UNIVERSITY OF NAIROBI
SCHOOL OF ENGINEERING
DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

FEB 540: ENGINEERING DESIGN PROJECT

PROJECT TITLE:

DESIGN OF A MODIFIED HAND OPERATED PINEAPPLE JUICE EXTRACTION MACHINE.

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A Report Submitted in Partial Fulfillment for the Requirements of the Degree of Bachelor of Science in Environmental and Biosystems Engineering, of the University Of Nairobi.

May 2015

Declaration

I declare that this project is my work and has not been submitted for award of a degree in any University.

Signature: ………………………………………. Date: ………………………………

OGOLA ZADOCK OLECHE

This report has been submitted for examination with my approval as a University supervisor.

Signature: ……………………………………… Date: …………………………………

Eng.Joackim Mutua

Dedication

I dedicate this project to my beloved Parents, my siblings and friends for their kindness and support throughout my undergraduate study.

Acknowledgement

I thank God for seeing me through the five years in campus and having given me good health, mental and physical strength as an undergraduate at the University of Nairobi.

Special thanks also go to Eng. Joackim Mutua for his guidance and intellectual support.

My gratitude also goes to the able EBE technical staff especially Mr.Wamutitufor the proficient guidance throughout this project.

I would also like to thank our chairman Prof. Eng. Ayub N. Gitau, the entire staff and student fraternity of the department of Environmental and Biosystems Engineering for their support.

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List of Acronyms and Abbreviations

CA – Controlled Atmosphere

RPM – Revolutions per minute

BEME - Bill of Engineering Measurement and Evaluation

Abstract

Harvested pineapple may go bad before they can be consumed, due to lack of appropriate technology and infrastructure. Up to 25% of the fruit is estimated to be lost before it reaches the market, because of poor handling and storage after harvest. Designing a juice extraction machine will ensure minimal wastage of the pineapples after harvesting and during transportation, since the pineapples will be processed to juice

Fruit juice extraction involves pressing of the fruit in order to get juice. The extraction process involves crushing squeezing and pressing of the whole fruit to obtain juice and reduce the bulkiness of the fruit to liquid and pulp. Hand extraction of juice is slow and tedious and also not hygienic. Using a machine for extraction is time saving, efficient, and has increased capacity and reduction in spoilage and waste. The various processes involved in fruit processing include; sorting, washing, pressing, slicing, crushing, extraction and pasteurization (heat treatment).

A manual operated juice extractor was designed and evaluated at the Department of Agricultural Engineering, Federal College of Agriculture, Akure, Ondo State Nigeria. This manually operated juice extractor was designed to save time, improve efficiency, increase capacity and reduction in spoilage and waste. The results showed that the machine produced efficiencies of 83.36 and 85.38% and extraction capacity was 1.23 kg/hr.

The design modification presented in this paper is aimed at complementing the performance of continuous screw expeller.

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Chapter one

1.0. Introduction

1.1. Background

Thailand, Philippines, Brazil and China are the main pineapple producers in the world, supplying early 50 % of the total output. Historians believe that the pineapple originated in Brazil in South America. It was imported to Europe later. It is also believed that Christopher Columbus and his crew members were probably the first few people from the European continent to have tasted the fruit. Kenya appears in the list of other important producers. Together with India, Nigeria, Indonesia, México and Costa Rica, Kenya forms the remaining 50% of pineapple producers. (Medina 2005)

You can grow your own pineapple by planting the top of the pineapple in soil, which may take about two years to produce fruit. In Kenya pineapple production in is entirely on plantations and is both capital and input intensive, it takes a sixth place in the top seven fruits (bananas, citrus fruits, mangos, avocado, passion fruit, pineapples and pawpaw) in Kenya in terms of area and total production. Total pineapple growth in Kenya over the 1992-2000 year period was 60%, this growth figures mainly relate on different technology and production systems.

Kenya is known for bulk processing which requires high capital cost and high input. Pineapple processing involves a series of operations; peeling, slicing and coring before juice extraction, which might be quite expensive limiting the small scale farmer.

1.2. Statement of problem and problem analysis

1.2.1. Problem statement

Harvested pineapple may go bad before they can be consumed, due to lack of technology and infrastructure. This in the long run reduces production, because farmers are reluctant to increase the input for most of the pineapple end up as waste.

Most of the pineapple is harvested when ripe and ready to consume, the farmers are expected to consume them within seven days after harvesting. Up to 25% of the fruit is estimated to be lost before it reaches the market, because of poor handling and storage after harvest. (Pineapple post-harvest operations, 2005 FAO, 2004)

1.2.2. Problem Analysis

In the country, there exists a pineapple processing plant in Del Monte Kenya Limited located near Thika Town, which is capital intensive. This plant limits the small scale farmer for it requires high startup capital and a large amount of pineapple input.

In this project a manual operated pineapple processing machine was designed, it will be used to process the harvested pineapple to juice. There will be minimal wastage of the products during transportation, since the pineapple will be processed to juice. This machine will embrace the young farmers, thus they will be able to handle the amount of pineapple lost after harvesting awaiting sale or consumption. The machine will maximize juice production, hence increased pineapple production. This will create more job opportunities in the rural setup and this will help eradicate poverty. Juice production is also a form value-addition that will increase the income of the farmers.

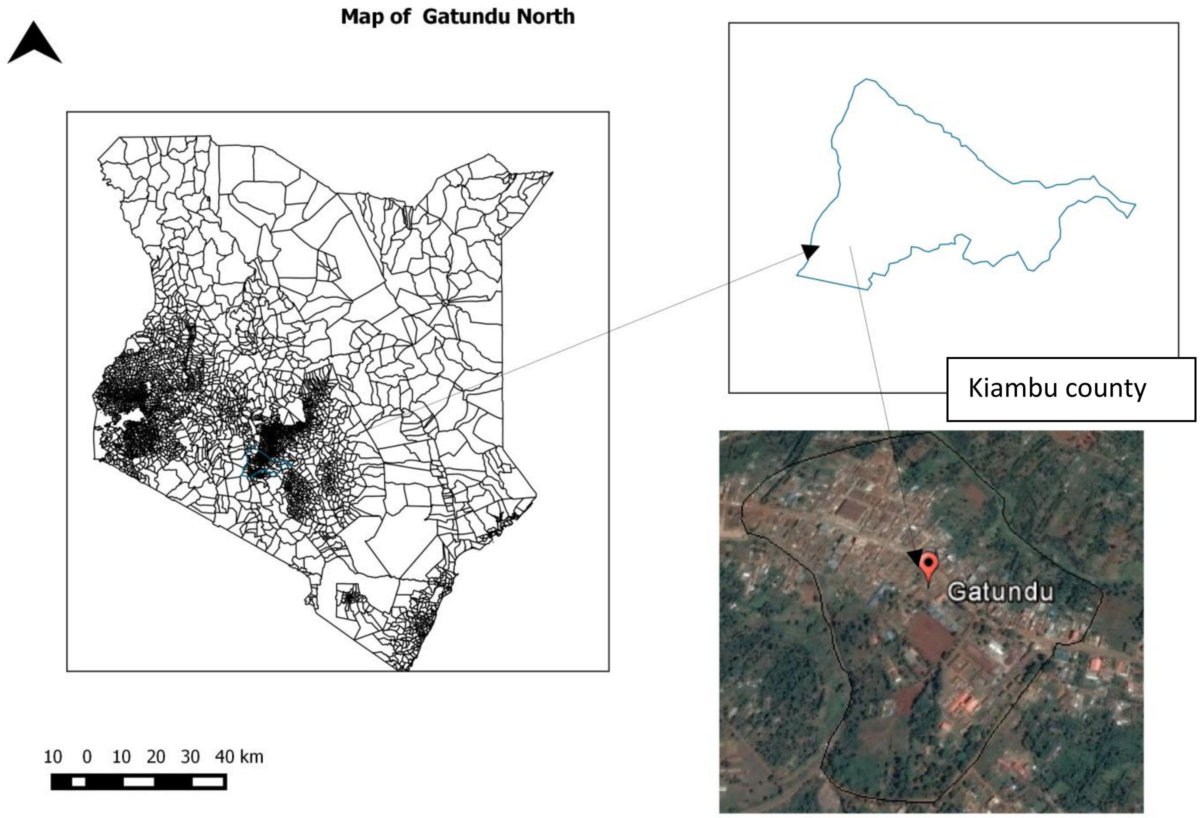
1.3. Site analysis and inventory

Kiambu County enjoys a warm climate with temperatures ranging between 12°C and 18.7°C and a rainfall aggregate of 1000mm each year. The cool climate makes it conducive for farming, June and July being the coldest months while January-March and September-October are the hottest months.

Gatundu north is a purely an agricultural area, a bigger portion of pineapple cultivation is carried out on small scale farms ranging from between one to two hectares per farmer. The expected yields are around50 – 60 dozens of pineapple per hectare, which is dependent on the size of the pineapple. A large pineapple on a local village market can be sold for 50 KSh per piece, in the regional West-Kenyan city Kisumu for 80KSh, and in Nairobi around 100KSh.

The available processing plants are mostly used for industrial purposes, which may require an electrical source of energy. Farmers may be required to travel long distances to process their fruits which might be quite expensive. Therefore, farmers ought to sell their products near their place of residence/by the road side. Some of the fruit are sold to local people for consumption which in the long run does not encourage production due to low returns.

Study area: Gatundu North constituency, Kanyoni sub – location



Kenya **Gatundu North constituency.**

Figure 1: Study area

1.4. Justification

There is need for a pineapple juice extraction machine that would significantly cater for the farmers harvest capacity and which many households can afford. This is with due consideration to the following reasons:

- Industrial pineapple juice extraction machines are too expensive to be purchased by the rural farmers.
- For most of the farmers, the cost of hiring the service of pineapple processing is high with respect to the amount of fruit output at the end of the farming season.
- Industrial processing machines require high energy inputs and pineapple input which limits most of the farmers to adopt such technology.

1.5. Overall objectives

The overall objective of project was to design a modified hand operated pineapple juice extraction machine, which will be able to produce pineapple juice for farmers to reduce pineapple fruit losses by selling them in the form of juice.

1.5.1. Specific objectives

The specific objectives of the project were;

1. Design of the screw conveyor
2. Design of the screw shaft.
3. Design of the capacity of the juice extractor.

1.6. Statement of scope

The project will encompass the design of; screw conveyor, the screw shaft, the juice extraction chamber. Since the machine will be a manually operated, its work output will depend on the operator(s) as well as on the machine itself. The operator will perform the juice extraction operation by rotating the screw shaft handle and therefore, proper handle height and shaft length will be necessary for efficient operation of the machine. Improper shaft height and shaft length will result in discomfort to the operator and difficulties in the smooth operation of the machine, thus resulting in lower work efficiency.

Chapter two

2.0. Literature review and theoretical frame work

2.1. Literature review

2.1.1. Pineapple farming

Agriculture in Kenya directly contributes 26 per cent of the Gross Domestic Product annually and another 25 per cent indirectly. The sector accounts for 65 per cent of Kenya's total exports and provides more than 70 per cent of informal employment in the rural areas. (The Agricultural Sector Development Strategy, 2010)

Therefore, the agricultural sector is not only the driver of Kenya's economy but also the means of livelihood for the majority of Kenyan people.

However, in spite of the importance of the agricultural sector, farming in Kenya has for many years been predominantly small scale, rain fed and poorly mechanized. In addition, institutional support and infrastructure have been inadequate.

Thailand, Philippines, Brazil and China are the main pineapple producers in the world, supplying early 50 % of the total output. Kenya appears in the list of other important producers. Together with India, Nigeria, Indonesia, México and Costa Rica, Kenya forms the remaining 50% of pineapple producers. (Medina, 2005)

Data of 2004 reveals that production of pineapples in Kenya, together with mangoes, avocadoes and passion fruit is characterized by an upward trend. With the data of 2004, pineapples take a sixth place in the top seven fruits in Kenya in terms of area and total production. Total pineapple growth in Kenya over the 1992-2000 year period was 60%.

Growth figures mainly relate on different technology and production systems. In Kenya, pineapple production in is entirely on plantations and is both capital and input intensive.

2.1.2. Pineapple description

Pineapple is a tropical plant with edible multi fruit consisting of coalesced berries which can grow in a temperature range of 18.3-45^{o}C. Pineapple is the second harvest of importance after bananas, contributing to over 20 % of the world production of tropical fruits.

Weight percent composition of a pineapple is: Pulp (33%), core (6 %), peel (41%) and crown (20 %). (Collins 1949,1960)

Figure 2: Pineapple fruit

They are consumed fresh, cooked, juiced and preserved. The leaves may be used to produce textile fiber employed as a component of wallpaper and furnishing. The fruit is quite perishable and will never become any riper than it was when harvested, it, if stored at room temperature it should be used within two days and if refrigerated can take 5 – 7 days.

The best way to see if a pineapple is ready is to smell it, when ripe it releases a very sweet aroma from the base. To smell this aroma, the pineapple should be at room temperature. It is recommended to choose a pineapple that feels heavy, indicating that it contains a lot of pulp and juice. It is prepared and sold on road sides as a snack, nearly 70% of the pineapple is consumed as fresh fruit in producing countries.

Figure 3: Different forms of pineapple fruit preparation

2.1.3. Pineapple processing

Bulk pineapple processing involves sorting, cleaning, peeling, slicing and coring before juice extraction, which might be quite expensive. The process of peeling is done to cut the skin and unused part from the pineapple, chopping involves cutting the fruit into pieces.

There is a series of physical properties of pineapples that play important roles during processing. Leverington (1970) described research works on the relationship between translucency and other quality characteristics. It was found that translucency is a quality attribute of the fruit. Translucent or semi-translucent slices are generally considered as desirable and associated with better flavor. A fully translucent pulp has an overripe flavor, while those not translucent are too sour. As pulp becomes more translucent air cavities decrease in size as well as in porosity. Internal color affects the appearance and acceptance of the fruit whereby yellow-gold color has been regarded as best. (SARH, 1994)

Pineapple is now consumed in the form of single strength or concentrated juice, dehydrated and/or sugared, canned in slices. Among the newer developments are dried chips, cocktail-type drinks, dried powdered, isotonic mixtures and wine; there are also new canned forms as whole fruit, bars, flakes and cubes.

2.2.Pineapple lost after harvesting

Factors that contribute to pineapple losses include;

- Inadequate harvesting, packaging and handling skills.
- Lack of adequate containers for the transport and handling of perishables.
- Inadequate refrigerated storage.
- Inadequate drying equipment or poor drying season.
- Traditional processing and marketing systems.
- Lack of knowledge used for management during marketing and storage.

The major environmental influences on the keeping quality of pineapple are the following (Watada,1986):

Temperature

The higher the temperature the shorter the storage life and the greater the amount of lose within a given time.

Humidity

There is movement of water vapor between the fruit and its surrounding atmosphere in the direction towards equilibrium water activity in the food and the atmosphere. When moist the fruit will give up moisture to the air and while dry it will absorb moisture from the air. Fresh pineapples have high moisture content and need to be stored under conditions of high relative humidity in order to prevent moisture loss and wilting.

Solar radiation

The solar radiation that falls upon the fruit held in direct sunlight increases the temperature above the ambient temperature. The amount of increase in temperature depends on the intensity of the radiation, the size and shape of the fruit and the duration of exposure to the direct rays of the sun. The intensity of solar radiation depends upon latitude, altitude, season of the year, time of day, and degree of cloud cover.

Altitude

Within given latitude the prevailing temperature is dependent upon the elevation when other factors are equal. There is on the average a drop in temperature of 6.5°C for each Km increase in elevation above sea level. Storing fruits at high altitudes will therefore tend to increase the storage life and decrease the losses in food provided it is kept out of the direct rays of the sun.

Atmosphere

The normal atmosphere contains by volume, approximately 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon IV oxide, various amounts of water vapor and traces of inert gases. Modifying the atmosphere can improve the shelf life and reduce wastage. One type of controlled atmosphere storage (CA) is refrigerated storage in which the level of oxygen is reduced to about 3% with the carbon dioxide content being raised to 1 to 5%, depending on the commodity. This CA storage may double the storage life over that of regular cold storage by slowing down the natural rate of respiration. Many fruits generate ethylene gas during ripening and the presence of this gas accelerates the rate of ripening. If the ethylene is removed from the atmosphere surrounding these fruits as it is generated, their storage life may be extended.

Experiments have shown that placing such fruits in a fairly gas-tight container with potassium permanganate, which absorbs ethylene gas, can substantially extend the storage life even at ambient temperature.

"Modified atmosphere storage" is another type of controlled atmosphere storage, which entails storage of horticultural products in a beneficial atmosphere. Modified atmosphere storage can be obtained in boxes, polyethylene film which acts as a barrier to the escape of carbon dioxide and the ingress of oxygen. Another method of obtaining a modified atmosphere storage is by the addition of dry ice which increases the carbon dioxide in the atmosphere.

Time

The longer the time of storage, the greater is the deterioration in quality and the greater the chance of damage and loss. Storage time is a critical factor in loss of fruits, especially those that have a short natural shelf life.

2.3.The major technologies for reducing losses

2.3.1. Gentle handling

Gentle handling should be practiced to minimize bruising and breaking of the skin. Pineapples are very sensitive to impact and exhibit high pressure-sensitivity. If stored on its side, the fruit, each item of which weighs approximately 1 - 1.8 kg, rapidly bruises, leading ultimately to rot, i.e. it forms "pressure sores". For this reason, the cargo is only transported upright, in special cartons or boxes.

Because of its impact- and pressure-sensitivity, the fruit has to be handled with appropriate care. The required temperature must always be maintained, the fruit must be protected from moisture to reduce the risk of premature spoilage.

2.3.2. Temperature control/ Refrigeration

Cooling the produce extends storage life by reducing the rate of physiological change and retarding the growth of spoilage fungi and bacteria. Cooling is the foundation of quality protection.

Figure 4: refrigeration

There are several ways of reducing the storage temperature (Watada 1986);

Table 1:ways of reducing the storage temperature

Cooling technique	Environmental effect
a) Keep out of direct rays of sun.	This is an easy low-cost method with minimal effect on the environment. Almost all societies can provide shade at low economic or environmental cost.

b) Use natural cooling, e.g., harvest during the cool early morning hours, open stores for ventilation during the cool of the night, utilize the cool temperature of high altitude or a natural source of cold water when available.	Minimal environmental costs.
c) Evaporative cooling obtained by drawing dry air over a moist surface.	Minimal environmental and economic costs. Restricted to areas of low humidity and low-cost water.
d) Mechanical refrigeration.	Energy costs and economic costs are relatively high but give most positive control of temperature. Generated heat is dumped into the environment.
e) Cool promptly after harvest.	High energy cost.

Table 2: Optimum storage conditions for fresh fruits and vegetables

Optimum Storage Temperature	Commodity
0-5 C (Cold Storage)	Apple, Apricots, Artichokes, Asparagus, Beans, Beets, Broccoli, Brussels, Sprouts, Cabbage, Cantaloupes, Carrots, Cauliflower, Celery, Cherries, Collards, Corn, Dates, Figs, Grapes, Kiwifruits (ripe), Pears (ripe), Peas, Plums, Radishes, Rhubarb, Spinach, Strawberries, Turnips.
5-10 C (Cool Storage)	Avocados (ripe), Beans, Blueberries, Cucumbers, Eggplant, Melons (ripe), Okra, Peppers, Pineapple (ripe), Squash (summer), Tangerines.
10-18 C	Bananas, Coconuts, Grapefruit, Lemons, Limes, Mangoes, Melons (unripe), Nuts, Papayas, Pears (unripe), Pumpkins, Squash

(Slightly Cool Storage)	(winter), Sweet Potatoes, Tomatoes.
18-25 C (Room Temperature Storage)	Avocados (unripe), Nectarines (unripe), Onion (dry), Peaches (unripe), Potatoes, Watermelons.

2.3.3. Juice Extraction

Fruit juice extraction involves the process of crushing, squeezing and pressing to obtain juice and reduce the bulkiness of the fruit to liquid and pulp. There are two types of extractions;

i) The fruits are crushed and pressed continuously in one operation.

ii) The fruits are crushed or cut into small pieces and these are subsequently pressed in a suitable press.

Broadly, there are four types of equipment employed for the extraction of fruit juices.

Halving and Burring Machines

Malta orange, grape-fruit, lemon are cut by a special machine in which the fruit is placed in a conical cup in a wheel which brings the fruit against a stationery or revolving knife. The fruit is cut into two halves, which drop into a receptacle placed below. The burrs (or roses) are made of stainless steel, aluminium, nickel, or non-odorous hard wood. They are conical in shape and are ribbed driven by a motor. The cut halved fruit is held against the revolving burr and the reamed juice is collected in a vessel kept below. There are generally two burrs, one each one either side of the shaft. Several single burrs can also be fitted in series. By regulating the speed of the burr and the pressure on the fruit held against it, any excessive tearing of the tissues can be avoided.

Continuous Screw Expeller Press

These presses are similar in principle to the familiar household meat mincer. The segments of the fruit are fed through a hopper at one end of a feeding screw, revolving inside a conical jacket, which is perforated. The diameter of the perforations depends upon the type of fruit. The juice flows out through the perforations and the pomace comes out at the end of the conical jacket. The flow of pomace, and hence the pressing pressure of the screw, can be adjusted to some extent by means of movable disc at the conical end of the perforated jacket. Small power driven screw type extractor (1/2 to 1 HP) has now been introduced.

Figure 5: Continuous screw expeller press

The juice extracted is generally thick and cloudy and contains a considerable amount of macerated pulp. The juice should be passed through sieves to remove the pulp to the desired extent. Screw-type juice extractors are useful in case of tomatoes, grapes, etc.

In the case of pineapple, however, the pieces of fruits are first crushed in a screw type crusher and then from the crushed material the juice is separated effectively in a centrifuge widely employed in the sugar and chemical industries. This technique has recently been found highly effective in pineapple juice production.

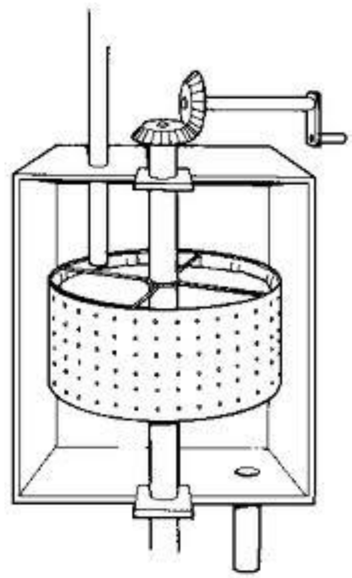


Figure 6: Centrifuge

Plunger-Type Press

The halved citrus fruit is held on an inverted cup in which it is pressed by an automatic adjustment against a metallic cone fitting into the cup. The clearance between the cup and the cone is slightly greater than the usual thickness of the peel of the fruit so that very little of the peel oil or emulsion is pressed out.

Figure 7: Plunger-type press

Roller-Type Press

Roller presses made of hard granite or wood, are specially designed to extract juice from sour limes. The whole lime fed through the rollers. These presses are in extensive use in West Indies and Jamaica. They have been introduced in some of the Indian factories also.

Figure 8: Roller type press (cane juice)

Crusher for Grapes, Berries

A grape crusher consists to two fluted or grooved rollers made of wood or metal. These are arranged horizontally and revolve towards each. The clearance between the two is adjustable. The fruit which is fed to the hopper at the top falls between the rollers and gets crushed. Strawberries and some other berry fruits which contain gum are first heated and then crushed. Tomatoes can also be crushed in these crushers.

Pressing

Two types of presses are used for pressing the juice from the crushed fruit. They are;

i. The basket press.

Basket presses which are of various designs and capacities are worked manually by hydraulic pressure. The manually operated press consists of a strong cylindrical basket made of wooden salts. It rests on a wooden or metallic base. There is a strong screw at the top of the frame. The crushed fruit is folded in a piece of strong cloth and placed inside the basket.

By turning the screw by hand or with a hydraulic pump the juice is pressed out. It flows out through the salts in the basket into the bottom tray from which it is channeled into a collecting vessel. The basket press has been found useful in the case of apple, grape, pomegranate etc.

Figure 9: Basket press

ii. The rack and cloth press.

In this type of press, the crushed fruit is spread as a layer in a coarse woven cloth of cotton or nylon and folded into a square suited to the size of the platform of the press. Several such layers are arranged alternately between racks built of wooden salts.

The built-up layers are subjected to hydraulic pressure by means of a pump. The juice is pressed out gradually due to increasing pressure in the pile. The released juice is collected at the base of the pile. Various types of these presses, which are in use in several countries, are claimed to give higher yields of clear juice than the basket type presses. In California, however, basket presses are preferred for extraction of juice from grapes. Rack and cloth presses are in use in a few factories in India specializing in the production of apple juice.

Figure 10: Rack and clothe press

Other Types of Extractors

Special devices for extracting juice have been designed in the U.S.A., Australia, etc., for fruits like pomegranate, passion fruit, etc. At the Quetta Fruit Preservation Laboratory, a manually working basket press has been successfully employed for the extraction of juice from whole pomegranates.

Poore has described a special pulper for passion fruit in which the juice is extracted by reaming the halved fruit. A continuously operating device has been employed in Australia to extract the pulpy juice along with the seeds from passion fruit.

Freshly extracted and screened juices contain appreciable quantity of oxygen which should be removed before packing. The special equipment used for the purpose is called a de-aerator. The de-aerated juice is subsequently heated in a flash-pasteurization equipment.

2.4.Machine design

The extraction part will have a hopper, extraction chamber, juice outlet and a stand. The cylindrical drum houses a uniform diameter screw conveyor to enhance juice extraction. The conveyor presses the pineapple against the drum to enhance juice extraction and juice flow.

The main component of the extraction chamber will be made of stainless steel used to handle food products. The juice extraction part will use a screw conveyor installed in a cylinder perforated at the base, this will ensure most of the juice is obtained out of the pulp.

Initially there have been so many sophisticated machines developed by other countries. These machines have locked out the small scale farmer, for they are quite expensive to install and require a large amount of input.

2.5.Theoretical Frame work

The design of the modified pineapple juice extraction machine will be done from locally available material to enable juice production.

There are engineering design factors that may affect the design of the machine; the design of the screw shaft, designing the efficient mechanism to be used to rotate the screw shaft and determining the capacity of the screw conveyor.

2.5.1. Design of screw conveyor

The screw conveyor is the main component and most functional unit of the extraction chamber. Using P_s as 0.1m, N 50rpm, D 0.1m, d 0.05m, therefore inlet velocity V is 0.016m/s. The screw will be designed using the expression in the equation below as:

Equation 1: Screw pitch

$$P_s = \frac{4VDL}{\frac{\pi}{4}D^2 - d^2 N}$$

Equation 1

Where;

$P_s =$ is the screw pitch,

V is the inlet velocity of raw material,

D is the outside diameter of screw,

d is the inside diameter of screw,

L is the length of the screw shaft, and N is the shaft speed.

Therefore, left at both ends of the screw shaft for the fittings of the bearing at both ends was determined thus:

Equation 2: Clearance at both ends

$C = \frac{1}{2} L - P_L$ **Equation 2: Clearance at both ends**

C – Clearance at both ends

P_L – Pitch length

2.5.2. Design of screw shaft

In operation, the screw shaft is meant to convey, press and squeeze the chopped pineapple pieces for juice extraction. To safeguard against bending, the diameter of the shaft is determined from the equation given by Khurmi and Gupta (2008) as:

Equation 3: Diameter of screw shaft

$d_s^3 = (\frac{16}{\pi S_S} (Kb\ Mb)2 + (Kt\ Mt)2)^{\frac{1}{2}}$ **Equation 3: Diameter of screw shaft**

Where;

d_s is diameter of the screw shaft, S_s is maximum shear stress, K_b is combined shock and fatigue factor for bending, K_t is combined shock and fatigue factor for torsion, M_b is bending moment of the shaft and Mt is torsional moment of the shaft.

Taking Ss = 40 x 10^6 N/m^2, K_b= 1.5, K_t = 1.0, M_b= 21.10 Nm, M_t = 69.18Nm and π = 3.142; hence, d_s = 0.021 m. Therefore, the diameter of the screw should be of stainless steel not less than 21 mm.

2.5.3. Design of the capacity of the juice extractor

The processing capacity of the pineapple juice extractor will be taken as the capacity of the screw conveyor which is the main functional unit of the extraction chamber of the extractor. It will be determined from the equation given below as:

Equation 4: Processing capacity

$Q = 3600 \text{ X } S \text{ X } V \text{ X } \gamma \text{ X } K$ **Equation 4: processing capacity**

Where;

S – Conveyor housing field area

V – Travelling speed of the conveyor

γ - Material density

K – Material decrement coefficient

Travelling speed, V (m/s) = $\frac{t\,.n}{60}$

Conveyor housing field area, S (m^2) = $\frac{\lambda \pi D^2}{4}$

Chapter three

3.0. Design Methodology

The methods used in this design are in phases; desk study, field study and finally communication of results.

3.1. Desk study

Data will be collected from relevant books, the internet, inquiries from the lecturers/supervisors and technicians.

3.2. Field study

Data will be collected from rural pineapple farmers in the site under study. In a 2 hectares land, the farmer can harvest around 50- 60 bags of pineapples. Whereby, a bag can hold between 12 to 24 pineapples depending on the size of the fruit.

About 25% of the harvested pineapple are lost will being transported to the market due to poor handling methods. Pineapples are exposed to sun's heat while being sold in the open air market; this contributes to its decay due to increased microbial activity.

Pineapples are mostly harvested when they are ripe, when stored in a good environment can have a shelf life of around two weeks.

In the peak harvesting period (April and August), the farmers may end up losing more pineapple due to increased produce. They may be forced to sell their produce at very low prices to be able to minimize losses after harvesting.

3.3. Design of a modified hand operated pineapple juice extraction machine.

3.3.1. Design considerations

The parameters considered in the design of the machine include;

- Overall height of the machine to facilitate ease of operation
- Overall width and breadth of the machine for the purpose of the machines efficiency.

3.3.2. Working principle of the machine design

This machine will extract juice from the pineapple whereby the chopped fruit will be crushed and pressed continuously. The machine is to be operated by applying force to rotate the crank handle.

The motion of the handle will facilitate the rotation of the screw shaft, which will squeeze the chopped pineapples against the perforated cylindrical drum to extract juice.

The juice will be collected at the bottom while the pomace will be discharged at the extreme end.

3.3.3. Design specifications

The design of this juice extraction machine is based on design specifications whose choices are based on;

- Availability of construction materials for fabrication
- Cost of materials
- Desired machine size
- Machinability (installation)
- Durability
- Prolonged life of the machine

Overall machine dimensions 1000mm X 600mm X 200 mm

Screw shaft 800 mm in length and 50 mm in diameter

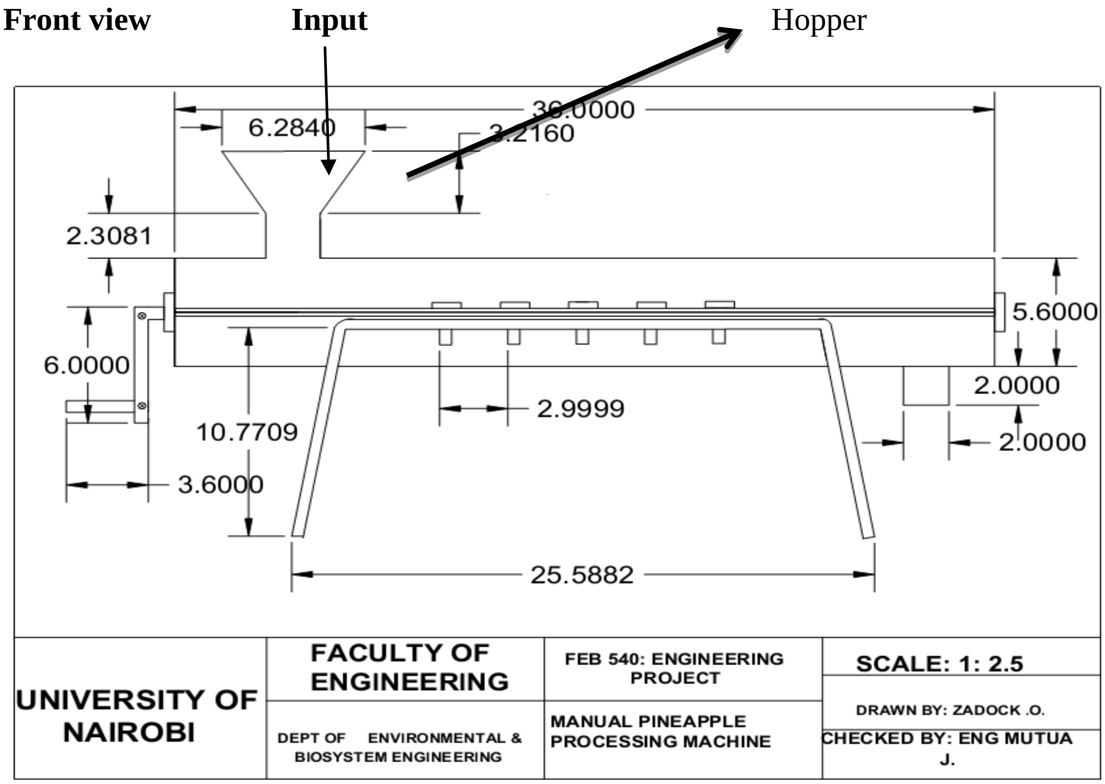
Hopper of overall height 150 mm, inlet allowance 200 mm X 200 mm

Handle of length 100 mm and height 150 mm

Steel bars $1\frac{1''}{2}$ by $1\frac{1''}{2}$ and 2mm thick

3.3.4. Design diagram

Front view



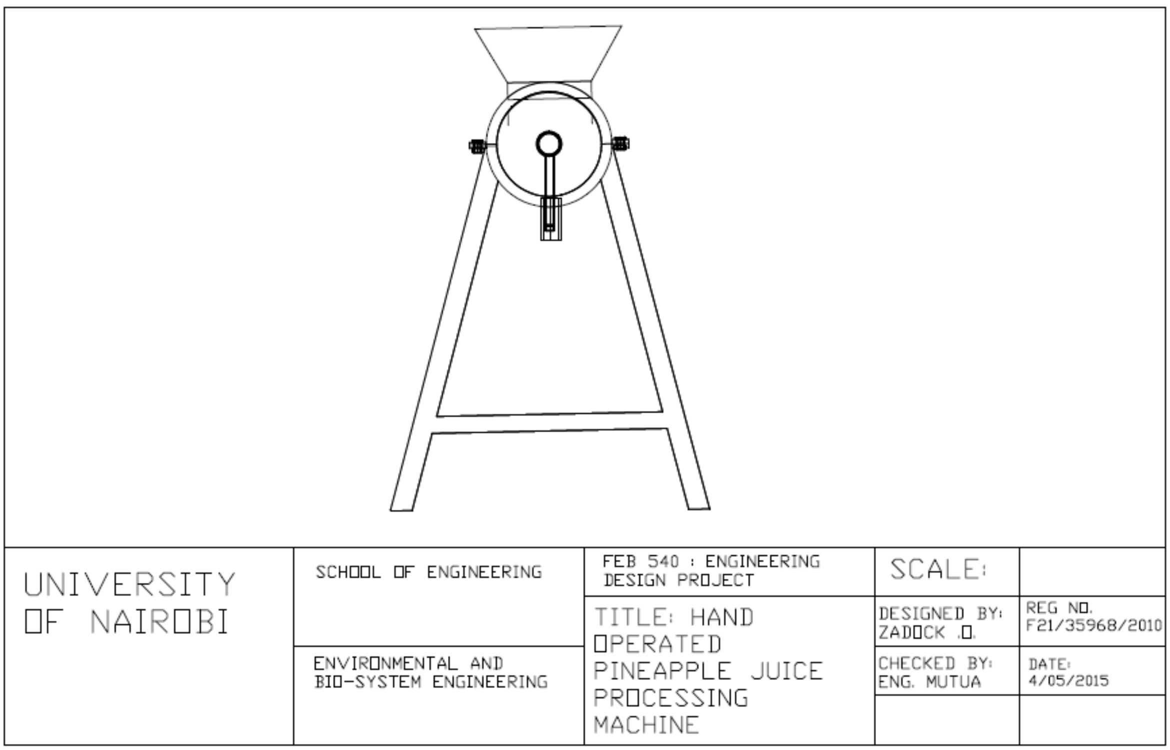
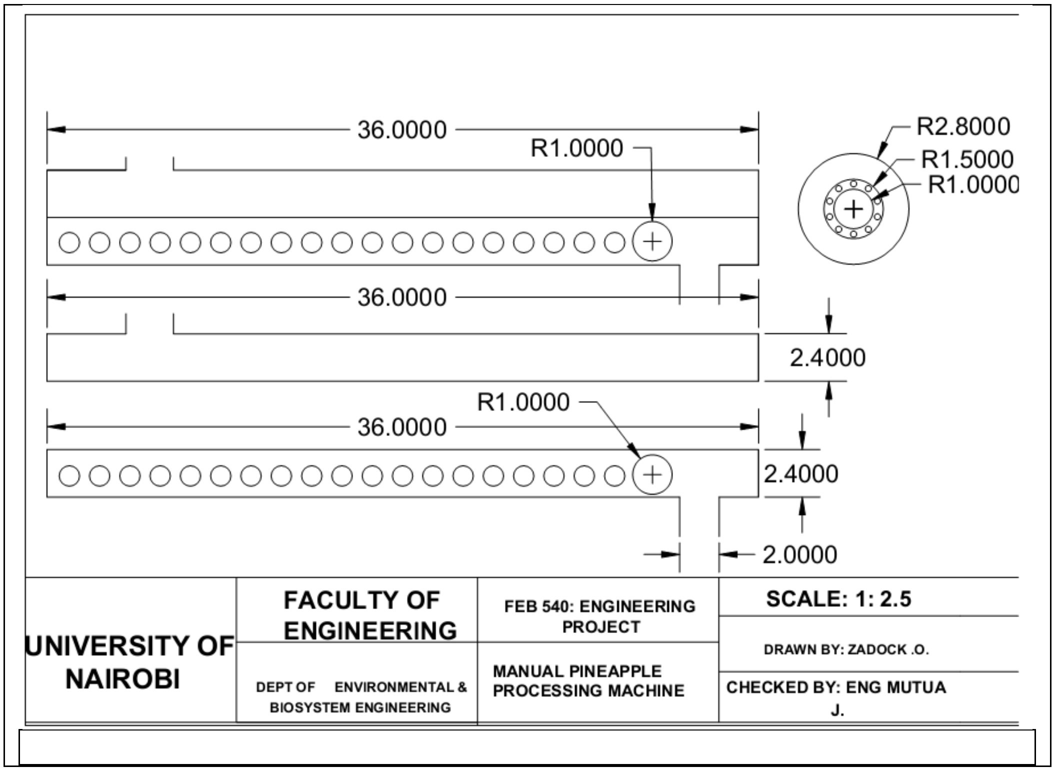
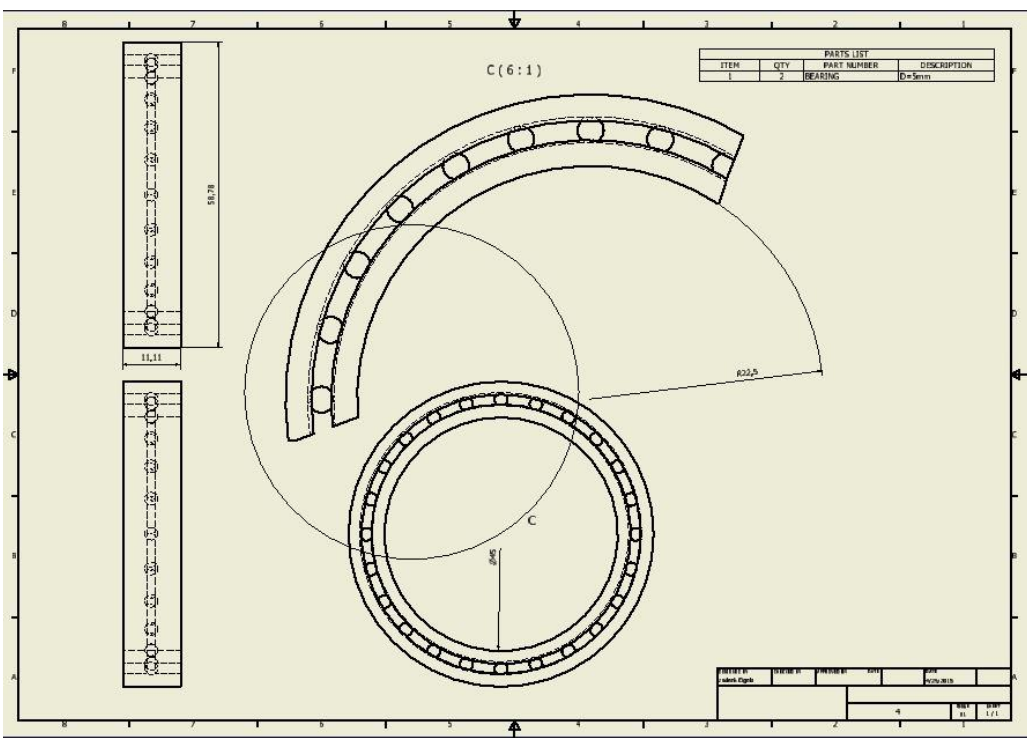


Figure 11: Machine design

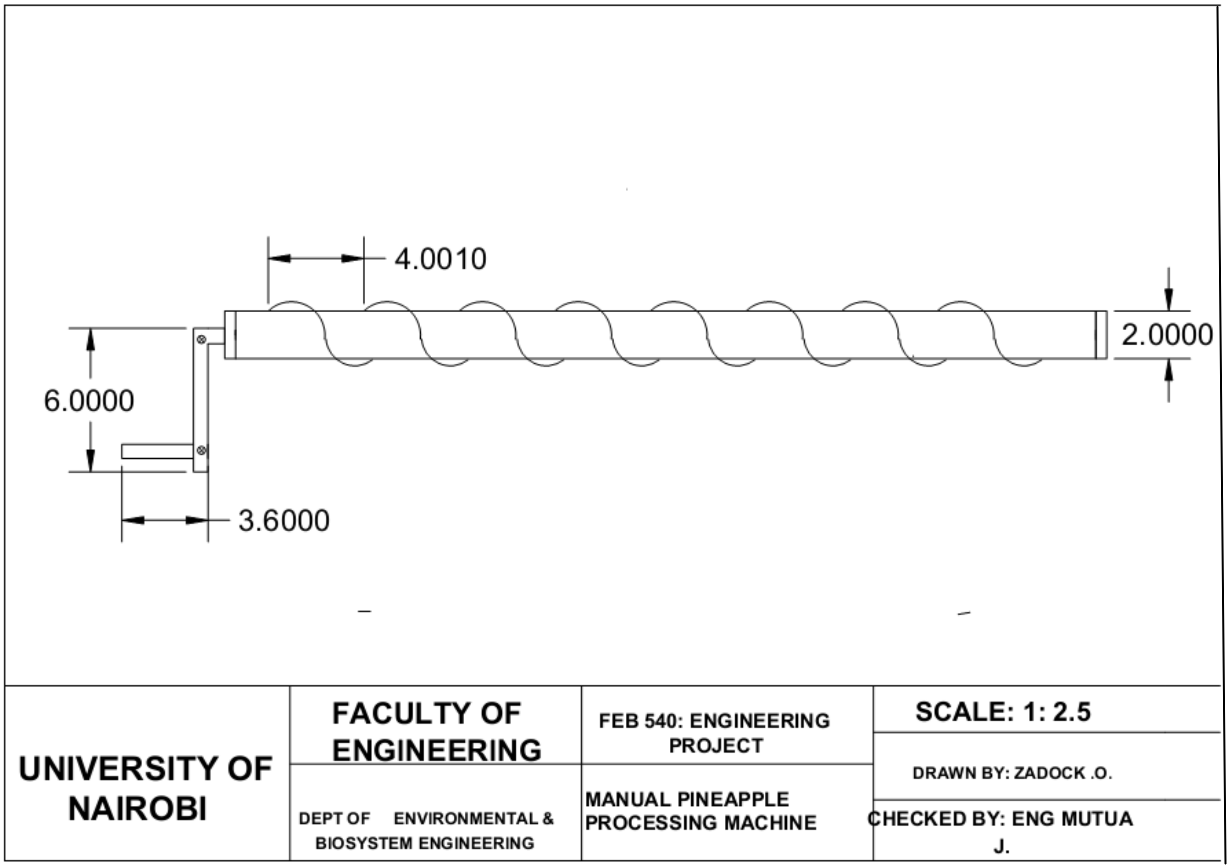
3.3.5. Components of the design



Perforated cylinder



Bearing



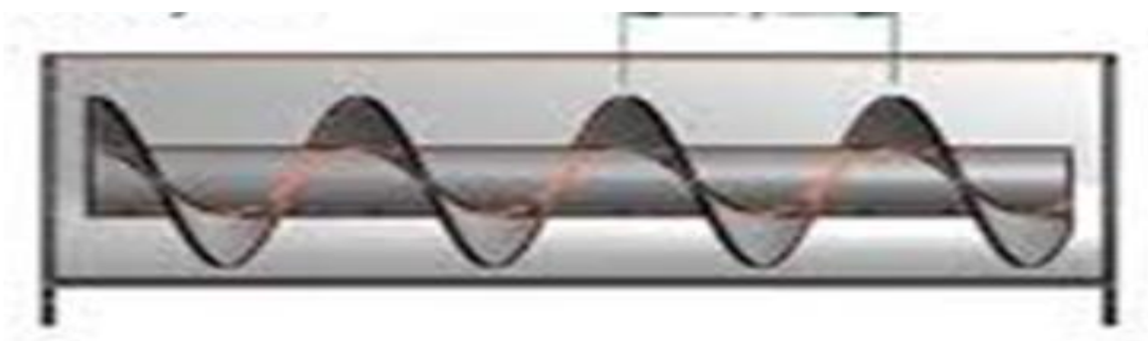


Figure 12: Components of the design

3.4. Design analysis

3.4.1. Housing design

Conveyor housing field area (m^2) = S = $\frac{\lambda \pi D^2}{4}$

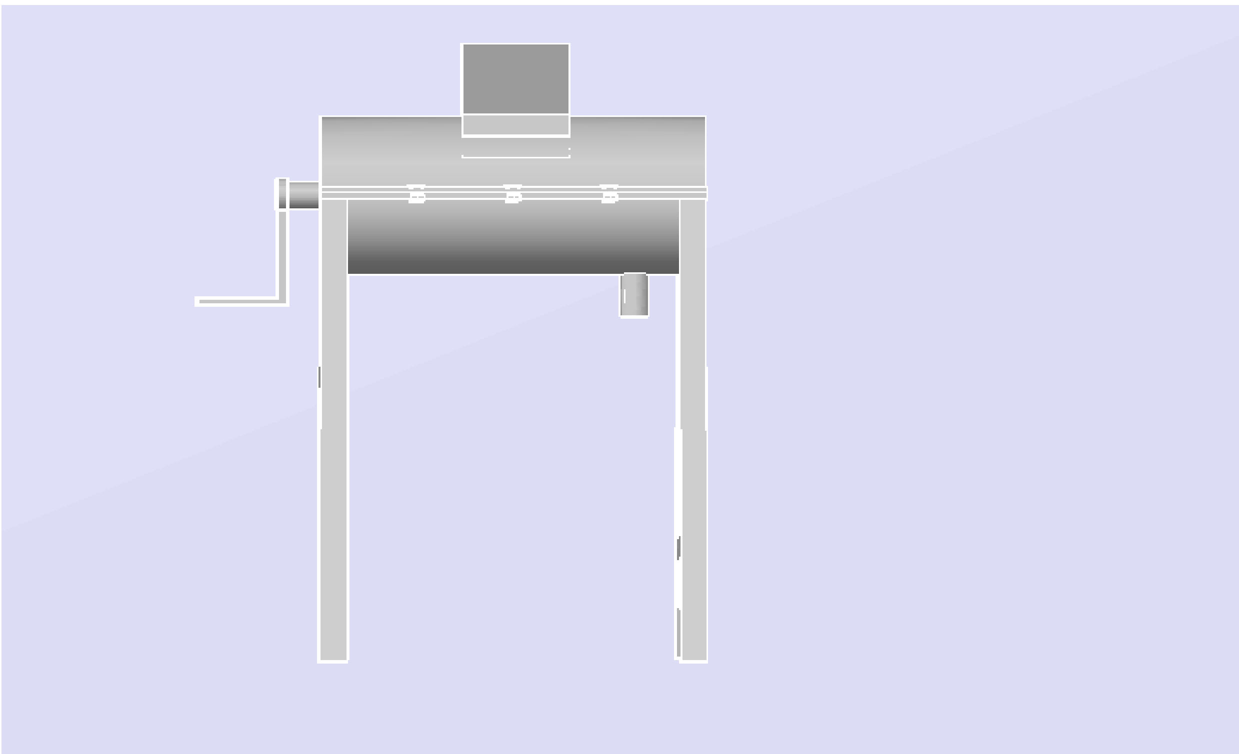


Figure 13: Housing design

3.4.2. Hopper design

The hopper is designed to be fed in a vertical position only. The material to be used for the construction is mild steel sheet metal, which is readily available in the market at affordable costs.

The hopper has the shape of a frustum of a pyramid truncated at the top, with top and bottom having rectangular forms. This is illustrated below;

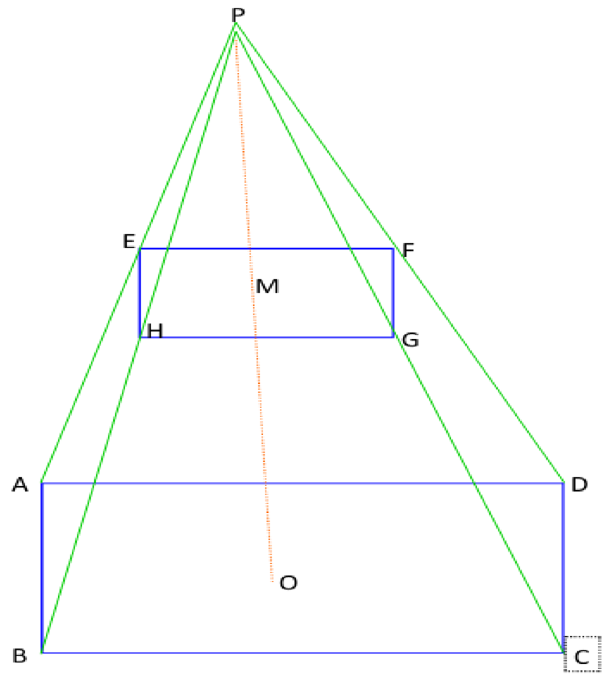


Figure 14: Hopper design

From the principle of similar triangles, for triangles PMG and POC with M and O being the Centers of EFGH and ABCD respectively:

PM/MG = PO/OC, or PM = PO x MG/OC.

The volume of the hopper is given by:

V_{hopper}= [(Area of Base) x height]/3

= [(AB x BC) x h – (EH x HG) x x]/3,

Where,

h- Overall height

x – Height of the truncated top

3.4.3. The main frame

The main frame supports the entire weight of the machine, that is;

- Weight of hopper and casing
- Weight of screw shaft and handle
- Bearings, Nuts and bolts

The two design factors considered in determining the material required for the frame are weight and strength. In this design work, angle steel bar of 1.5 ” by 1.5 ” and 2mm thickness is to be used.

3.3.4. Shaft design

A shaft is a rotating or stationary member, usually of circular cross-section having such elements as gears, pulleys, flywheels, cranks, sprockets and other power transmission elements mounted on it Shigley (1986).

The design in this paper comprises a screw shaft joined to a crank handle at the end. The shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions.

For this design a shaft of diameter 50mm and length 800mm shall best serve the interests of achieving the overall machine width and also lower the costs of materials that would be required if the machine is to be constructed.

3.3.5. Bearing selection

Bearing must be selected based on its load carrying capacity, life expectancy and reliability (PSG Tech 1989). The relationship between the basic rating life, the basic dynamic rating and the bearing load is:

C = [L/L10]1/KP, or C/P = [L/L10]1/K

[C/P]K = L/L10, or L10 = [C/P]K/L.

But L = 60n/106 million revolutions, therefore, L10 = (106/60n) x [C/P] K,

Where:

L10 = life of bearing for 90% survival at one million revolutions;

L = required life of bearing in million revolutions (mr);

n = rotational speed (rev/min);

C = basic dynamic load rating (N);

P = equivalent dynamic bearing load (N);

K = exponent for life equation with:

K = 3 for ball bearing;

K = 10/3 for roller bearing.

Also, P = radial load + axial load,

P = (XFr + YFa),

Where:

X = radial load factor for the bearing;

Y = axial load factor for the bearing;

Fr = actual radial bearing load (N);

Fa = actual axial bearing load (N).

The table below shows the recommended life value in operation.

Table 3: Recommended life value of bearings

Type of operation	Life in operation
Infrequently operated	500
Brief operation only	4,000-8,000
Intermittent operation	8,000-15,000
One shift operation	15,000-30,000
Continuous operation	30,000-60,000
Continuous operation with high production capacity	100,000

Chapter four

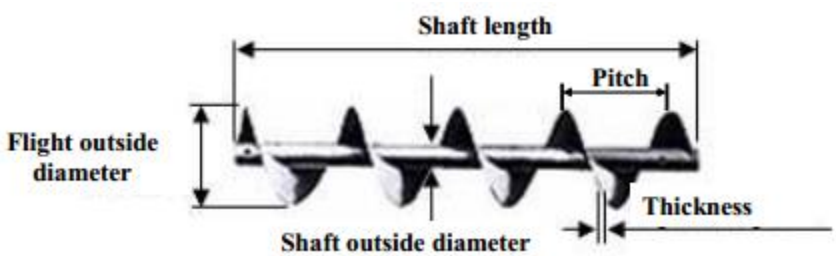
4.0. Design calculations, Results and Discussion

4.1. Design Calculations

4.1.1. Design of the screw conveyor

The screw conveyor is the main component and most functional unit of the extraction chamber. The screw will be designed using the expression in the equation below as:

$$P_s = \frac{4VDL}{\frac{\pi}{4}D^2 - d^2 N}$$



Where;

P_{s} = is the screw pitch,

V is the inlet velocity of raw material,

D is the outside diameter of screw,

d is the inside diameter of screw,

L is the length of the screw shaft, and N is the shaft speed.

Using inlet velocity, V of 0.0818 m/s, N 50rpm, D 0.1m, d 0.05m

$$P_s = \frac{4 \text{ X } 0.0818 \text{ X } 0.1 \text{ X } 0.9}{\frac{\pi}{4}(0.1^2 - 0.55^2)50}$$

Therefore, Screw pitch, P_s = 0.1m = 100 mm

Therefore, left at both ends of the screw shaft for the fittings of the bearing at both ends was determined thus:

$C = \frac{1}{2} L - P_L$

C – Clearance at both ends

P_L – Pitch length = 0.8 m = 800 mm

L – Shaft length = 0.9 m = 900 mm

$C = \frac{1}{2}(0.9–0.8) = 0.05$ m = 50 mm

A clearance of 50 mm will be left at both ends for fitting the bearings.

4.1.2. Design of screw shaft

The screw shaft is meant to convey, press and squeeze the chopped pineapple pieces for juice extraction. To safeguard against bending, the diameter of the shaft is determined from the equation given by Khurmi and Gupta (2008) as:

$$d_s^3 = \left(\frac{16}{\pi S_S} (\text{Kb Mb})2 + (\text{Kt Mt})2 \right)^{\frac{1}{2}}$$

Where;

d_s is diameter of the screw shaft, S_s is maximum shear stress, K_b is combined shock and fatigue factor for bending, K_t is combined shock and fatigue factor for torsion, M_b is bending moment of the shaft and Mt is torsional moment of the shaft.

Taking $S_s = 40 \times 10^6$ N/m^2, K_b= 1.5, K_t = 1.0, M_b= 21.10 Nm, M_t = 69.18Nm and π = 3.142;

$$d_s^{\,3} = \left(\frac{16}{\pi\, X 40 X\, 10^{-6}}\left((1.5\, X\, 21.10)^2 + (1.0\, X\, 69.18)^2\right)^{\frac{1}{2}}\right.$$

d_s= 0.021 m = 21 mm

Hence, d_s = 0.021 m. Therefore, the diameter of the screw should be of stainless steel not less than 21 mm.

4.1.3. Design of the capacity of the juice extractor

It will be determined from the equation given below as:

Q = 3600 X S X V X γ X K

Where;

S – Conveyor housing field area

V – Travelling speed of the conveyor

γ - Material density

K – Material decrement coefficient

Travelling speed, V (m/s) = $\frac{t\,.n}{60}$

V (m/s) = $\frac{0.1\, X\, 50}{60}$ = 0.083 m/s

Conveyor housing field area, S (m^2) = $\frac{\lambda\pi D^2}{4}$

S (m^2) = $\frac{0.32\, X\, \pi\, 0.1^2}{4}$ = 2.5133 m^2

Type of load	λ
Heavy and abrasive	0,125
Heavy and a little abrasive	0,25
Light and a little abrasive	0,32
Light not abrasive	0,4

Therefore;

Q = 3600 X 2.5133 X 10^{-3} X 0.083 X 650 X 1

= 488 kg/hr.

But, the bulk density of pineapple is 0.65 kg/l

Processing capacity = 488/0.65 = 750 liters/hr.

Hopper Volume = $\frac{0.2^2\ X\ 0.15}{3}$ = 2 X 10^{-3} m^3 = 2 liters

Pineapple bulk density = 650 kg/m^3

Mass of feed, m = 650 * 2 X 10^{-3} = 1.3 kg

Assume 10 minute operation

Extraction capacity (kg/hr.) = $\frac{Weight\ of\ juice\ extracted}{Time\ spent\ for\ extraction}$

Extraction capacity = $\frac{1.3\ X\ 60}{10}$ = 7.8 kg/hr

But, Pineapple bulk density = 650 kg/m^3

Extraction capacity (liters/hr.) = 7.8 * 1000/650 = 12liters/hr.

4.2. Discussion

4.2.1. Discussion of the results

The work output of the machine will depend on the machine as well as the operator. The operator will rotate the crank handle after feeding the chopped pineapple in the hopper.

Proper crank height and length is necessary for efficient operation of the machine. Improper length will result in discomfort to the operator during examination process, which would result in lower work efficiency. Thus the design is based on the specified parameters 100mm and 150mm for length and height respectively.

A crank handle speed of 50 rpm generates 750liters/ hr, volumetric capacity of 488 kg/hr.

After juice extraction, sometime can be used to chop the available fruit for processing. Rest would be necessary, to adjust arm work in accordance to Aminoffetcel. (1998).

4.2.1. Effectiveness of the Project's Machine Design

Based on the major technologies/ methods of reducing fruit losses after harvesting;

Gentle handling is practiced to minimize bruising and breaking of the skin during transportation from the farm to the market/store.

Temperature control increases the shelf life, thus protecting the quality of the fruit, the higher the temperature the shorter the storage life. Keeping the pineapple out of direct rays of the sun is quite cheap and easy to implement. Natural cooling can be useful; harvesting during the cool early morning hours, open stores for ventilation during the cool of the night. This technique is based on the surrounding climatic conditions, when the temperatures are high it may not be effective.

Evaporative cooling involves drawing dry air over the pineapple. The will be movement of water vapor between the fruit and the surrounding atmosphere in the direction towards equilibrium. The moist fruit will give up moisture to the air, while dry it will absorb moisture from the air. Fresh pineapples have high moisture content and need to be stored under conditions of relative humidity to prevent moisture loss and wilting. This might be quite a challenge for the fruit has to be stored in a controlled environment which requires costly investment in stores.

Refrigeration is the most appropriate method for it assures long shelf life and preservation of the fruit quality. It is quite expensive to acquire and maintain the refrigerator, thus locking out the small scale farmer.

Juice extraction involves crushing, squeezing and pressing the fruit to obtain juice and reduce the bulkiness of the pineapple to liquid pulp. This technique is effective for it can be carried out under all climatic conditions, the only cost incurred will be to purchase/ fabricate the machine and the other variable cost (maintenance cost) will be dealt with as the business grows. From this design, the machine will be economically viable for fabrication will be from locally available material. The simplicity in operation and fabrication it will be technically feasible and socially acceptable. Also, from the design the machine it can the used to extract juice from other fruit like mangoes, grapes etc. The perforated cylinder will have to be changed to be able to handle other fruits, the perforations have to be of different diameters based on the size of the fruit.

4.2.1.1. Bill of Engineering Measurement and Evaluation

The following table presents a BEME for the list of material of this project modification and possible construction or fabrication of this design's hand operated Pineapple juice extraction machine.

S/N	Item	Description	Unit	Cost (KES)
1.	Sheet metal	1mm thickness, standard size	1	1200
2.	Bolts and nuts	M 13	6 pieces	120
3.	Shaft solid	Mild steel (D,50 mm, L, 800mm)	1 piece	1500
4.	Handle	With sleeve	1 piece	500
5.	Bearing	D, 50mm	2 pieces	600
6.	Stainless steel mesh	1.0 mm thickness	1 piece	1000
7.	Stainless steel sheet	1 mm thickness, standard size	1	1500
8.	Stainless steel plate	2 mm thickness, standard size	1	2000
9.	Mild steel angle iron	50 x 50mm, standard length	1	3000
10.	Welding electrode	Gauges 12 stainless steel	4 dozens	1070
11.	Welding electrode	Gauge 10 stainless steel	2 dozens	535
12.	Welding electrode	Gauge 12 mild steel	8 dozens	1600
13.	Cutting disc	Φ 200 mm	1	100
14.	Grinding disc	Φ 200 mm	1	100
15.	Labour			4000
16.	Contingencies			1500
	Total			20325

Chapter five

5.0. Conclusion and Recommendations

5.1. Conclusion

This machine has been designed to be fabricated with the use of locally available materials.

The machine is simple and allows for its comfortable use in a standing posture for it can easily be operated by either male or female. This is justified by an overall height 1.25 m of the machine design as well as the low energy requirement.

The machine can help reduce pineapple lost after harvesting, thus enhance the handling methods. The energy requirements depend on the amount of feed in the machine.

5.2. Recommendation

- Fabrication and construction of the machine from the design presented in this paper.
- Testing of the machine for its performance and efficiency at 50rpm handle cranking to compare the expected results and the achievable outcome.
- Incorporation of cleaning and separation device for the removal of unwanted material.

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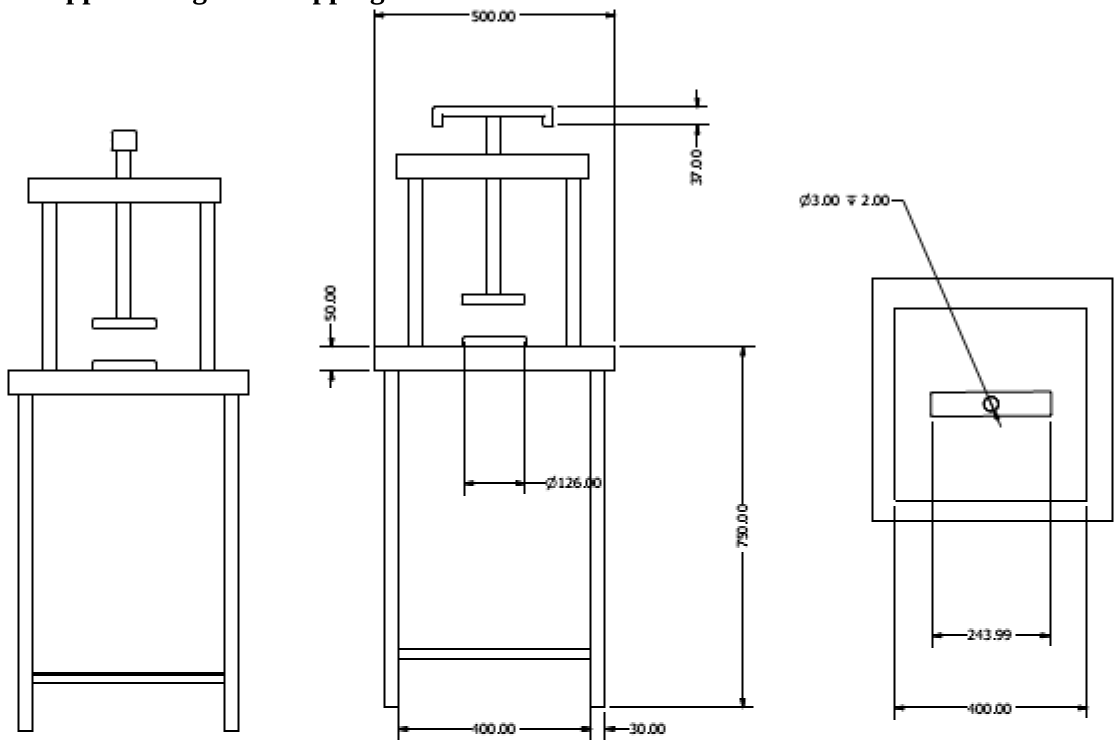
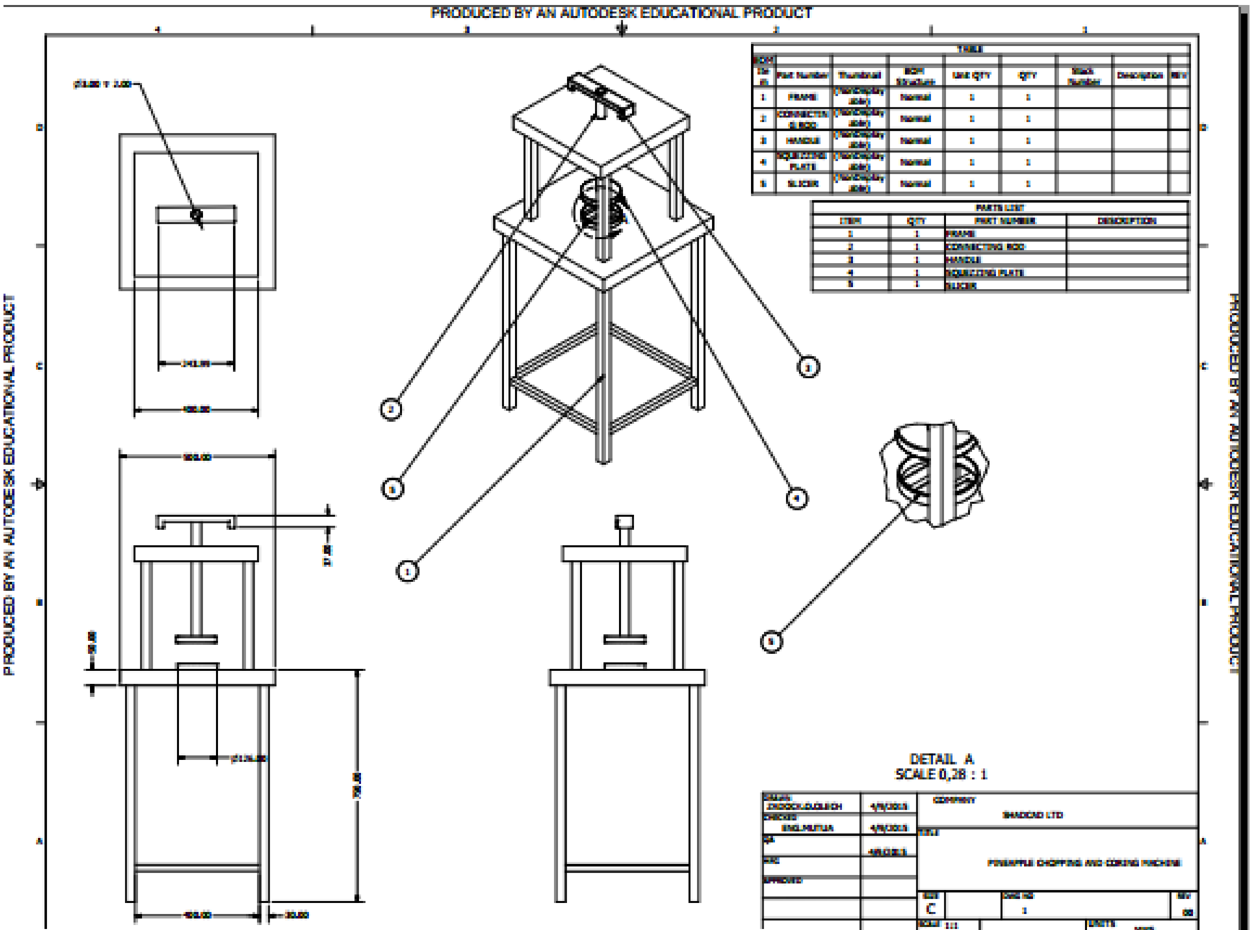
7.0. Appendices

Appendix A

Pineapple coring and chopping machine



Side view Front view Top view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Appendix B


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Appendix C

Work programme (Ghant chart)

Activity	Sept					Oct				Nov				Dec				Jan				Feb				Mar				Apr				M
	wk	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Choosing of two topics from the available list.																																		
Submission of two concept notes of the chosen topics.																																		
Submission of Expanded concept note																																		
Data collection field activities.																																		
Submission of full proposal.																																		
Oral Seminar Presentation.																																		
Data collection																																		
Data entry and analysis.																																		
Report documentation and report writing.																																		
Handing in Draft Final Report.																																		
Oral Exam/Defense																																		
Handling in of Final Report.																																		