set of crisscross blades in different chambers and at different speeds. The intersection of the set of crisscross blades serves as crushing zones, because of the brittleness of cassava roots. Additionally, the principle of using the pressure from newly chipped cassava root to push out the previously chipped ones has led to the chips being compressed together. The useof a set of piston-like fingers, can eliminate such a problem with complete evacuation of chipped cassava out of the path of the crisscross blades.

In the mechanization of cassava processing operations such as peeling, cutting and milling, persitent problems encountered by designers include constant breakage and damage of the root during handling, sometimes exceeding 10% (Odigboh and Ahmed, 1982). The problem suggests a need for adequate data on the relevant engineering properties of the root. Some work has been done in that regard.

Aseogwu (1981), has studied the growing habit and responses of cassava tubers in creep and stress relaxation and has proposed models to represent those "Behaviors". He measured such properties as stress relaxation modulus and creep compliance. Odigboh (1983), has conducted some tests on the mechanical properties of the plant. Igbeka (1984), has conducted extensive work on the mechanical and rheological properties of cassava. He has studied such properties as modulus of deformation, shear strength, hysteresis loss, degree of elasticity and failure energy as affected by moisture content. Ohwovoriole *et al*; (1988), has studied the physical and mechanical properties of peeled and unpeeled cassava, including length, weight, diameter, poisson's ratio, shear strength,cutting force and rupture stress. These studies have provided data for the design of the different component of the present chipping machine.

2.2 Cassava as a Crop (*Manihot esculenta*)

Cassava (*Manihot esculenta*) originated in Latin America where it is still widely cultivated and from where it was introduced into Africa about the 16th century. It is a major staple for millions of people in the humid and sub-humid tropics of the world where its high productivity and convenience as an energy source makes it an indispensable component of farming and food systems. Cassava also has many industrial uses espesially in Asia and Latin America.

There are many wild species in the genus Manihot distributed over several countries in the Americas. The exact number is yet unknown possibly due to instability of species boundaries resulting from natural interspecific hybridization (Rogers and Appan, 1973).

2.3.0 Cassava Food Processing

Cassava (Manihot esculenta), also known as tapioca or Manioc is one of the most important cheap sources of carbonhydrate in developing tropical countries. It is highly important in Nigeria and Africa accounting for approximately half of their staples. Its efficient production of food energy, year-round availability and tolerance of extreme environmental stresses makes it eminently suitable for present farming and food systems in Africa, cassava is playing a major role in efforts to alleviate the African food crises. Over half of the world's total cassava production is in Africa and it has been estimated that 37% of the energy in the diet in tropical Africa comes from cassava (UNIFEM, 1989).

Chemically, cassava is composed of water (60-70%) and starch with minor amounts of protein, fibre, minerals, vitamins,and toxic component linamarin-a cyanide containing glycoside. The presece of this toxic factor demands special processing procedures to make the product safe for human consumption.

The toxic glycosides of cassava are reduced to safer levelduring processing. Toxicity is initially considerably reduced during peeling. Grating breaks down the internal cells and so releasing the enzyme which breaks down the cyanogenic glycoside complex and release hydrogen cyanide. During subsequent fermentation stages, almost a total breakdown of the glycoside occurs and the final frying, roasting or boiling step drives off the hydrogen cyanide.

Traditionally, cassava roots are processed by various methods into many different products and used in diverse ways, according to local custom and preference, to provide carbohydrates in the diet. The processes involved in cassava production and processing are labour-intensive, time-consuming and are normally performed by women and children. The various unit operations involved includes peeling, washing, grating, drying, boiling/steaming, frying, pounding, dewatering and others. Sun-drying, soaking, fermenting and other activities are old proven remedies used to reduce cyanide level.

Cassava can be eaten raw or boiled depending on variety or it can be processed into different products such as Gari(West Africa), Fufu(Nigeria, Ghana, Zaire), Chiwange(Central Africa), Lafun(Nigeria), Abacha(Nigeria), Starch, etc. Almost every households in rural Nigeria is involved in one another form of cassava processing to satisfy the household demand or sell outside.

Cassava and other root crops in general are cheap, available and essential energy source for many poor people who face problems of food availabilty. Although, they contain little protein or fat, some, particularly potato and yam are sources of vital vitamins(A&C).

2.3.1 The main advantages of cassava as a crop and a food.

i) It is a cheaper source of energy for the body.

ii) It can be cultivated easily and provided more dietary energy per hectare at a lower cost to the farmer, principally because of reduced labour inputs.

iii) It can be stored forup to 2years in the soil until required.

iv) Cassava processing provides employment and income for rural women.

v) Crude cassava starch is an important industrial material, can be produced by women's co-operatives.

2.4.0 Objectives of Cassava Processing

Cassava processing activities are undertaken because of the following reasons:

1. Reduce post harvest losses of fresh tubers as cassava is extremely perishable and must be either consumed or processed within 24-48hours of harvest (Cock, 1985).

2. Elimination or reduction of cyanide content. Processing is a key element in reducing the concentration of hydroen cyanide in cassava tubers and leaves. Reduction in concentration of this toxic element to a safe level is necessary for both human and animal consumption. Consumption of inadequately processed cassava has chronic effects on health and nutritional well-being and it can lead to death.

3. Removal of the inedible parts.

4. Processing leads to the convertion of the perishable roots into stable products of prolonged shelf life.

5. Processing also improves palatability and increase variety in the diet by providing a range of attractive flavours, colours, aroma and texture in food.

6. Reduce transportation cost because cassava is bulky and heavy hence, expensive to transport over long distances.

7. Provide raw materials for small-scale cassava-based rural indutries.

8. Imroves the net economic value of the product by raising its quality.

2.5.0 Principles of Processing Techniques

About two-third of the cassava used in Africa for food is eaten after specialized traditiona processing usually at the farm or village level. The processing methods comprise combinations of some of the following activities: peeling, boiling, steaming, slicing/chipping, grating, soaking or steeping, fermenting, pounding, frying, roasting, pressing, sieving, drying and milling.

2.5.1 Peeling

This involves the removal of the inedible outer layers of the cassava and is traditionally done with a knives.

2.5.2 Washing

Washing involves soaking the peeled or unpeeled tubers in a pool of water and washed with hand and the aid of scotch pad. Cleaning should take place at the earliest opportunity in a food process both to prevent damage to subsequent processing equipment and to prevent time and money from being spent on processing contaminants which are then discarded. Washing is thus an effective method of processing and protecting the consumers.

2.5.3 Drying

Drying is the elimination of excess water from the material in order to bring the total moisture content to a level considered to be safe for long term storage. The excess water in casava or other organic agricultural produce is responsible for intensive microbial activity leading to the formation of molds and general deterioration of the product.

Drying is mostly done in the open air under sunlight on the roofs of building, road sides, concrete patches, spread on mats or directly on tampered accumulate tremendous heat energy during the day time and releases it during the night, providing a natural heat exchanger. The above method of drying however, have problems. The quality of the product is low due to contamination by dust, particles of plants and other foreign matters, sometimes stones and fragments of glass.

Drying becomes very difficult during the rainy season. It is during this time that the price of lafun and other dried cassava products goes up as lack of sunny hours for drying reduces the quantity of products marketed. Drying during the rainy season is a very cumbersome procedure as the drying product has to be taken in and out, or left in the rain causing harmful deterioration and loss of quality due to formation of fungi.

2.5.4 Frying and Roasting

Frying and roasting is the most difficult part in garri processing and is normally done on earthen ware oven, the fuel efficiency of which is very low. Apart from its low negative effect by heating the immediate surroundings which include the fryers. Roasting is widely practiced throughout Africa where traditional echniques include burying the whole root in hot ashes or holding it on top of the fire.

In gari processing, proper roasting is important to ensure a good quality of the product. Both frying and roasting enhances the flavour of the ccassava and most importantly reduce its moisture content. When packed properly, fried products can have a shelf-life of several months.

2.5.5 Grating

The action of grating into fine shreds or pulps is a step common in the processing of many cassava food products and facilitates subsequent steps in process e.g, dewatering, drying or pulping. The process alters the texture of the raw materials. Grating methods range from simply rasping the roots on the trunks spines of palms through simple hand raspers of mechanized graters.

2.5.6 Milling/Grinding/Pounding

This is done traditionally in Nigeria using wooden mortars and pestles. However, milling technologies using powered plate mills or ocassionally hammer mills have spread rapidly throughout Nigeria, resulting in every village having one or a few millers who perform custom service at fixed charges. After preliminary processing, including slicing or shredding and drying, the cassava roots can be ground to a flour which are being used in many traditional dishes such as fufu, lafun etc. Also pounding changes the texture of the previously prepared cassava to a more palatable paste-like consistency.

2.5.7 Sieving

Sieving is done with purpose of removing the excess fibrous material and to separate undesirable particles from mixed materials as used in starch extraction and gari. Separation is acheived using sieves made out of metal or local plant material or finely wooden cloth material in case of starch extraction.

2.5.8 Fermentation

Fermentation is an important step in the processing of cassava. Fermentation results in a reduction in the level of toxic components. In fermenting cassava, two methods are commonly practiced which may be conveintly considered as the 'dry' and 'wet' methods.

The dry method is used in the production of gari and is essentially fermentation in the presence of air. The grated cassava passes through two statges of fermentation. During the first stage, starch is broken down and acid is produced. Subsequently, breakdown is the cyanide containing toxic components occurs through the action of naturally occuring enzymes in the root releasing hydrogen cyanide. The conditions at the end of this first stage allows the growth of a range of micro organisms that produce compounds which give garri its characteristic flavour. Much of the cyanide is lost during fermentation, the remainder being largely driven off during the final roasting step.

The simple wet methos of fermentation, sometimes referred to as retting, takes place in the absence of air. Cassava roots, either pilled or unpeeled are soaked in water for several days until they soften. The materials is then broken up, seived and finally squeezed to remove water. Although culturally acceptable in many areas, cassava processed in this way has a somewhat unpleasant odour.

2.5.9 Dewatering

Dewatering, as the name implies, involves the removal of internal liquid from the cassava by pressing. It is an important method of rediucing toxicity. Traditionally, heavy weights are placed on the prepared pulp and the expelled liquid is allowed to drain away. Improved method uses presser such as screw press or hydraulic press.

2.5.10 Boiling and Steaming

Cassava is often cooked by boiling or staeming either for direct consumption or as one step in a processing system. This does not preserve the crop which is usually eaten soon afterwards, unless it is further processed. Boiling and steaming are also im[ortant in cassava processing to particularly detoxify the material.

2.5.11 Starch Extraction

Industrially, starch is extracted by a combination of wet milling, sieving, and either centrifuging or settling. Starch can also be extracted by simpler methods. The juice draining from cassava during dewatering may be collected and left to stand allowing the starch to settle. After decanting the liquid layer, the remaining starch may be rinced and further processed into flour by pounding or grinding and drying.

2.5.12 Chipping

Traditionally, chipping is done with hand knives which cut the tubers into small unequal pieces. Improved methods, both manual and powered chipping machines, however, shred the tuubers into uniform sizes that dry and ferment quickly and uniformly.

2.6. Cassava Foods and Process Description

The majority of the total world production of cassava is processed for direct human consumption depend among other things, upon geographic location and ethnic origin.

Some of the most common of cassava foods in Nigeria include fresh roots, leáves, llafun, gari, fufu, abacha e.t.c.

2.6.1 Cassava Roots

Low cyanide cassava roots are eaten raw as a snack, boiled, steamed or roasted. In some areas, the boiled or steamed roots are pounded. In other areas, medium and high-cyanide cassava roots are sliced, cooked in large amounts of water and then eaten as a snack or a staple such as Abacha.

2.6.2 Lafun

This is a very popular food, especially among yorubas of rural south-western Nigeria. The operations included are peeling, soaking, pulverizing, dewatering and drying. Soaking of the peeled or unpeeled tuber is a critical process requiring 4-5 days to soften tissue which gives the desired flavour. Dewatering of the pulverized mash is necessary to reduce the moisture content of the mash and accelerate drying process. The dry product is milled producing the floury product, lafun.

Lafun is prepared into paste which is eaten with soups or stews containing meat, vegetables, thus providing a nutritionally balanced combination of ingredients.

2.6.3 Gari

Gari is a fermented, gritty, starchy food prepared from casava into gari usually takes 3 to 5 days and involves peeling, washing, grating, fermenting, pressing, sieving and frying. However in localities where a bland gari taste is preferred (for example Edo and Delta states) the mash is fermented for only one day. Fermentation is very important because it gives gari its prefered sour flavour, and detoxified. The safe level of cyanide in gari as specified by the Nigerian Food and Drug Administration is 10ppm (1mg HCN per 100g of gari).

During frying, gari particles are continously tossed in the frying pan to ensure uniflorm frying pan to ensure uniform frying to prevent burning. Palm oil may be added to the frying surface and prevent buring or to give the gari an appealing yellow colour.

2.6.4 Abacha

This is a common cassava food prepared in eastern Nigeria. The process includes peeling of cassava, boiling the roots, and shredding the boiled roots to produce long slices. These shreds are then soaked in water for 24 hours and spread in the sun to dry.

2.6.5 Cassava Flour

Traditional cassava flour is produced in Nigeria are used as thick paste to be eaten with the usual accompainments of stew, soups and gravies cassava flour in modern techniques is being used in numerous baking preparations. The essential operations involved in cassava flour production are peeling, washing, chipping, drying, milling and bagging.

2.6.6 Cassava Chips

Dried cassava chips are milled 'into flour, which can be used for many purposes including livestock feeding.

2.6.7 Cassava Starch

Cassava starch is undoubbted one of the most important product of cassava. Starch can be produced as an end product, but iit can also be used as a raw material for other products. Textile, paper, and pharmaceutical industries as well as battery manufacturers need starch and its derivatives.

The essential operations involved in starch production are peeling, washing, grinding, screening, settling, decanting, drying, finishing and bagging.

2.7.0 Improved Processes and Technologies

A whole range of processing techniques and equipments have been developed to alleviate the arduous, monotonous and time consuming activities undertaken in the traditional methods. These acheivements are not from import of new or sophisticated technology but from improving traditional processes.

Improvement done on traditional methods are given in the table below;

Table 2.1 Improvement done on Traditional Processes and Equipments

Unit Operation	Traditional Process (Equipment)	Improved Process (Equipment)
Peeling	Knives	Peeling stand
Grating	Punched Galvanized iron sheets	Mechanical grates
Chipping	Knives	Screw press, Hydraulic press & wooden press
Fermenting	Bags on bare floor, baskets	Fermentation racks
Dewatering	Stones, heavy woods	Screw press, Hydraulic press & wooden press
Drying	Mat, Roadside, Roofs, Concrete floor	Drying trays, concrete floor
Frying/Roasting	Clay pot, Iron pot	Iron pot, half drum
Sifting	Trays woven from raffia midribs	Boxes with sets of wire mesh
Milling/Grinding/Pounding	Pestles and mortars	Hammer mill, Disc mil, plate mill, roller mills
Gari Frying	Earthenware stove	Stove with chimneys

Source: IITA, (1992)

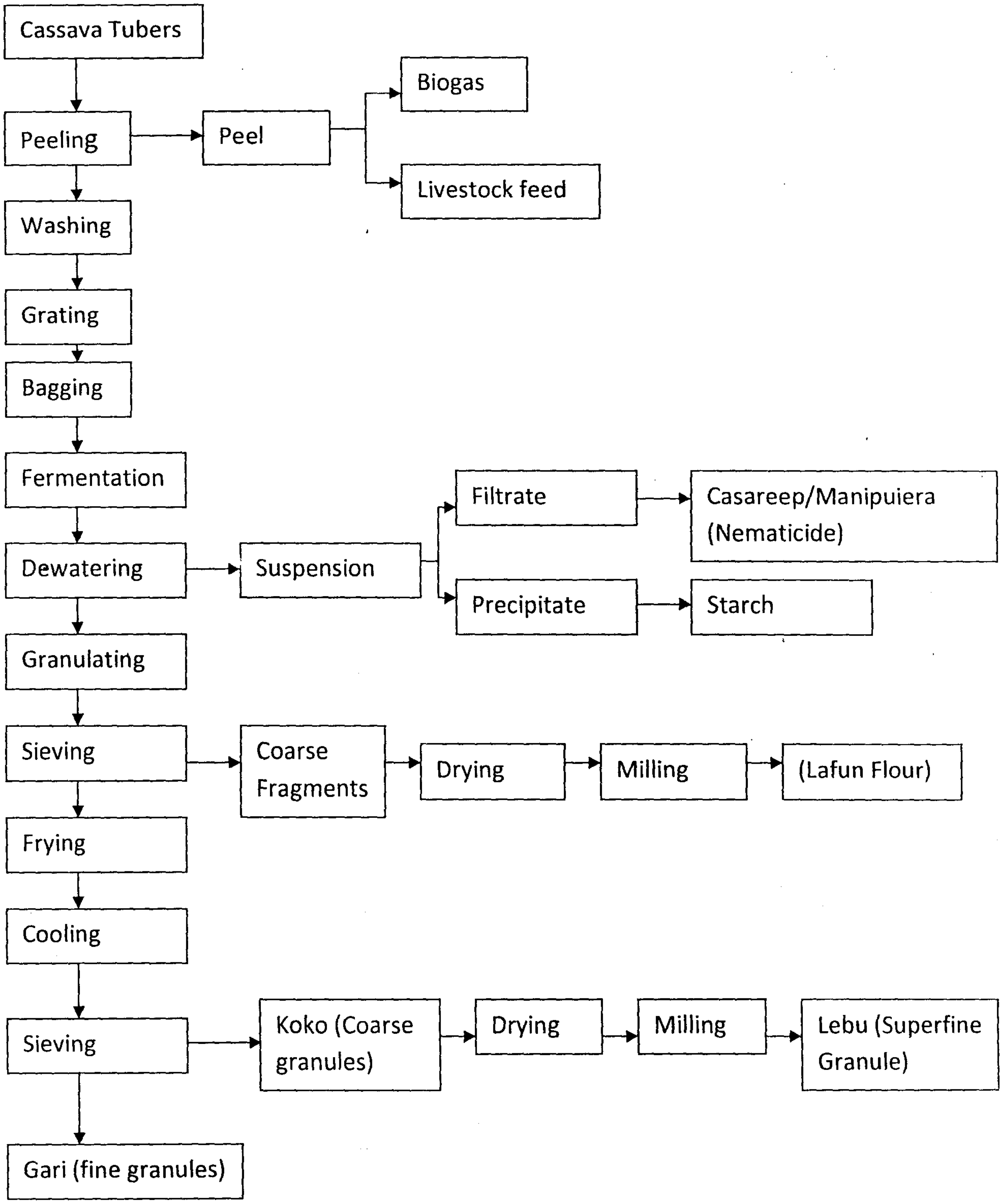


Fig. 2.1: ***The By-Products of Gari Processing (Oyewole et al; 1986)***

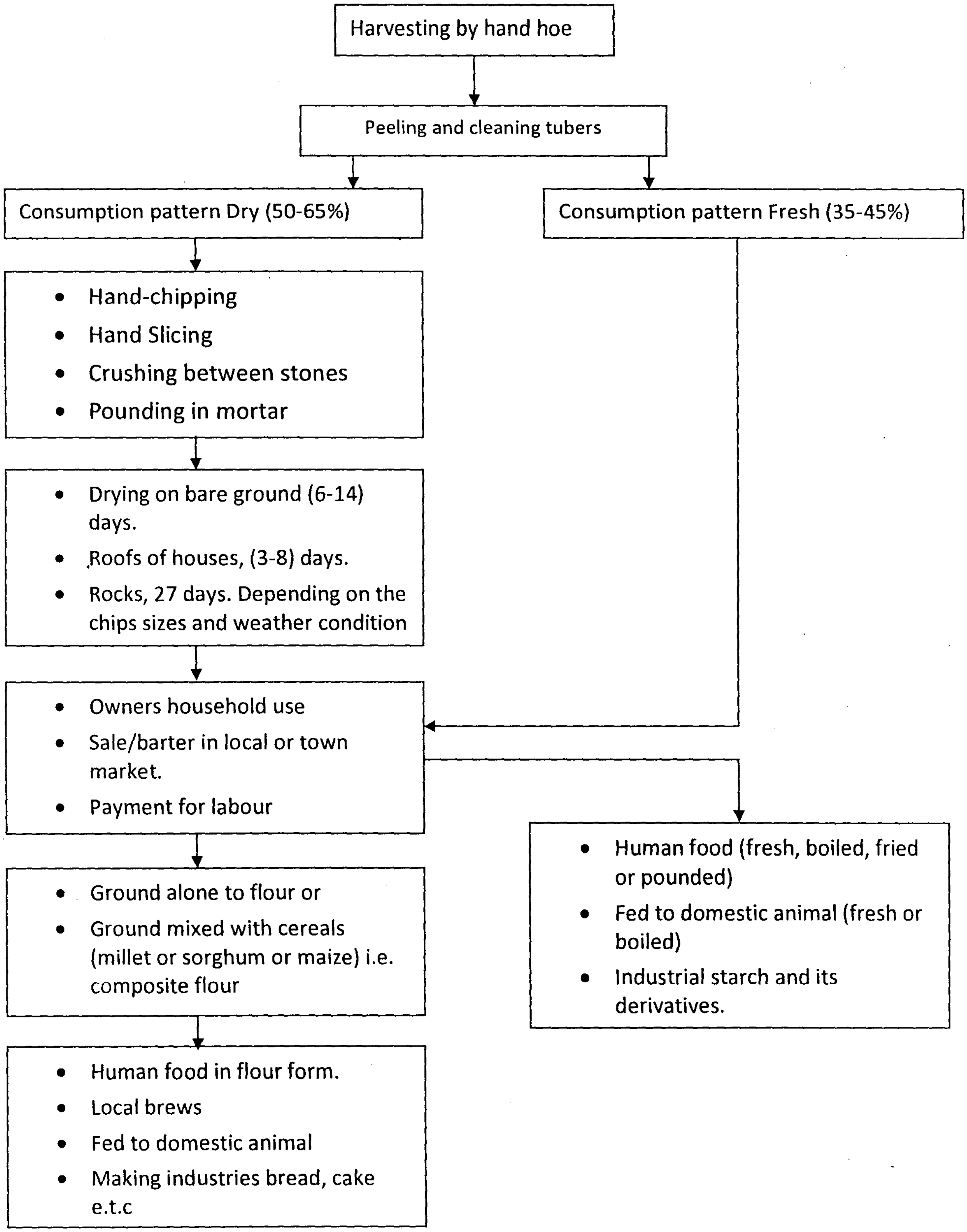


Fig. 2.2: Flowchart on Traditional Processing and Utilization Patterns for Cassava in Nigeria. (Kwatia, 1986)

CHAPTER THREE

3.0 DESIGN ANALYSIS AND CALCULATION

3.1 Ergonomics

Ergonomics is the study of environment, conditions and efficiency of workers. In modern designs, this aspect has received a very wide priority in order to make man comfortable at work.

3.1.1 Maximum Human Power

The power available from the human muscle depends on an individual. The estimated maximum power for work of long duration for example eight hours per day by a healthy man in his working environment is 75w (0.1HP), (Murrell, 1965).

3.1.2 Maximum Pedalling Force

The maximum force required to operate a pedal by a seating operator without backrest as in the bicycle is estimated to be 30lb (134N), (Sundararaja-Morthy, 1979).

3.1.3 Sprocket and Chain Design Analysis

The pitch diameter of a sprocket is computed based on known chain pitch and number of teeth on the sprockets. A normal bicycle chain in American standard has a pitch, P_{bp} of 0.5" (12.7mm), a chain width (W_C) of 8mm and a roller diameter (D_R) of 8.5mm (Sundararaja-Morthy, 1979).

For this design, a standard pinion and wheel sprockets of 22 and 44 numbers of teeth respectively are to be used for smooth running of the driving unit (bicycle).

A simple chain drive consists of two sprockets and a transmitting chain. The small sprocket is called the Pinion while the bigger one is called the Wheel.

a) **The Wheel (Driving) Sprocket**

i) The pitch diameter, (D_{pw})

$$D_{pw} = \frac{P_{bp}}{\text{Sin}\,(180/Z_W)}$$

ii) The bottom diameter, (D_{BW})

$$D_{BW} = D_{pw} - D_R$$

iii) The outside diameter, (D_{OW})

$$D_{OW} = P_{bp}\,[0.6 + \cot\,(180/Z_W)]$$

iv) The caliper diameter of the wheel sprocket, (D_{CW})

$$D_{CW} = P_{bp} \times \text{Cos}\,(90/Z_W) - D_R$$

v) The angular speed of the wheel sprocket, (ϖ_w)

$$\varpi_W = \frac{P_{mH}}{F_{pd} \times R_{WC}} \text{ (in rad/sec)}$$

The standard wheel used has a crank radius of 180mm

vi) Speed in rev/min

$$N_W = \frac{\varpi_W \times 60}{2\pi}$$

vii) The chain pitch line velocity of the wheel sprocket, (V_{CW})

$$V_{CW} = \frac{\pi \times N}{60}$$

viii) Torque generated at the wheel sprocket, (τ_w)

$$\tau_w = F_{pd} \times R_{WC}$$

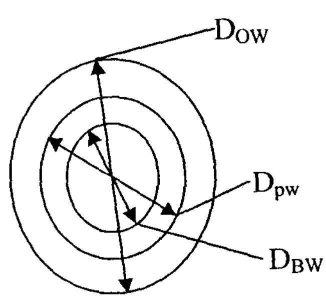


Fig. 3.1(a): Wheel Sprocket

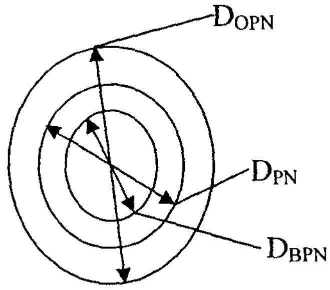


Fig. 3.1(b): Pinion Sprocket

b) **The Pinion (Driven) Sprocket**

i) The pitch diameter, (D_{PN})

$$D_{PN} = \frac{P_{bp}}{\sin(180/Z_{PN})}$$

ii) The bottom diameter, (D_{BPN})

$$D_{BPN} = D_{PN} - D_R$$

iii) The outside diameter, (D_{OPN})

$$D_{OPN} = P_{bp}\,[0.6 + \cot(180/Z_{PN})]$$

iv) The caliper diameter of the wheel sprocket, (D_{CPN})

$$D_{CPN} = P_{bp} \times \cos(90/Z_{PN}) - D_R$$

v) Since there can be no pedaling force on the pinion sprocket, the chain pitch line velocity of the pinion (driven) sprocket will be equal to the wheel pitch line velocity because the motion is transmitted by the chain to the pinion.

$$\therefore V_{CW} = V_{CPN}$$

vi) The angular speed of the pinion sprocket, (ϖ_{PN})

$$\varpi_{PN} = V_{CPN}/D_{PN} \text{ (rad/sec)}$$

vii) The speed of the pinion (driven) sprocket, (N_{PN})

$$N_{PN} = \frac{\varpi_{PN} \times 60}{2\pi}$$

viii) Torque generated at the pinion sprockets (τ_{PN})

$$\tau_{PN} = T_C \times D_{PN}/2$$

c) **The Chain Design Analysis**

i) The chain length, (L_P): In ref 3, the length of chain in number of pitches is given by:

$$L_P = \frac{Z_{PN} + Z_W}{2} + \frac{2C}{P_{bp}} + \frac{[Z_W - Z_{PN}]^2}{2\pi} \times \frac{P_{bp}}{C}$$

ii) The chain tension, T_C on the chain depends on the power transmitted and the chain speed. The tension is given by:

$$T_C = \frac{HP \times 75 \times g}{V_C}$$

iii) The tangential force, F_K transmitted by the chain

$$F_K = P_{mH}/V_C$$

iv) The tension caused by centrifugal forces (F_g)

$$F_g = \rho_C v_c^2$$

Where; ρ_C = chain density = 0.44kg/m (Roslar, 1983)

V_C = chain pitch line velocity for both wheel and pinion sprockets

v) The total force, F_{TOT} on the chain

$$F_{TOT} = F_g + F_k$$

vi) Chain bearing pressure per unit hinge area, P_K

$$P_K = \frac{F_K \times K_S}{A_{CH}} \leq [P]$$

$$K_S = K_{dyn} \times K_y \times K_{ten} \times K_{lub}$$ (Berezovtsky et al, 1988)

K_{dyn} = 1

K_y = 1

K_{ten} = 1.25

K_{lub} = 1

A_{CH} = 47.8mm2

[P] = 12.34Mpa (Berezovtsky et al, 1988)

vii) The maximum tangential force (F_{Mt}) that can be transmitted by the proposed chain without causing excessive wear of the link hinge:

$$F_{Mt} = [P] \times A_{CH}$$

viii) Chain actual bearing pressure, P_{bc}

$$P_{bc} = F_{TOT} / A_{CH}$$

ix) Determination of factor of safety, S, against chain breakage:

$$S = \frac{F_b}{F_{TOT}} \geq [s]$$

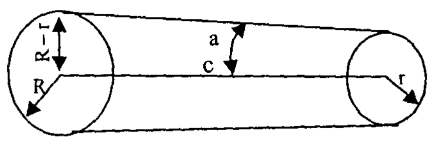


Fig. 3.2: Chain Drive Arrangement

3.1.4 Design Analysis of Bearing at Chipping Shaft

Bearings are machine elements intended to support axle and shafts. They take up the radial loads imposed on the shafts or axles; they called and transmit them to the casing of the machine frame. The bearing type selection is determined based on the bearing life and size (Baumeister et al, 19' 8).

The design procedures are as follows:

i) Selection of the bearing life, L_{IO} and the type of bearing.

ii) Determination of dynamic load, P_r on the bearing.

iii) Determination of required capacity, C_r using the formula:

$$C_r = \frac{P_r(L_{IO} \times N_C)^{1/k}}{Z_b}$$

iv) Comparing C_r with the standard bearing capacity, C_O which gives the dynamic basic load rating. However, for this design and fabrication, the two sets of bearings used were of diameters 25mm (internal) and 52mm (external). The series used is FS: UCP 206 (standard).

3.2 Design Calculations

3.2.1 The Wheel (Driving) Sprocket Design Calculation

a) The pitch diameter, D_{pw}

$$D_{pw} = \frac{P_{bp}}{\sin(180/Z_w)}, \text{ where } P_{bp} = 12.7\text{mm and } Z_w = 44\text{teeths}$$

$$\Rightarrow D_{pw} = \frac{12.7}{\sin(180/44)} = 178.02\text{mm}$$

b) The bottom diameter, D_{BW}

$$D_{BW} = D_{pw} - D_R, \text{ where } D_{pw} = 178.02\text{mm and } D_R = 8.5\text{mm}$$

$$\Rightarrow D_{BW} = 178.02 - 8.5 = 169.52\text{mm}$$

c) The outside diameter, D_{OW}

$$D_{OW} = P_{bp}\,[0.6 + \cot(180/Z_W)],$$

Where, $P_{bp'} = 12.7$mm and $Z_W = 44$ teeths

$$\Rightarrow D_{OW} = 12.7[0.6 + \cot(180/44)]$$

$$= 12.7[0.6 + \cot(4.0910)]$$

$$= 12.7[0.6 + (1/\tan 4.0910)]$$

$$= 185.19\text{mm}$$

d) The caliper diameter of the wheel sprocket, D_{cw}

$$D_{cw} = P_{bp}[\cos(90/Z_W)] - D_R,$$

Where, $P_{bp} = 12.7mm$, $Z_W = 44$ teeths and $D_R = 8.5mm$

$$\Rightarrow \quad D_{cw} = 12.7[\cos(90/44)] - 8.5$$

$$= 12.7[\cos 2.0455] - 8.5$$

$$= 4.1919mm$$

e) The angular speed of the wheel sprocket in rad/sec

But, from ergonomics, the maximum human power and applied load on the pedal are known; we have,

$$\varpi_w = \frac{P_{mH}}{F_{pd} \times R_{wc}},$$

Where, $P_{mH} = 75W$, $F_{pd} = 134N$ and $R_{wc} = 180mm$

$$\Rightarrow \quad \varpi_w = \frac{75}{134 \times 180} \times \frac{1000}{1}$$

$$= 3.1095rad/sec$$

f) Speed of the wheel in rev/min

$$N_w = \frac{\varpi_w \times 60}{2\pi},$$

Where, $\varpi_w = 3.1095rad/sec$

$$\Rightarrow \quad N_w = \frac{3.1095 \times 60}{2\pi} = 29.6892rev/min$$

g) The chain pitch line velocity of the wheel sprocket, V_{CW}

$$V_{CW} = \frac{\pi \times D_{PW} \times N_W}{60},$$

Where, $D_{PW} = 178.02mm$, $N_w = 29.6892rev/min$

$$\Rightarrow \quad V_{CW} = \frac{\pi \times 178.02 \times 29.6892}{60 \times 1000},$$

$V_{CW} = 0.2768 m/s$

h) Torque generated at the wheel sprockets, τ_w

$$\tau_w = F_{pd} \times R_{wc},$$

Where, $F_{pd} = 134N$ and $R_{wc} = 180mm$

$$\tau_w = 134 \times (180/1000)$$

$$\tau_w = 24.12Nm$$

3.2.2 The Pinion (Driven) Sprocket

a) The pitch diameter, D_{PN}

$$D_{PN} = \frac{P_{bp}}{\text{Sin}(180/Z_{PN})}, \quad \text{where } P_{bp} = 12.7mm \text{ and } Z_{PN} = 22\text{teeths}$$

$$\Rightarrow \quad D_{PN} = \frac{12.7}{\text{Sin}(180/22)} = 89.2388mm$$

b) The bottom diameter, D_{BPN}

$$D_{BPN} = D_{PN} - D_R,$$

Where $D_{PN} = 89.2388mm$ and $D_R = 8.5mm$

$$\Rightarrow \quad D_{BPN} = 89.2388 - 8.5 = 80.7388mm$$

c) The caliper diameter of the pinion sprocket, D_{CPN}

$$D_{CPN} = P_{bp}[\cos(90/Z_{PN})] - D_R,$$

Where, $P_{bp} = 12.7mm$, $Z_{PN} = 22$ teeths and $D_R = 8.5mm$

$$\Rightarrow \quad D_{CPN} = 12.7[\cos(90/22)] - 8.5$$

$$= 12.7[\cos 4.0909] - 8.5$$

$$= 4.1676mm$$

d) The outside diameter of the pinion sprocket, D_{OPN}

$$D_{OPN} = P_{bp}[0.6 + \cot(180/Z_{PN})],$$

Where, $P_{bp} = 12.7mm$ and $Z_{PN} = 22$ teeths

$\Rightarrow \quad D_{OPN} = 12.7[0.6 + \cot(180/22)]$

$= 12.7[0.6 + (1/\tan 8.1818)]$

$= 95.9504mm$

e) There can be no pedaling force on the pinion sprocket, the chain pitch line velocity of the pinion (driven) sprocket will be equal to the wheel pitch line velocity as the motion is transmitted by the chain to the pinion. Therefore,

$V_{CW} = V_{CPN} = 0.2768m/s$

$\therefore \quad V_{CPN} = 0.28m/s$

f) The angular speed of the pinion sprocket in rad/sec

$$\varpi_{PN} = \frac{V_{CPN}}{R_{PN}}$$

Where, $V_{CPN} = 0.28m/s$, $R_{PN} = D_{PN}/2 = 89.2388/2 = 44.6194mm$

$$\Rightarrow \quad \varpi_{PN} = \frac{0.28}{44.6194} \times \frac{1000}{1}$$

$= 6.0512rad/sec$

g) Speed of the pinion sprocket in rev/min

$$N_{PN} = \frac{\varpi_{PN} \times 60}{2\pi},$$

Where, $\varpi_{PN} = 6.0512rad/sec$

$$\Rightarrow \quad N_{PN} = \frac{6.0512 \times 60}{2\pi} = 57.7777rev/min$$

h) Torque generated at the pinion sprocket, τ_{PN}

$\tau_{PN} = T_C \times D_{PN}/2,$

Where, $T_C = 272.5N$ and $D_{PN} = 89.2388mm$

$$\Rightarrow \quad \tau_{PN} = \frac{272.5 \times 89.2388}{2 \times 1000}$$

$\tau_{PN} = 12.1519Nm$

3.2.3 **The Design Calculation of the Chain**

a) The length of chain in number of pitches, L_P

$$L_P = \frac{Z_{PN} + Z_W}{2} + \frac{2C}{Pbp} + \frac{(Z_W - Z_{PN})^2}{2\pi} \times \frac{P_{bp}}{C},$$

Where, Z_W = 44 teeths, Z_{PN} = 22 teeths, C = 465mm, and P_{bp} = 12.7mm

$$\Rightarrow \quad L_P = \frac{22 + 44}{2} + \frac{2 \times 465}{12.7} + \frac{(44 - 22)^2}{2\pi} \times \frac{12.7}{465}$$

= 106.5631pitches OR 106.5631 x 12.7 = 1353.3514mm in length

b) The chain tension, T_C

$$T_C = \frac{H.P \times 75 \times g}{V_C},$$

Where, H.P = 0.1, g = 9.81m/s^2 and V_C = 0.28m/s

$$\Rightarrow \quad T_C = \frac{0.1 \times 75 \times 9.81}{0.28}$$

$$T_C = 272.5N$$

c) The tangential force transmitted by the chain, F_K

$$F_K = \frac{P_{mH}}{V_C},$$ where P_{mH} = 75W and V_C = 0.28m/s

$$\Rightarrow \quad F_K = \frac{75}{0.28}$$

$$= 277.7778N$$

d) The tension caused by centrifugal forces, F_g

$$F_g = \rho c V_c^2$$

(3.20)

Where; ρc = 0.44kg/m^3 and V_C = 0.28m/s

$$\Rightarrow \quad F_g = 0.44 \times (0.28)^2$$

$$= 0.0321N$$

e) Angle between tangent and centre line, a

$$a = \sin^{-1}[(R - r)/C],$$

where, R = 89.0114mm, C = 465mm and r = 44.6194mm

$$\Rightarrow \quad a = \sin^{-1}[(89.0114 - 44.6194)/465]$$

$$a = 5.4782^{o}$$

$$a \approx 6^{o}$$

f) The total force on the chain, F_{TOT}

$$F_{TOT} = F_g + F_k$$

where $F_g = 0.0321N$ and $F_k = 277.7778N$

$$\Rightarrow \quad F_{TOT} = 0.0321 + 277.7778$$

$$F_{TOT} = 277.8099N$$

$$F_{TOT} \approx 277.8N$$

g) The chain bearing pressure per unit hinge area, P_K

$$P_K = \frac{F_{TOT} \text{ x } K_S}{A_{CH}} \leq P$$

where $F_{TOT} = 277.8099$, $A_{CH} = 47.8mm^2$

$$Ks = K_{dyn.} \text{ x } K_y \text{ x } K_{ten} \text{ x } K_{lub} \quad \Rightarrow \quad Ks = 1 \text{ x } 1 \text{ x } 1.25 \text{ x } 1$$

$$\Rightarrow \quad P_K = \frac{277.8099 \text{ x } 1 \text{ x } 1 \text{ x } 1.25 \text{ x } 1}{47.8} \leq (12.34)$$

$$P_K = 7.2649MPa \text{ and } P = 12.34MPa$$

$$\Rightarrow \quad P_K < P$$

h) The maximum tangential force, F_{mt} to be transmitted without excessive wear of the link hinge

$$F_{mt} = P_k \text{ x } A_{CH}$$

where $P_k = 7.2649MPa$ and $A_{CH} = 47.8mm^2$

$\Rightarrow \quad F_{mt} = 7.2649 \times 47.8$

$F_{mt} = 347.2623N$

g) Chain actual bearing pressure, P_{bc}

$P_{bc} = F_{TOT} / A_{CH}$

where $F_{TOT} = 277.8099N$ and $A_{CH} = 47.8mm^2$

$$\Rightarrow \quad P_{bc} = \frac{277.8099}{47.8}$$

$P_{bc} = 5.8119MPa$

j) The factor of safety (S) against chain breakage

$$S = \frac{F_b}{F_{TOT}} > [S]$$

where $F_b = 16464N$ (constant), $F_{TOT} = 277.8099N$

[S] = 8.33 (Berezovtsky; et al, 1988).

$$\Rightarrow \quad S = \frac{16464}{277.8099}$$

$S = 59.2635$

$\therefore \; S > [S]$

3.2.4 Design Calculation of the Chipping Wheel

a) The diameter of flat pulleys normally ranges from 20 – 5400mm (Khurmi and Gupta, 2006). The design adopted a pulley (wheel) diameter of 380mm.

b) Determine the thickness of the wheel, t using

$t = (D/200) + 6mm$ (Khurmi & Gupta, 2006)

where, D = diameter of the wheel = 380mm

$\Rightarrow \quad t = (380/200) + 6mm$

t = 7.90mm (24mm thickness was adopted)

Considering that aluminum is used in the cast for its anti-rust and hygienic condition, a wheel thickness of 24mm was adopted, because of the purpose the wheel was designed for.

c) The number of arms may be taken as 4 for pulley diameter from 200mm to 600mm and 6 for diameters from 600mm to 1500mm (Khurmi & Gupta, 2006).

But for this design, the wheel is provided with eight arms, which are elliptical in shape. The cross-section of the arm is obtained by considering the arm as cantilever i.e. fixed at the hub end and carrying a concentrated load at the rim end. The length of the cantilever is equal to the radius of the pulley. It is further assumed that at any given time, the power is transmitted from the hub to the rim or vice versa, through only half the total number of arms (Khurmi & Gupta, 2006).

i) Let τ_{PN} = torque transmitted = 12.1519N

R_P = Radius of pulley

$$= \frac{380}{2 \times 1000} = 0.19\text{m}$$

n = Number of arms = 8

$$\therefore \text{ Tangential load per arm, } W_T = \frac{\tau_{PN}}{R(^n/_2)} = \frac{2\tau_{PN}}{Rn}$$

$$\Rightarrow \quad W_T = \frac{2 \times 12.1519}{0.19 \times 8} = 15.99\text{N}$$

ii) Maximum bending moment on the arm at the hub end,

$$M = \frac{2\tau_{PN}}{R(^n/_2)} \times R = \frac{2\tau_{PN}}{n}$$

$$\Rightarrow \quad M = \frac{2 \times 12.1519}{8} = 3.04N$$

iii) Section Modulus,

$$Z = \frac{\pi}{32} \times b_1(a_1)^2$$

where b_1 = minor axis = 25mm and a_1 = major axis = 60mm

$$\Rightarrow \quad Z = \frac{\pi}{32} \times 0.025 \times (0.06)^2$$

$$Z = 9 \times 10^{-6} m^3$$

d) Diameter of the hub (d_h) in terms of the shaft diameter (d) may be fixed using the relationship:

i) $d_h = 1.5d + 25mm$

which means the diameter of the hub should not be greater than 2d (i.e. twice the shaft diameter).

$$\Rightarrow \quad d_h = 1.5d + 25mm, \text{ where } d = 25mm$$

$$d_h = (1.5 \times 25) + 25mm$$

$$d_h = 62.5mm$$

ii) The length of the hub, L_h was found using

$$L_h = (\pi/2) \times d$$

where d = 25mm = diameter of the shaft

$$\Rightarrow \quad L_h = (\pi/2) \times 25$$

$$L_h = 39.3mm$$

e) The wheel comprises of the Rim, Hub and Arms:

i) Area of the hub,

A_h = Area of the major diameter – Area of the minor diameter

$$\Rightarrow A_h = \pi (R_h^2 - r_h^2)$$

where $R_h = 62.5/2 = 31.25mm$ and $r_h = 27/2 = 13.5mm$

$\therefore A_h = \pi[(31.25)^2 - (13.5)^2]$

$A_h = 2495.4mm^2$

ii) Volume of Hub, $V_h = A_h L_h$

where $L_h = 39.3mm$, $A_h = 2495.4mm^2$

$\Rightarrow V_h = (2495.4 \times 39.3)mm^3$

$V_h = 98069.22mm^3$

iii) Area of the Rim,

A_r = Area of the major diameter – Area of the minor diameter

$\Rightarrow A_r = \pi(R_r^2 - r_r^2)$

where $R_r = 380/2 = 190mm$ and

$r_r = \frac{380 - 24 \text{ (thickness)}}{2} = 178mm$

$\therefore A_r = \pi(190^2 - 178^2)$

$A_r = 13873.3mm^2$

iv) Volume of the Rim, $V_r = A_r \times t$

where, $A_r = 13873.3mm^2$ and $t = 24mm$

$\Rightarrow V_r = (13873.3 \times 24)mm^3$

$V_r = 332958.6mm^3$

v) Area of the Arms,

A_a = Total Area of the wheel, A_w – Removed area (area of sector, A_s x 8)

$\Rightarrow A_a = A_w - (A_s \times 8)$

But $A_w = \pi R_w^2$

$\Rightarrow A_w = \pi \times (380/2)^2$

$A_w = 113411.5mm^2$

And, $A_s = 8 \times (\theta/360) \times \pi r_w^2$

where $\theta = 22.5^o$ and r_w = minor radius of the wheel.

$\Rightarrow \quad A_s = [(22.5/360) \times \pi \times 178^2)] \times 8$ arms

$A_s = 49769.1mm^2$

$\therefore \quad A_a = (113411.5 - 49769.1)mm^2$

$A_a = 63642.4mm^2$

vi) Volume of arm, V_a = Area of arm, A_a x Thickness of arm, t_a

$\Rightarrow \quad V_a = A_a \times t_a$

where $A_a = 63642.4mm^2$ and $t_a = 6mm$

$V_a = (63642.4 \times 6)mm^3$

$V_a = 381854.4mm^3$

vii) Volume of wheel, $V_w = V_h + V_r + V_a$

where, $V_h = 98069.2mm^3$,

$V_r = 332958.6mm^3$ and $V_a = 381854.4mm^3$

$\Rightarrow V_w = (98069.2 + 332958.6 + 381854.4)mm^3$

$V_w = 812882.2mm^3$

$V_w = 8.13 \times 10^{-4}m^3$

viii) Weight of the wheel, $W_w = V_w \times \rho_w \times g$

where, ρ_w = density of the wheel = 7200kg/m3 (cast iron)

(Khurmi & Gupta, 2006)

$g = 9.81m/s^2$ = acceleration due to gravity

$V_w = 812882.2mm^3 = 8.13 \times 10^{-4}m^3$

$\Rightarrow \quad W_w = (8.13 \times 10^{-4}) \times 7200 \times 9.81$

$W_w = 57.424N$

$W_w \approx 57.4N$

Mass of chipping wheel, $M_{cw} = \frac{57.4}{9.81} = 5.85kg$

3.2.5 Design Calculation of the Chipping Plate

a) Determine the number of punches on the plate.

i) The average diameter of cassava tuber is 50mm.

The average length of cassava tuber, L_t is 300mm (IITA, 1992).

Therefore, Area of tuber, $A_t = \pi r_t^2$

Where $r_t = \frac{50}{2} = 25mm$

$$\Rightarrow \quad A_t = \pi \times (25)^2$$

$$A_t = 1963.5mm^2$$

ii) Volume of cassava tuber, $V_t = A_t \times L_t$

where, $A_t = 1963.5mm^2$ and $L_t = 300mm$

$$\Rightarrow \quad V_t = (1963.5 \times 300)mm^3$$

$$V_t = 589050mm^3$$

iii) Adopting 10mm diameter for each punch on the chipping plate, it produces strips (chips) of 10mm and the length of the chips depend on the position of the tuber at the time of cutting. But usually the average length of chips,

$L_c = 60mm$ (IITA, 1992).

Area of chips, $A_c = \pi r_c^2$

Where $r_c = \frac{10}{2} = 5mm$ (radius of the punch)

$$\Rightarrow \quad A_c = \pi \times 5^2$$

$$A_c = 78.54mm^2$$

iv) Volume of chips, $V_c = A_c \times L_c$

where, $A_c = 78.54mm^2$ and $L_c = 60mm$

$$\Rightarrow \quad V_c = (78.54 \times 60)mm^3$$

$$V_c = 4712.4mm^3$$

v) Number of punches on the chipping plate,

$$N_p = \frac{\text{volume of cassava tuber, } V_t}{\text{Volume of cassava chip, } V_c}$$

Where, $V_t = 589050mm^3$ and $V_c = 4712.4mm^3$

$$N_p = \frac{589050}{4712.4}$$

$$N_p = 125 \text{ punches or holes}$$

Therefore, 128 punches were considered which means at a complete rotation of chipping mechanism about one tuber of cassava is chipped.

b) The total area of chipping plate, $A_{TP} = \pi r_{TP}^2$, where r_{TP} = radius of the entire chipping plate = $^{360}/_2$ = 180mm and thickness, t_{cp} = 0.6mm.

i) $\Rightarrow \quad A_{TP} = \pi \times 180^2$

$$A_{TP} = 101787.6mm^2$$

ii) Area of the punches, $A_p = \pi r_p^2$, where, $r_p = \frac{10mm}{2} = 5mm$

$$\Rightarrow \quad A_p = \pi \times 5^2$$

$$A_p = 78.54mm^2$$

iii) Total area of the punches = $A_p \times N_p$ (number of punches = 128)

$$\Rightarrow \quad 78.54 \times 128 = 10053.12mm^2$$

iv) Area of the removed centre, $A_{rc} = \pi r_{rc}^2$, where r_{rc} = 29mm

$$\Rightarrow \quad A_{rc} = \pi \times (29)^2$$

$$A_{rc} = 26421.1mm^2$$

v) The required area of chipping plate, $A_{cp} = A_{TP} - (A_p \times N_p) - A_{rc}$,

where, $A_{TP} = 101787.6mm^2$, $A_p = 78.54mm^2$,

$N_p = 128$ and $A_{rc} = 2642.1mm^2$

$$\Rightarrow \quad A_{cp} = 101787.6 - (78.54 \times 128) - 2642.1$$

$$= 89092.4mm^2$$

vi) Volume of chipping plate, $V_{cp} = A_{cp} \times t_{cp}$,

where, $A_{cp} = 89092.4mm^2$ and $t_{cp} = 0.6mm$

$$\Rightarrow \quad V_{cp} = (89092.4 \times 0.6)mm^3$$

$$V_{cp} = 53455.4mm^3$$

$$V_{cp} = 5.3455 \times 10^{-5}m^3$$

vii) Mass of chipping plate, $M_{cp} = V_{cp} \times \rho_{cp}$,

where, $V_{cp} = 5.35 \times 10^{-5}m^3$ and $\rho_{cp} = 7900kg/m^3$

$$\Rightarrow \quad M_{cp} = (5.35 \times 10^{-5} \times 7900)kg$$

$$M_{cp} = 0.423kg$$

3.2.6 Design of the Shaft

a) Mass of the chipping assembly, M_{ca}

$$M_{ca} = M_{cw} + M_{cp}$$

where, M_{cw} (mass of chipping wheel) $= 5.85kg$

M_{cp} (mass of chipping plate) $= 0.42kg$

$$\Rightarrow \quad M_{ca} = (5.85 + 0.42)kg$$

$$M_{ca} = 6.27kg$$

Therefore, weight of chipping assembly, $W_{ca} = M_{ca} \times g$

where, $M_{ca} = 6.27kg$, $g = 9.81m/s^2$

$$W_{ca} = 6.27 \times 9.81$$

$$W_{ca} = 61.51N$$

b) Tangential force on the chipping assembly,

$$F_{ca} = M_{ca} \times r_{ca} \times \omega_{PN}^2$$

where, $M_{ca} = 6.27kg$, $r_{ca} = 190mm = 0.19m$ and $\omega_{PN} = 6.0512rad/sec$

$$\Rightarrow \quad F_{ca} = 6.27 \times 190 \times (6.0512)^2$$

$$F_{ca} = 43.62N$$

c) Vertical tangential force,

$$F_{TV} = F_{ca} Sin\ a$$

where, $F_{ca} = 43.62N$, $a = 6^o$

$$\Rightarrow \quad F_{TV} = 43.62 \times Sin\ 6^o$$

$$F_{ca} = 4.56N$$

d) Horizontal tangential force,

$$F_{TH} = F_{ca} Cos\ a$$

where, $F_{ca} = 43.62N$, $a = 6^o$

$$\Rightarrow \quad F_{TV} = 43.62 \times Cos\ 6^o$$

$$F_{ca} = 43.38N$$

e) Vertical tensile force on the driven (Pinion) sprocket,

$$F_{VTN} = F_{TOT}\ Sin\ a$$

where, $F_{TOT} = 277.8N$, $a = 6^o$

$$\Rightarrow \quad F_{VTN} = 277.8 \times Sin\ 6^o$$

$$F_{VTN} = 29.04N$$

f) Horizontal tensile force,

$$F_{HTN} = F_{TOT}\ Cos\ a$$

where, $F_{TOT} = 277.8N$, $a = 6^o$

$$\Rightarrow \quad F_{HTN} = 277.8 \times Cos\ 6^o$$

$$F_{HTN} = 276.28N$$

g) Calculation of the reaction forces on the vertical components

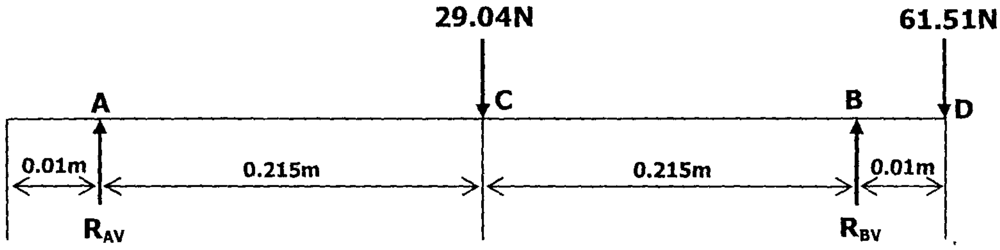


Fig. 3.3: Free Body Diagram for Reactions in Vertical Components of the Forces

$$\Sigma Y^{\uparrow +} = 0$$

$$R_{AV} + R_{BV} - 29.04 - 61.51 = 0$$

$$\Rightarrow \quad R_{AV} + R_{BV} = (61.51 + 29.04)N$$

$$R_{AV} + R_{BV} = 90.55N$$

Taking moment about A

$$\Sigma M_A^{\uparrow +} = 0$$

$$(29.04 \text{ x } 0.215) - (R_{BV} \text{ x } 0.43) + (61.51 \text{ x } 0.44) = 0$$

$$\Rightarrow \quad 0.43R_{BV} = (29.04 \text{ x } 0.215 + 61.51 \text{ x } 0.44)Nm$$

$$R_{BV} = \left(\frac{6.24 + 27.06}{0.43}\right)N$$

$$R_{BV} = 77.46 \text{ N}$$

Therefore, $R_{AV} = (90.55 - 77.46)$ N

$$R_{AV} = 13.09 \text{ N}$$

h) Bending moment calculations

$M_{AV} = M_{DV} = 0$

Bending moment at C, $M_{CV} = (13.09 \text{ x } 0.215) = 2.81Nm$

Bending moment at B, $M_{BV} = (13.09 \text{ x } 0.43) - (29.04 \text{ x } 0.215) = -0.62Nm$

Shear Force at A, $S_A = 13.09N$

Shear Force at C, S_C = 13.09 – 29.04 = -15.95N

Shear Force at B, S_B = -15.95 + 77.46 = 61.51N

Shear Force at D, S_D = 61.51 – 61.51N = 0N

i) Bending moment and shear force diagram for vertical component.

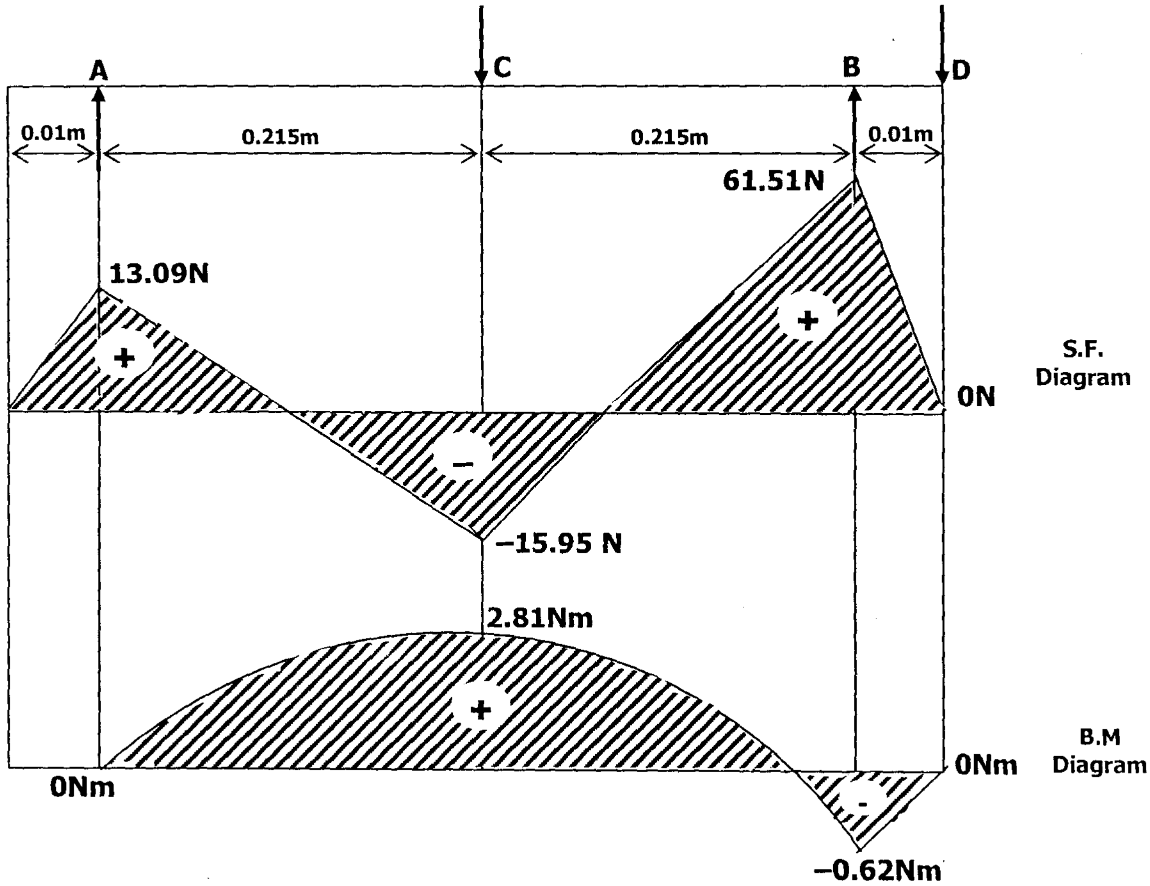


*Fig. 3.4: **Bending Moment and Shear Force Diagram for the Vertical Components***

j) Calculation of the reaction forces on the horizontal components. But, for the horizontal component, the only force is the force on the Pinion sprocket is the only force acting on the shaft at an inclined angle of 6°.

F_{HTN} = F_{TOT} Cos a

⇒ F_{HTN} = 277.8 x Cos 6°

F_{HTN} = 276.28N

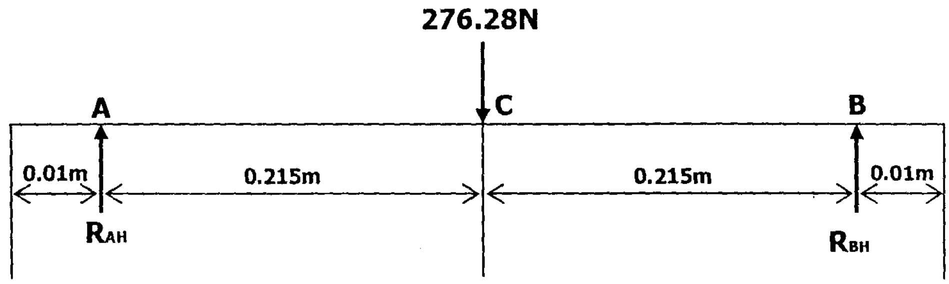


Fig. 3.5: Free Body Diagram for Reactions in Horizontal Components of the Forces

k) Calculation of the reaction forces on the horizontal components;

$$\Sigma F_{HTN}^{\uparrow +} = 0$$

$$\Rightarrow \quad R_{AH} + R_{BH} = 276.28N$$

Taking moment about A

$$\Sigma M_{AH}^{\uparrow +} = 0$$

$$-(276.28 \times 0.215) + (R_{BH} \times 0.43) = 0$$

$$0.43R_{BH} = 59.40Nm$$

$$R_{BH} = \frac{59.40Nm}{0.43}$$

$$R_{BH} = 138.14N$$

Substituting 138.14N for R_{BH}

$$\Rightarrow \quad R_{AH} = (276.28 - 138.14)N$$

$$R_{AH} = 138.14N$$

l) Bending moment calculations.

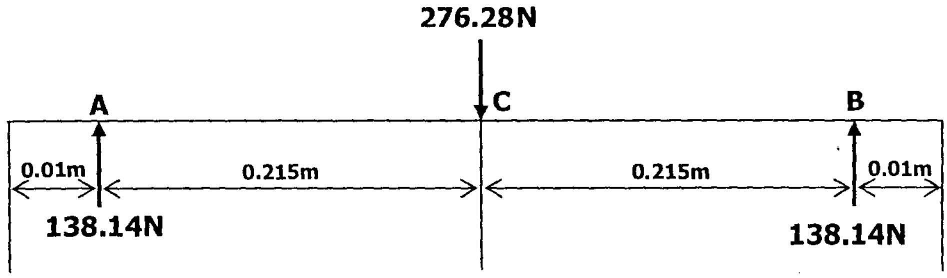


Fig. 3.6: Free Body Diagram for Horizontal Components of the Forces

We know that bending moment at A and C,

$$M_{AH} = M_{BH} = 0$$

Bending moment at C, $M_{CH} = 138.14 \times 0.215 = 29.70$Nm

m) Bending moment diagram for horizontal components.

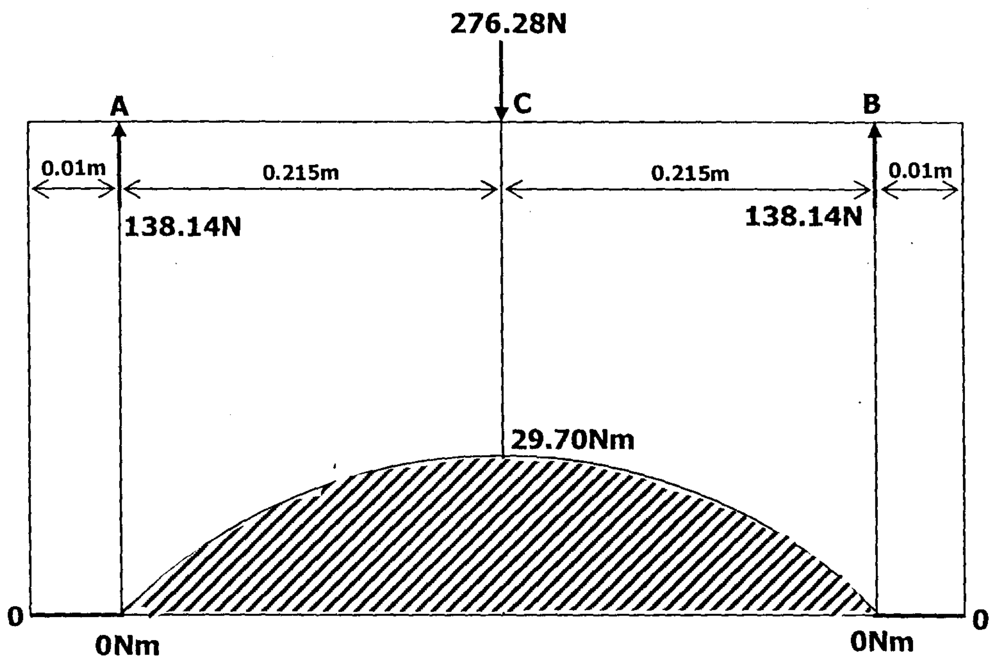


Fig. 3.7: Bending Moment Diagram

n) The resultant bending moment,

$$M_b = \sqrt{(M_{bV})^2 + (M_{bH})^2}$$

where, $M_{bV} = 2.81Nm$, $M_{bH} = 29.70Nm$

$$\Rightarrow \quad M_b = \sqrt{(2.81)^2 + (29.70)^2}$$

$$M_b = 29.83Nm$$

o) The resultant bending moment diagram

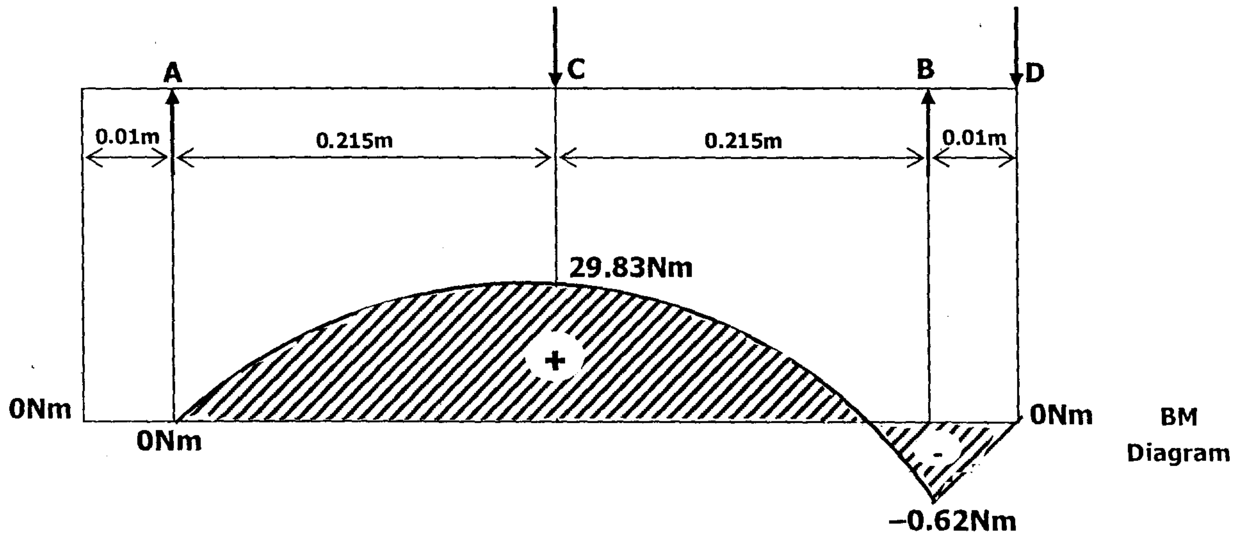


Fig. 3.8: Resultant Bending Moment Diagram

p) Calculation of the diameter of the shaft, d is given by the expression below;

$$d^3 = \frac{16}{\pi S_a} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

For a solid shaft with little or no axial loading,

Where, d = Diameter of the shaft

K_t = Combined shock and fatigue factor for torsion

K_b = Combined shock and fatigue factor for bending moment

M_b = Maximum bending moment

M_t = Torsion moment

S_a = Allowable shear stress of the shaft material = 56×10^6 N/m^2

For a shaft with key way to hold the chipping wheel in place, S_a is reduced by 25%

$$\Rightarrow \quad 0.75S_a = 0.75 \times 56 \times 10^6 \, N/m^2$$

For rotating shafts, load suddenly with minor shocks only, $K_b = K_t = 1.5$

$$d^3 = \frac{16}{\pi \times 42 \times 10^6} \sqrt{(1.5 \times 29.83)^2 + (1.5 \times 12.15)^2}$$

$$d^3 = 1.2126 \times 10^{-7} \sqrt{2354.25}$$

$$d^3 = 1.2126 \times 10^{-7} \times 48.5206$$

$$d^3 = 5.8836 \times 10^{-6}$$

$$d = (5.8836 \times 10^{-6})^{\frac{1}{3}}$$

$$d = 0.0180m$$

$$d \approx 18.05mm$$

Therefore, 25mm shaft is adopted.

3.2.7 Calculation of Bearing at the Shaft

The bearing data are given below:

i) Type of bearing: single row ball bearing

ii) Bore diameter $B_D = 25mm$

iii) Bearing Number: 200series (UCP 206)

a) The type of bearing selected is the single row ball bear, which can withstand radial load. The rated life of the bearing, $L_{10} = 65{,}000{,}000$hours.

b) Determine the dynamic load on the bearing.

P_r = maximum load on the chipping shaft

$F_H = P_r$, where F_H, the horizontal force on the shaft $= 277.8N$

$\therefore \; P_r = 277.8N$

c) Determine the required capacity of the bearing, C_r using equation 3.39:

$$C_r = \frac{P_r(L_{IO} \times N_C)^{1/k}}{Z_b}$$

where $P_r = 277.8N$, $L_{IO} = 65{,}000{,}000$, $K = 3$,

$N_C = 57.7777 rev/min$ and $Z_b = 18.5$

$\Rightarrow$ $Cr = 23213.2N$

3.3 System Design

Production design is the critical link between the chains of events that start with a creative idea and ends with a successful market product.

3.3.1 Material Selection

An improperly chosen material can lead not only to failure of the parts or component, but also to avoidable cost. Therefore, the selection of an appropriate material is part of the design process and the responsibility of the designer. The success of a design depends much on the choice of material which is often the most important design problem.

Materials are selected to provide characteristics that are essential to design and also desirable. It is also very important to make a careful choice of the best material to serve the design need. Also it is important to give careful thought to the factors that will have a bearing on the successful performance of the part that is made. Most times, the choice of materials dictates the manufacturing process to be used and the manufacturing cost of the product.

Successful material selection depends on the ability to satisfy the mechanical properties and factors, the following principal selection factors are:

i) Mechanical properties (i.e. strength, durability)

ii) Finishing and coating

iii) Composition and density

iv) Machinability

v) Economy (i.e. material and production cost)

3.3.2 Steps of Materials Selection

a) Analysis of material required – this includes mechanical properties and chemical composition.

b) Identification of alternative materials

c) Selection of the best materials

d) Development of design, data for critical application.

CHAPTER FOUR

4.0 PERFORMANCE TEST, MAINTENANCE AND COST EVALUATION

4.1 . Machine Component

The pedal operated cassava chipping machine is a machine designed for easy production of chips, such as yams, cassava, potato, sweet potato chips etc. The machine is pedal operated. The machine consists of the following components, feeding chute, chipping plate, chipping wheel, shaft, bearings, frame, sprockets and chains and pedals.

4.1.1 Machine Description

Feeding chute is in shape of a funnel or a frustum cut in a slanting form, to give certain angle of inclination to the chipping plate. This chute is bolted to the frame.

Feeding chute in a chipper is a component through which the material to be chipped is first fed to the chipping mechanism.

Chipping plate (stainless steel) is the steel which when correctly heat treated and finished, resists oxidation and corrosion from most corrosive media. These steels are very tough and can be forged and rolled but after difficulty in machining. They can be easily welded and after welding it becomes susceptible to corrosion. This susceptibility to corrosion is called inter-crystalline corrosion or weld decay. The steel provide excellent resistance to attack by many chemicals, it is extensively used in chemical, food, paper making and dyeing industries. It has density of about 7900kg/m^3.

The chipping mechanism is made from stainless steel of high tensile sheet of about GA 24, cut into circular plate 360mm diameter, and pressed to form alternative 4mm deep concentric grooves. Two rows of alternative punches of 10mm apart are made on each grove along eight equidistant radial line (the punches or holes are 8 holes per row and 2 rows on each groves, the first and second row are arranged in special way) which make it 16 punches per grooves for the eight, grooves the total punches is 128 punches.

Chipping wheel is one of the major components of the machine. It is about 380mm diameter. The wheel is divided into eight equidistant parts; it is made from aluminium cast and machined on the Lathe machine to give proper finishing.

The function of chipping wheel is to support the chipping plate and to excrete chips of chipping mechanism.

The shat is made of mild steel rod of 25mm diameter and 500m long, it is this shaft that is supported by the two bearings, carries the wheel, pinion and chipping plate.

The frame structures of the machine are made up of mild steel (angle from 1.5 x 1.5) cut into various sizes required or according to the dimension and joined by first tacking it and later welding. The frame dimension is 900 x 500 x 400mm.

4.2 **Maintenance**

To maximize the use of pedal operated cassava chipper, the following routine maintenance should be observed.

i) Constant lubrication of the bearing must be observed.

ii) If any little crack should be observed on the bearing, it should be replaced.

iii) The chipping mechanism should be washed after every operation.

iv) The bolt and nut holding the chipping mechanism to the shaft should be well tightened before setting it in operation.

v) The machine should be stopped before collecting the unchipped tubers from under the machine.

vi) The chain (links and rollers) should constantly be checked to avoid sudden failure.

vii) The chain should always be cleaned with paraffin using a stiff or iron brush by moving chain to ensure penetration.

viii) The sprockets should be cleaned and lubricated regularly.

ix) Checks must be made from time to time for security of attachment, correct alignment and prevention of signs of damage.

4.3 Performance Test

The performance or functional requirements of the project was first expressed in terms of physical, mechanical and chemical properties.

The weight of the machine is one of the major factors that were considered. Many steps were taken to reduce the weight to minimum possible through the material selection and method of assembling (aluminium was used for casting of chipping wheel and feeding chute). To achieve maximum mechanical efficiency, a careful selection of material with correct shape and size was made (angle iron was used for the frame work). In case of corrosion chemical and other environmental factors (galvanize sheet was used to cover the top and stainless steel was used for the chipping plate). The welded portion and frame are painted.

The objectives of the test are:

a) To determine the efficiency of the machine.

b) To evaluate the performance of the chipping machine.

4.3.1 **Results**

The machine was tested and the tables below shows the results obtained.

i) **Test for Effectiveness**

The effectiveness of the machine was calculated based on the input force (pedalling force) and the total force output (the horizontal and vertical forces on the grating shaft).

The pedalling force, F_P = 134N

The summation of all horizontal and vertical forces

F_N = 4.56N

F_{HTN} = 61.51N

F_{VTN} = 29.04N

Therefore, the total force on the chipping shaft = 95.11N

Table 4.1: **Effective Table**

Pedalling Force, F_P (N)	Total Output Force (N)
134	95.11

Effectiveness is the ratio of work output to work input, mathematically,

$$= \frac{\text{Work output, } W_o}{\text{Work input, } W_i} \times 100\%$$

$$= \frac{\text{Total output force } T_o}{\text{Total pedalling force, } T_i} \times 100\%$$

$$= \frac{95.11}{134} \times 100\%$$

$$= 71.0\%$$

ii) **Test for Efficiency**

A weighed cassava was fed to the machine at the required rate and the product was collected and weighed.

Table 4.2: Efficiency Table

Weight of Cassava fed (kg)	Weight of the Chips (kg)
16	12

The efficiency (η) can be calculated as

$$\eta = \frac{\text{Weight of chips}}{\text{Weight of cassava fed}} \times 100\%$$

$$\eta = \frac{W_C}{W_F} \times 100\%$$

$$\eta = \frac{12}{16} \times 100\%$$

$$\eta = 75\%$$

4.4 Discussion of Results

The size of tubers, particularly the diameter affected the cranking speed. The operation slows down when fed with bigger tubers because of the higher resistance due to increased area of contact with the chipping plate.

This can be related to the feeding rate, small tubers can be fed in batch compare to the big tubers which are fed one after the other. The efficiency of the machine in terms of the force requirement was calculated to be 71.0% while the efficiency in terms of chipping was calculated to be 75%.

4.5 **Materials and Cost Analysis**

The cost of producing a pedal operated cassava chipper mainly depends upon the local cost of material, manufacturing cost and the overhead cost. The table below shows the summary of the bill of materials:

Table 4.3: Bill of Materials

S/No.	Items	Quantity	Unit Price (₦)	Amount (₦)
1.	Chipping plate	1	8000	8000
2.	Chipping wheel	1	2500	2500
3.	Feeding chute	1	1500	1500
4.	Ball bearings	2	400	800
5.	Chain	1	500	500
6.	Wheel sprocket	1	350	350
7.	Pinion sprocket	1	250	250
8.	Pedal	1 pair	200	200
9.	Bicycle seat	1	700	700
10.	Angular steel bar	3	1500	4500
11.	Galvanize steel	-	1000	1000
12.	Paint	4 litres	1500	1500
13.	Grease	2 tins	200	400
14.	Bolt and nut	10	10	100
15.	Wheel connecting pins	2	50	100
16.	Bicycle frame	1	1950	1950
17.	Electrodes	25	20	500
18.	Shaft	1	1000	1000
	TOTAL			**25,850**

Manufacturing Cost

i)	Welding and assembly of the bicycle and other parts	=	₦3000.00
ii)	Painting	=	₦ 500.00
	Total	=	**₦3,500.00**

Overhead Cost

i)	Transportation	=	₦2000.00
ii)	Miscellaneous expenses	=	₦1000.00
	Total	=	**₦3,000.00**

Total Cost

Total cost implies the cost of materials, the manufacturing cost and the overhead cost.

i)	Material cost	=	₦25,850.00
ii)	Manufacturing cost	=	₦ 3,500.00
ii)	Overhead cost	=	₦ 3,000.00
	Total	=	**₦32,350.00**

TEST SAMPLE

TEST SAMPLE

UNCHIPPED CASSAVA

MACHINE AT WORK

FULL PHOTOGRAPH OF MACHINE

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A pedal operated cassava chipper has been designed and fabricated using locally available materials such as mild steel, aluminium cast, galvanize sheet and stainless steel sheet. The machine proves to be a perfect and efficient substitute for the traditional methods of slicing cassava tuber. The design also provides to be suitable or best for those in rural areas, as well as those in town and cities due to frequent power failure we are experience in the country.

The chipper was able to achieve a chipping efficiency of 75%. However, with little and proper adjustment between the chipping plate and feeding chute machine efficiency will be more.

The machine was also designed considering the low cost involved and can be affordable to the rural community. Each component of the machine is made from materials readily available in the market and only the chipping plate may have to be replaced after long use or when the quality of chips produced is declining.

5.2 Recommendations

Evidence from tests suggests that elliptical chain wheels with a relatively small degree of elongation, that is, with a ratio of major to minor axis of the chain wheel ellipse of no more than 1.1:1 do allow most pedalers to produce a little more power. No subject tested showed a reduction in power. It is therefore recommended that, when elliptical chain wheels are available at a reasonable price, they be used.

When pedalling a stationary device on a hot or humid day at more than about half the maximum possible power output, there is a considerable danger of the pedaler's collapsing because of an excessive rise in body temperature. Therefore it is essential that an individual pedalling such a stationary device in hot or humid conditions be provided with shade from the sun, plenty of water, and preferably some sort of fan.

The efficiency can be improved upon by proper adjustment between feeding chute and chipping plate and more of such machines can be constructed and made available to cassava flour producer at affordable cost or in form of loan under a co-operative society.

REFERENCES

Asegwu, N. S. (1981). Determination of Some Mechanical Properties of Cassava Root (Manihot esculenta crantz), M.Sc. Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria, pp. 53 – 56.

Asiedu, J. J. (1989). Processing Tropical Crops (Technological Approach), First Edition, Published by Macmillan Press Ltd., pp 1 – 6.

Bellantin, R. and Richard (1975): Bicycle Handbook. Pan Book Limited, London, pp. 118 – 205.

Busari Rasheed Amao (2005): Design and Construction of Manually Operated Cassava Chipping Machine, Unpublished Project Report submitted to Agricultural Engineering Department, Federal University of Technology Minna, Niger State, Nigeria.

Butterworth, B. (1980): Farm Workshop and Maintenance. 2nd Edition, Revised Industrial Press N.Y., pp. 103 – 114.

Darrow, Ken and Pam, Rick (1977): "Energy: Pedal Power" from Appropriate Technology Sourcebook, pp. 189 – 196, Stanford, California: Volunteers in Asia, Inc.

Elsevier (1989): Agricultural Compendium for Rural Development in Tropics and Subtropics, Third Edition.

Food and Agricultural Organization (1992). Food Production Year Book. Food and Agricultural Organization of United Nation, Rome Italy, pp. 30 – 34.

Food and Agricultural Organization of United Nation (1988): Root and Crop Challenges and Opportunities, Longman, pp. 7 – 98.

Grace, M.R. (1987): Cassava Processing Feed and Agricultural Organization of the United Nation. Pp. 166.

Igbeka, J. C. (1984). Some Mechanical and Rheological Properties of Yam and Cassava. Africa Journal of Science Technology, pp. 27 – 40.

I.I.T.A. (1992): Post Harvest Technology Unit and the Group Training Unit.

Indigenous Technology Development Commercialization in Nigeria. Published by Foundation for the Promotion and Commercialization of Indigenous Technology (FOPCIT). Enugu State, Vol. 1, No. 1, 1987.

Isiyaku, A.M. (2005): Design and Construction of Melon Sheller with Blower. Unpublished Project Report, Agricultural Engineering Department, Federal University of Technology, Minna, Niger State, pp. 23 – 43.

Khurmi, R. S. and Gupta, J. K. (2006): Machine Design, Reprinted with Correction. Chad and Company Limited, New Ram Nagar, New Delhi – 11005.

Khurmi, R. S. (2006): Strength of Materials. Twenty Second Edition S. Chad and Company Limited New Ram Nagar, New Delhi – 11005, pp. 270 – 557.

Konz, S. (1983): Work Design Industrial Ergonomics. John Wiley and Sons Inc., pp. 14 – 63.

Kwatia, J. T. (1986). Rural Cassava Processing and Utilization Centres. UNICEF/IITA Collaborative Programme for Household Food Security and Nutrition, pp. 8 – 15.

Lawal, A. I. (1965): Design and Construction of a Static Bicycle and Bevel Gear Drive Unit to Drive a Sugarcane Crusher (B. Eng. Thesis): A.B.U. Zaria, pp. 13 – 57.

Macdonald, I. and John (1984). Tropical Field Crops, First Edition, pp. 8 – 9.

Murrel, K.F.H. (1965): Ergonomic – Man in His Working Environment, (2nd Edition). Chapman and Hall Publishers, pp. 56 – 72.

Ofori, F and Hahn, S.K. (1994). Ninth Symposium of International Society, for Tropical Root Crops in Developing Economy, organized by International Society for Tropical Root Crops in Collaboration with the Government of Ghana, pp. 259 – 288.

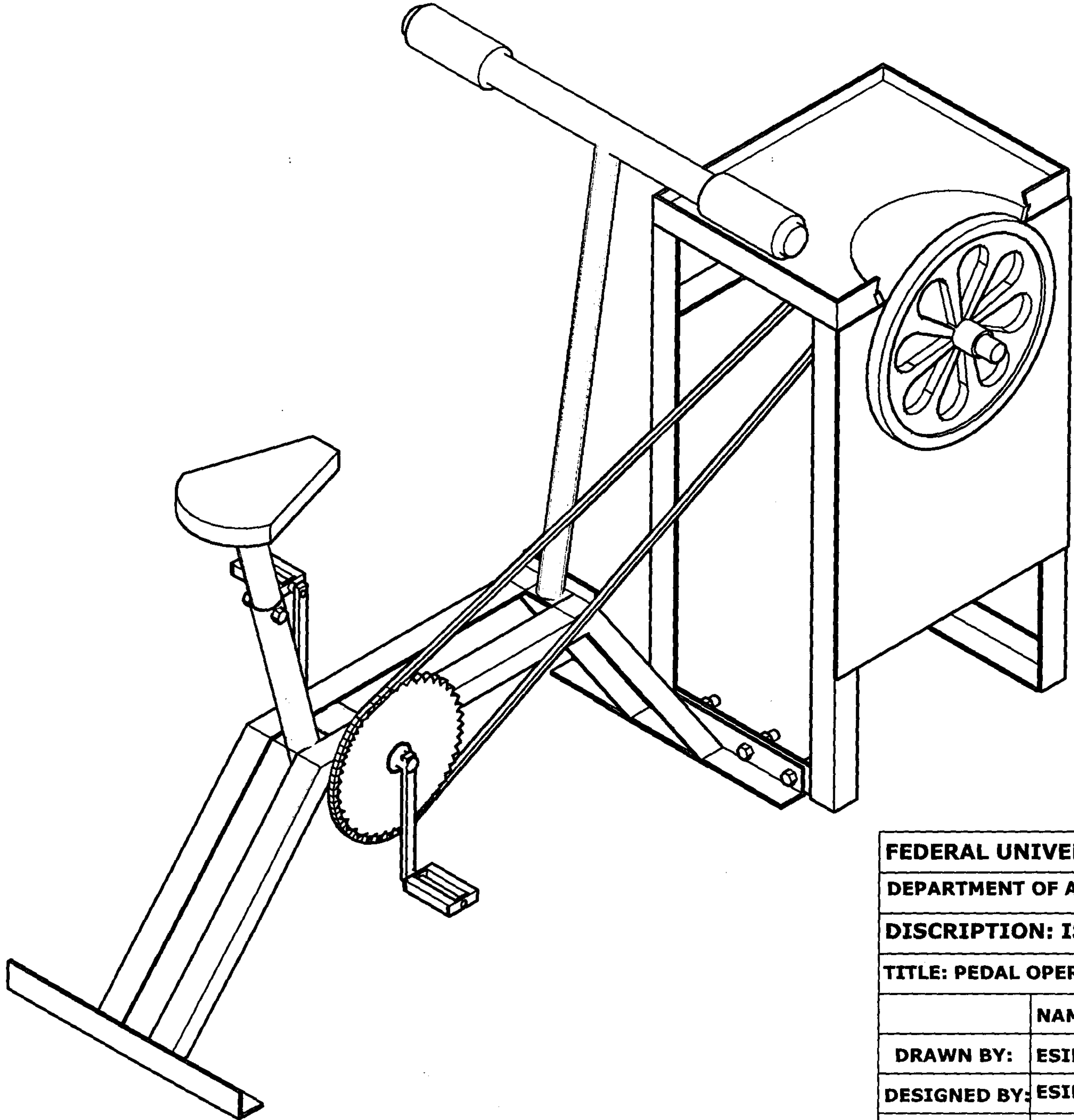
Onwueme, I. C. (1978). Crop Science, First Edition, pp. 68 – 72.

Oyewole, T. (1986). Cassava Processing in Ibadan Area: Technique and Proceses. IITA Socio-Economic Unit Ibadan, pp. 280 – 281.

Pedal Power: A Supplement to Energy for Rural Development, Washington D.C., National Academy Press, 1981, pp. 137 – 148.

Ryder, G. H. (1969): Strength of Materials. (3rd Edition). Macmillan Press Limited, pp. 86 – 92.

Usman Bello (2008): Design of Agricultural Machinery. Unpublished Class note Agricultural Engineering Department Federal University of Technology, Minna, Niger State, Nigeria, pp. 1 – 70.



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DEPARTMENT OF AGRIC AND BIORESOURCES ENGINEERING				
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DESIGNED BY:	**ESIMI, J. S**	**04/ 18439EA**		
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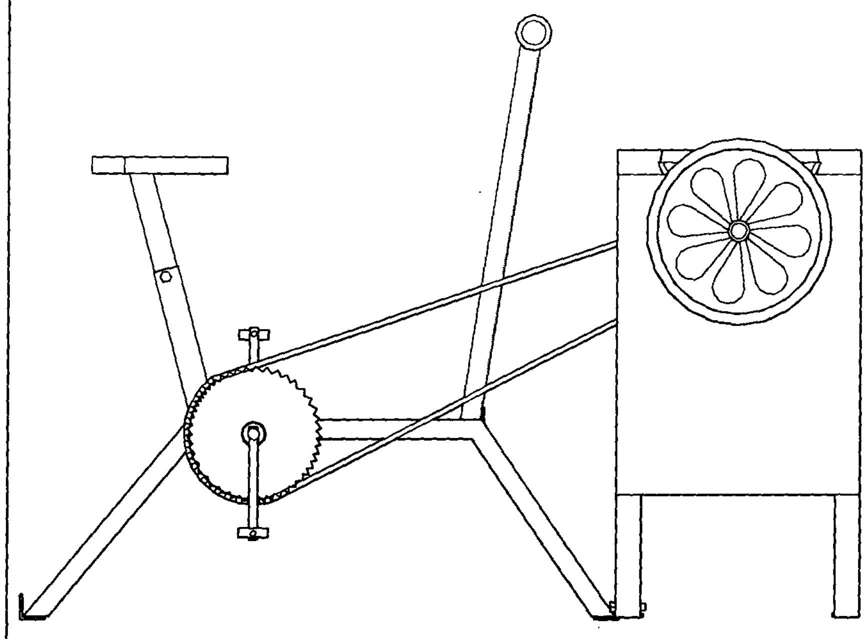

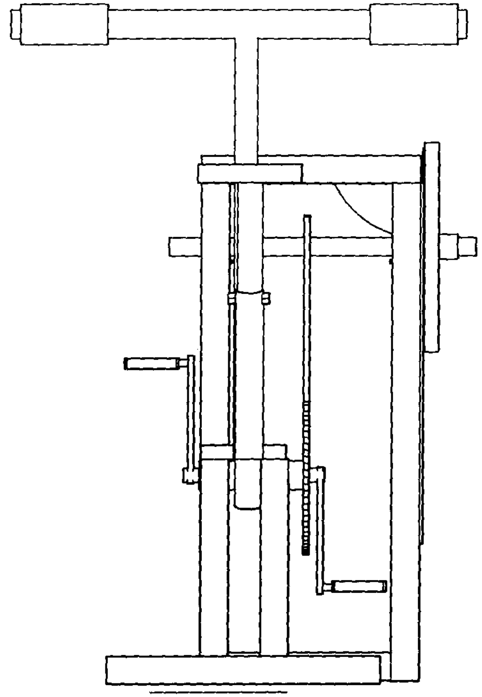

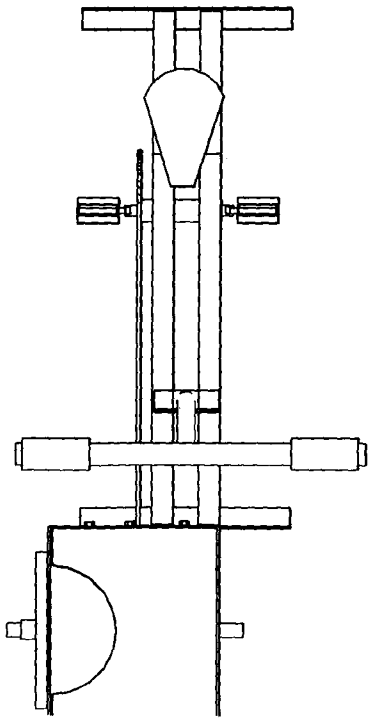

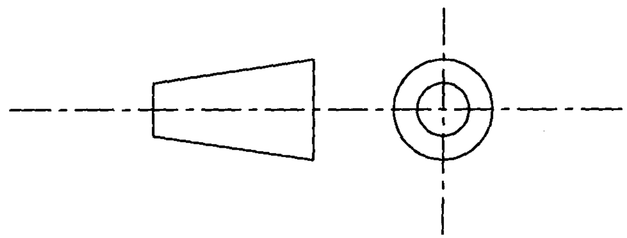

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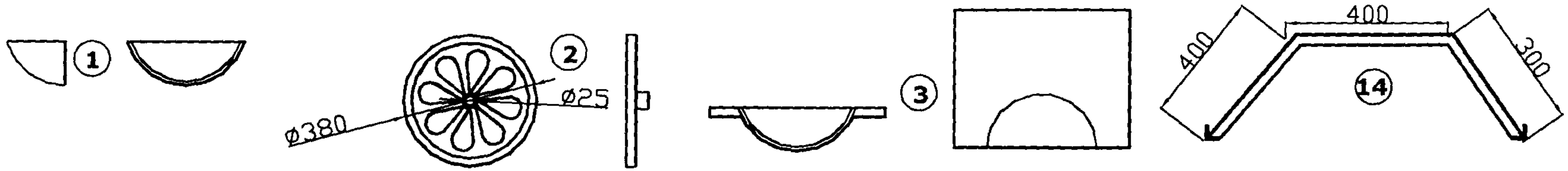

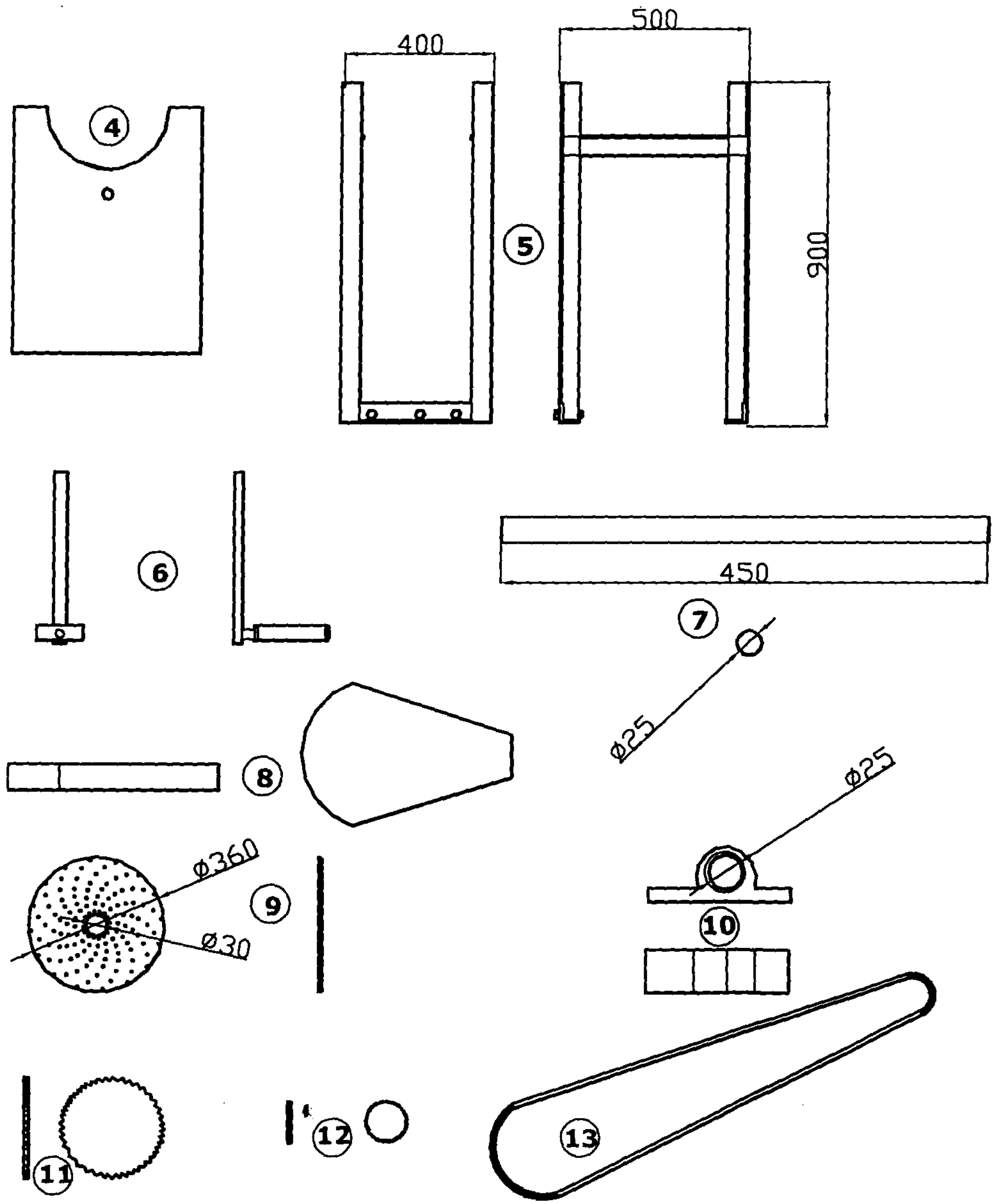

S/N	DISCRIPTION	MATERIAL	QTY
1	FEEDING CHUTE	ALUMINIUM	1
2	CHIPPING WHEEL	ALUMINIUM	1
3	HOPPER	STEEL SHEET	1
4	SIDE COVER	STEEL SHEET	1
5	MACHINE STAND	MILD STEEL	1
6	PEDAL	RUBBER	2
7	SHAFT	MILD STEEL	1
8	SADDLE	RUBBER	1
9	CHIPPING PLATE	STAINLESS STEEL SHEET	1
10	BEARING	ALLOY STEEL	2
11	WHEEL	ALLOY STEEL	1
12	PINION	ALLOY STEEL	1
13	CHAIN	ALLOY STEEL	1
14	BICYCLE STAND	MILD STEEL	1

ALL DIMENSIONS IN mm

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DISCRIPTION: PART DRAWING				
TITLE: PEDAL OPERATED CASSAVA CHIPPER				
	NAME	MATRIC NO.	SIGN	DRG. NO. 03
DRAWN BY:	ESIMI, J. S	04/ 18439EA		
DESIGNED BY:	ESIMI, J. S	04/ 18439EA		
CHECKED BY:	DR. ADGIDZI			SCALE 1:10
APPROVED BY:	DR. ADGIDZI			DEC. 2009