DESIGN AND CONSTRUCTION OF A MOTORIZED MANGO JUICE EXTRACTOR

BY

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2004/18339EA

DEPARTMENT OF AGRICULTURAL & BIORESOURCES ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NIGER STATE

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEENRING (B.ENG) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING,

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FEBRUARY, 2010.

DECLARATION

I hereby declare that this project work is a record of a research work 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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Ola, Adedapo Oyeniyi

17/02/2010

Date

CERTIFICATION

This Project entitled "Design and Construction of Motorized Mango Juice Extractor" by Ola Adedapo Oyeniyi, meets the regulation governing the award of 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 Almighty God the author and the finisher of our faith who makes it possible for me to complete the program successfully whose hand lies my future and to my lovely parent Mr Ezekiel Adewoye Ola and Mrs Mojisola Abigel Ola.

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My greatest appreciation goes to the Almighty God the Supreme being, the ruler of the whole universe and the chief the judge in the last day, who has given me the grace by keeping me alive and enablement to the successful completion of this project.

I want to express my gratitude to my supervisor Mrs B. Orhevba and to all lecturers in the department for their effort to ensure I procure relevant knowledge and training throughout this programme. May God grant you long life to enjoy the fruits of your labour (Amen)

Special thanks to my Mr & Mrs Ola for their love, care, prayers and also for being there for me morally and financially, may you eat the fruit of your labour (Amen).

Equally, my thanks go to my brother's and also to my uncle, Mr Ademola Ola and Pastor A.A Adisa. I appreciate you all for your love, endurance and support.

Finally, am also indebted to friends and colleagues, my project mate, friends in the department, school and outside school relatives and all well wishers. May God bless you all.

ABSTRACT

A mango juice extractor was designed and fabricated. The work was aimed at increasing the production of fresh juice from mango fruits without damaging or crushing the mango seed. The machine was designed with a screw conveyor (auger) welded to the shaft which presses the peeled mangoes against the perforated drum and conveys the mangoes as the shaft rotate to extract the juice. The juice throughput was found to be 0.06kg/sec and the juice extraction efficiency was 65%. A device of this nature can be used in a small scale industry.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Fruits are means by which flowering plants disseminate seed they are found everywhere and mostly cultivated by the peasant farmers. Fruit crops such as mangoes, oranges, pineapples and cashews have become established in many of the forest zones of West Africa and are widely grown in the francophone countries (Adewumi, 1999).

Fleshy fruits are produced in many parts of West Africa and from research, it has been observed that the consumption of fruit juice by an average Nigerian family is relatively high and the production is mainly for home consumption, since the limited quantity of fruits produced is insufficient to supply an export market. The fruits are grown mainly for the juice they produce and the most important West African fleshy fruit is the mango (Macrase *et al*, 1997). These grow well, mostly in the middle belt of the country.

Fruits have greater nutritive value far greater than that of synthetic product, which are at present being bottled and sold in large quantities throughout the country. The annual production of carbonated beverages like lemonade, strawberry, lime-juice, and other artificially flavoured beverages synthesis run into several million bottles. If real fruit could be substituted for these preparations, it would be favorable to the consumer as well as to the fruit juice grower. There is a great potential in the country for the production of fruits and other fruit-based beverages (Tendon *et al*, 1998).

With the rapid progress in fruit farming that has taken place during the last two decades, vendors in some of the large towns are increasingly selling fresh fruit juice. The demand for fresh fruit juice is on the increase, but this cannot be gotten easily, when the fruits are out of season. Fruit juice, therefore have to be preserved in a form in which they can be made available to the public during the off-season (Tendon *et al*, 1998).

1.1.1 The Mango Fruit

Mango (*mangifera indica*) is a fleshy fruit with edible portion up to 60 - 75% of the fruit weight. The flesh of a ripe mango contains about 15% sugar mostly sucrose, vitamin A and little amount of Vitamins B and C (Ngoddy, 1995). Mango is a succulent fruit. It varies in size from 2.5cm – 3.0cm long and up to 7.5cm in diameter. It has different shapes such as rounded, egg shaped, oblong and sometimes with a depression (Kordylas, 1995). The young fruits develop in spring and are harvested from early summer through autumn as there are early, mid and late cultivars. Its weight ranges from 0.1kg to 0.85kg depending on the species. The bottom end may be depressed, elevated, or intermediate. The outer layer is fairly thick and doted. The fleshy part, which is edible, varies in thickness, texture and flavor. It may be soft, free of fibers, sweet and juicy or fibrous with a turpentine-like flavor. The seed inside (endocarp) is thick, stony, woody and fibrous. The seed varies in sizes and the covering is represented in two layers. It contains two fleshy cotyledons (Kordylas, 1996).

1.1.2 Origin and Distribution

One of the most celebrated and heavily consumed of tropical fruits; the mango is often represented in ancient Indian art work and is said to have been seen by Alexander the great and his soldiers in the Indus valley in 327BC. In the past two centuries, it has spread to most part of the tropics and some subtropical areas as well. It has reached international commerce, and is on increasing demand, especially by relocated people now outside the warm climates as well as by gourmets in temperate regions. It has therefore earned the attention of food scientists everywhere. (Mathews, 2000).

1.1.3 Uses and Utilization of Mango

Unlike Nigeria where mangos are majorly consumed raw, Asian countries like India make use of mango for different types of meal ranging from liquid (juice) to solid meals. Mango fruits can be used in making jams, pastries, natural flavoring in ice creams, jellies and sometimes dried in the sun and seasoned with turmeric powder which serves as savory agent for soups and vegetable. It can be canned in specially coated cans or glass jars and preserved as free natural juice or in India as juicy pulp strained from fibrous ripe mangoes, dehydrated and utilized as cereal flakes.

The skin, seed and the kernel inside the seed could be regarded as wastes of the mango fruit. These wastes are processed in India and fully maximized. Pectin is extracted from the seed, which has almost, same quantity as that of apple. The kernel inside the endocarp is roasted and powdered and can be consumed, especially in times of scarcity of food. The skin can be dried and grinded which is then added with other savoury agents and used as spice in soup. (Cutrufelli *et al*, 2001).

1.2 Statement of the problem

1. Unprocessed mango get spoilt easily, compared to the processed ones, (i.e. in juice form)
2. Extraction of mango juice by squeezing with hand is time consuming, laborious and inefficient.

1.3 Objectives of the Project

The main objectives of the project are:

1. To design and construct a mango juice extractor.
2. To extract mango juice without damaging or crushing the mango seed.

3. To increase the production of locally made fresh mango juice.

1.4 Justification of the project

Mango juice is said to be rich in sugar, minerals, vitamins and other nutrients. They are delicious and have universal appeal unlike other beverages. Hence, designing a machine that will efficiently extract the juice from the mango fruits will make the juice available all season, at the same time reducing wastage.

The production of this fresh fruit juice has decreased substantially. Its declining popularity, especially among urban population has led to a rapid increase in the importation of juice. This is due to inadequate processing and preservation of the product (mango) which can ensure its availability all year round. In order to increase the availability and supply of the juice it is necessary to design and construct a machine for extraction of mango juice.

1.5 Scope of the project

This work covers the design and construction of a mango juice extractor which can be useful for domestic purposes. The machine also has the ability to remove the seed effectively without crushing the seed with the extracted juice.

CHAPTER TWO

2.0 LITERATURE REVIEW

Fruits are one of the most components of our diet because of their excellent contribution of Vitamins A, B and C, minerals such as calcium, iron, dietary fiber and good source of carbohydrates. They are important raw materials for our domestic, agro-industrial and export product. In view of the above reasons, fruit need to be carefully handled, carefully processed, efficiently packaged and well stored at dry season to reduced nutrient and financial losses as well as maintaining their availability all the year round.(Taylor, 1998).

In the tropics, there are many seedling mangoes so fibrous that they cannot be sliced. People bruise the fruit by massaging it between the hands, then make a hole in the stem end and press the juice out. In order to increase the production of mango juice, it is necessary to device equipment for extracting the juice and proper preservation of the juice extracted. (Mathew, 2000).

2.1 Juice Extraction

The extraction of juice from fruit is one of the steps in preserving and storing of fruit especially fruits that contain high percentage of moisture content. Fruit juice extraction involves the process of crushing, squeezing and pressing of whole fruit in order to obtain the juice and reduce the bulkiness of the fruit to liquid and pulp. The machine used is known as juice extractor. The machine is developed with the aim of expelling juice from fruits in substantial amount. (Adewumi, 1999).

The various process involved in fruit processing include sorting, washing, peeling (where applicable), pressing, slicing, crushing, extraction, filtration, pasteurization, packaging and storage. (Akhigbe, 1997). Within these stages of fruit juice processing, extraction seems to be most critical stage because if reasonable quantity of juice is not extracted, little or no fruit juice will be produced. The fruit juices have their best taste, aroma, and colour when they are freshly extracted. (Osasona, 1993).

2.2 Methods of Extraction

There are two major types of extracting juice;

1. The fruits are crushed and continuously pressed in a single operation.
2. The fruits are crushed and cut in small pieces and converted to juice in a mill and then pressed in a suitable press.(Gardhari, *et al*, 1992)

2.3 Types of Fruits Extractors

There are many types of equipment employed for the extraction of fruit juice such as;

1. Reamer Extractor
2. Taglith type Extractor
3. Halving and Burring Machine
4. Screw expeller press
5. Plunger-type press Rotary Juice Extractor

2.3.1 Reamer Extractor

This type involves the use of circular knife driven by motor, mounted in such a way that it cut through the fruits that are arrange in a V-shaped incline at an angle to the horizontal. The fruit rolling down then come in contact with the knife and its cut into two halves. These halved fruits are then held against the reamer. The reams are mushroom shaped structure with serrated heads against which the fruit is pressed. (Osasona, 1993).

2.3.2 Taglith Type Extractor

This machine comprises two pairs of revolving drums on the surface of each, which hemispherical hollow s have been embossed. The two drums of each pair rotate in opposite direction. The first is cut in the spherical space between the corresponding hollows of the two upper drums and is forced against a sharp blade which cut it into two. The halves are transferred to the hollow of the lower pair.

In the course of one revolution, the extractor head which carries hollow plunger of a spherical shape is pressed against the halved fruit. The juice flows through the plungers to a collecting manifold. The degree of pressing may be adjusted by varying the clearance between the drum-hollow surfaces and the plungers at the end of their stroke.
(Siddappa *et al*,1996)

2.3.3 Halving and Burring Machine

The fruits (especially citrus) are cut by a special machine in which the fruits are placed in a conical cup in a wheel, which bring the fruit against a stationary or revolving knife. The cut halve of the fruit is held against the revolving burr of the reamed, juice is then collected in a vessel kept below. Generally, there are two burrs one each on either side of the shaft. 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. (Siddappa *et al*, 1996).

2.3.4 Continuous Screw Expeller Press

These presses are similar in principle to the meat mincer. The segments of the fruit are feed through a hopper at one end of a feeding screw, revolving inside a conical jacket, which is perforated in section or throughout. The diameter of the perforations and the pomace comes out at the end of the conical jacket. The floe of the pomace and hence the pressing pressure of the screw can be adjusted to some extent by means of a movable disc at the conical end of the perforated jacket. The juice extracted is generally thick and cloudy so the juice should be passed through sieves to remove the pulp to the desired extent. (Girdhari *et al*, 1992).

2.3.5 Plunger Type Press

The halved citrus fruits are held on an interval cup in which it is pressed by an automatic adjustment against a metallic cone fitting with 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. (Kachru *et al*, 1997).

2.3.6 Roller Type Press

Roller presses are made of hard granite or wood. They are design to extract juice from sour limes. It crushes the fruit in a comminuting mill and the juice then extracted from the crushed material by means of a hydraulic press. In larger scale production, as in the case of apple juice, the crushing devices form an integral part of the press. (Girdhari *et al*, 1992).

2.3.7 The Rotary Juice Extractor

The design of rotary juice extractor is an application of the principle of the rotary extension macevator. The machine consists of an interval roller, which has radial orifices round it. On introduction of fruits, the machine squeezes the fruits for the juice to run out of the orifices. The machine in operation is feed with whole or halved peeled fruit through a hopper located on one side of the machine. Due to the difference in relative speed of rotations of both roller and die-ring coupled with the abrasive nature of the surface of the internal roller cause the rupturing of fruit caught between the roller and the outer ring. The inner surface of the die-ring is line with flat steel bar to serve as to direct de-juice fruit material to the point where that fall under gravity into a discharged tray which is placed in such a way that the pulp, on falling on it, rolls out of the machine.(Hams and Joachim, 1999)

2.4 Pulping Equipment

When fruits juice is extracted, it is observed to consist of suspended particles such as; coarse fruit tissue, pieces of skin, seed and others. It will therefore be necessary to separate the juice and the suspended matters using equipment called pulping equipment.

There are three types of pulping equipment commonly used viz;

1. Straining and Screening equipment
2. Settling or Sedimentation equipment
3. Filtration equipment

2.4.1 Straining and Screening Equipment

There are several types of straining and screening machines used in production of juice and these varying in design and installed capacity. A pulped made of stainless steel with power driven wooden, metallic or brush paddles revolving inside is highly useful in the case of citrus, tomato and mango juice. The fruit is feed through a hopper and crushed against the sieve by the paddles. The juice flows out through the sieve to the jacket and collected at the outlet below, while the coarse residue passed out of the lower end of the sieve.

2.4.2 Settling or Sedimentation Equipment

Settling or sedimentation is the separation of solids from fluid stream by using gravitational or centrifugal forces. Sedimentation is very often used in processing industry for separating dirt and debris from incoming raw materials, crystals from their mother liquior and dust or product particle from air streams. In sedimentation, particles are falling from rest under the force of gravity. The equipment used for sedimentation and settling of juice could be a wooden barrel or stainless steel tank with a stirrer. (Coulson and Richardson, 1998).

2.4.3 Filtration Equipment

Filtration is the removal of solutes (solid) particles from the solvent (fluid). Finely suspended particles in the juice are removed with special equipment known as filter. The filter press is of various capacity and design. The filtering media may be finely wooden cloth, canvas fiber, asbestos pads, cotton, porous porecelannic and pulp discs. A simple filtering device however, is a large bag of heavy dull cloth or felt similar to the ordinary jelly bag. The juice is heated with filter and placed inside the bag. Filtration with this system is rather slow but having a battery of such filter bags can increase the output. (Kachru *et al*, 1996)

2.5 Screw Conveyor

Screw conveyor sometimes called auger are usually made up of a plate steel helix mounted on a shaft which is powered at one end by an electric motor. As the shaft rotates, the material feed into it is moved forward by the trust of the lower part of the helix and is discharge through an opening at the far end of the trough.

Screw conveyors are used to handle finely divided powders, damp, sticky, heavy viscous materials, hot substances that may be chemically active and granular materials of all types. It is used for moving food products, batch or continuous mixing for extraction of juice from fruits and elevating jobs particularly where the run is short. (Henderson and Perry, 2002)

Screw conveyor is essentially designed for very low tonnage output where the assistance of positive discharge is a must and it offers an advantage in that the feeder itself can be easily enclosed making it dust tight. Thus, it provides a closed hopper and chute arrangement from the hopper to the delivering point. (Reisner, 1993).

There are two major classes of screw conveyor viz;

1. Vertical screw conveyor
2. Horizontal screw conveyor

In most cases, the horizontal screw conveyor is used except for elevation and movement of granular materials, where the vertical screw conveyor is been applied. It will then be necessary to talk about the horizontal screw, which is more relevant to the juice extraction.

2.5.1 Horizontal Screw Conveyor

They are usually operated in a U-shaped trough, with or without a cover, depending upon the type of service and the characteristics of the material being moved. The power requirement of a screw is a function of its length, elevation, type of hanger brackets, type of flights, the viscosity or internal resistance of the material, the coefficient of friction of the material on the flights and housing and the weight of the material.

The design of the screw conveyor depend on the material been processed. It could uniform pitch (long or short), decreasing pitch, decreasing diameter or the combination of decreasing pitch and decreasing diameter. (Henderson and Perry, 2002).

2.6 Preservation of Fruit Juice

Preservation is any measures by which juice are kept over a reasonable period of time. The principal objective of juice preservation is to maintain the quality and nutritional attributes while preventing spoilage. The high moisture content is responsible for the growth of yeast and bacterial and this change the colour, taste and aroma of the juice. In order to maintain the colour, taste and aroma, therefore juices have to be preserved. (Macrase *et al*, 1997).

Fruit juice preservation ensures that the consumer is provided with enjoyable good tastes which as far as possible retain its full nutritional value. It prevents health hazards caused by contamination of fruit with pathogenic organism. (Branen *el al*, 1998)

Freshly extracted juices are highly attractive in appearance, have good taste and aroma but deteriorates rapidly if kept for a long time as a result of the following;

a. Fermentation caused by mould, yeast and bacterial
b. Metallic ions from the equipment may get into the juice and spoil its taste and aroma
c. Chemicals present in the juice may react with one another and spoil the taste and aroma of the juice
d. Enzymes present in the juice may affect the colour and flavour
e. Air coming in contact with the juice may react with the glucosidal content in the juice and render it bitter. (Kachru *el at*, 1996)

Therefore, to retain the quality and natural nutritional value, it is necessary to preserve the juice. The following methods of preservation are employed;

1. Pasteurization
2. Addition of chemicals
3. Drying
4. Freezing

2.6.1 Pasteurization

This involves destruction of bacteria, mould, spores etc. This can be accomplished by the application heat by exposing the juice to a certain temperature between 80^{oc} to 95^{oc} for a certain time. Pasteurization of juice may be carried out before bottling and after bottling.of juice. After bottling of juice, the bottles are placed in a hot water for a given amount of time until the content reach the desired temperature. These reduce the chance of re-contamination of the juice. Also to pasteurize juice before bottling, this may be carried out in a stainless steel, aluminium sauce pan over a gas flame. It is best to use stainless steel pan to heat fruit juice as the acidity of the juice can react with aluminium in aluminium pans during prolonged heating. (FAO, 2001).

2.6.2 Addition of Chemicals

Preservation of fruit juice is to reduce spoilage and to increase the shelf life of the juice using chemical preservatives. The preservative chemical that can be added to fruit juice include;

a. Sulphur dioxide: used to preserve the colour of the juice during drying.

b. Sorbic acid: These inhibit the growth of moulds and yeast.

c. Citric acid: It is naturally used in carbonated beverages and is an acidifier of food

d. Benzonic acid: These inhibit the microbial activities and also inhibit growth of yeast and mould. (Adam and Moses, 1995).

2.6.3 Drying

This preservative method is known as dehydration. This involves the removal of water to obtain a dry powder of less than 6% moisture content. The process employed in drying of fruit juice includes;

a. Vacuum drying: As in evaporation process, the juices are dehydrated under vacuum to reduce drying temperature and enhance quality.

b. Foam mat drying: A foaming agent is added to the concentrate with whipping to produce heat stable foam. Foam drying has the advantage of using simple air drying.

c. Spray and drum drying: These are more efficient. A spray drying is designed so that the juice spray dries and is cooled below the sticky point before the particle hits the dryer wall and enters the collection system. The drum drying employing a hot roll, rotating in the fluid or feed between rollers. The film adhering to the roller surface is rapidly dried as it rotate out of the feed tank. Although the dried juice is in the glassy and sticky state. Cooling and grinding under low humidity produces a juice powder. (Karim and Chee-wai, 1999).

2.6.4 Freezing

This is an interesting method of food preservation. Juices are refrigerated to keep the growth of bacteria very low. Cold slow down the reactions associated with spoilage. In addition, water form crystals when frozen making it unavailable to bacteria that need water to thrive. (Nelson and Tressler, 1996).

2.7 Production Line for Mango Juice

The steps below show the basic stages involved in mango juice production.

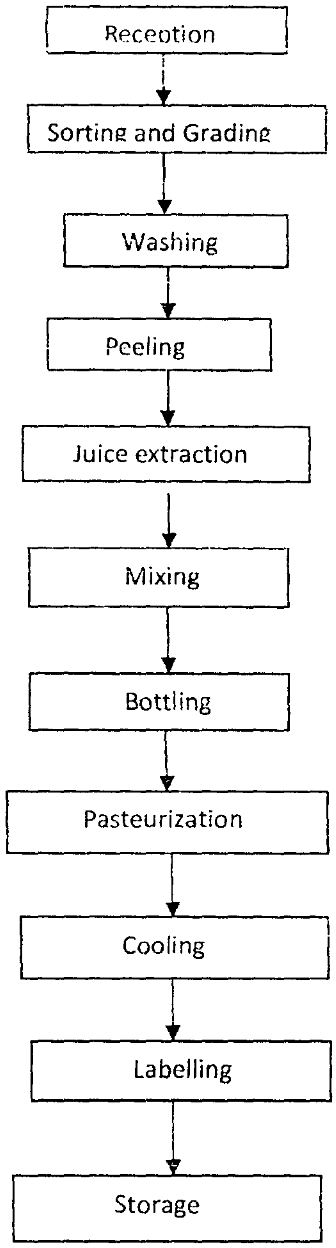


Fig 2.1: Production line for mango juice

The fully ripened fruit is used, washed, peeled and cut into slices with a stainless steel knife, pulp extractions is carried out with a hand driver or electrically operated juice extractor. (FAO, 1995).

2.8 Nutritive Value of Mango

Mango is an excellent source of carotene, vitamins A, B, C, E and K. It is also a source of mineral such as magnesium, calcium, copper, iron, phosphorus and manganese. Mango being high in calories and carbohydrate is good for weight gains. The phenolic compound found in mangoes has been found to have powerful antioxidant values that have been seen to be excellent for the immune system and help to protect against cancer. Mango being high in iron is said to be very good for pregnant woman as well as for people suffering from anaemia. (Percival, 2002). The Vitamin A, E and selenium present in mangoes provide protection against heart disease. The vitamin E present in mango is also said to help hormonal system function more efficiently and thus boosts sex life. (Ballo *et al*, 1997).

2.9 Economic Importance of Mango

Mango tree has been exploited for many purposes; the tree serves as shelter and wind breakers and helps to re-circulate soil nutrients in arid land. The gum extracted from the trunk is used for mending crockery in tropical Africa. In India, it is sold as substitute for gum Arabic. (Julia and Miami, 1997).

The mango stem bark has been developed on industrial scale to be used as a nutritional supplement, cosmetic and phytomedicine. The tree bark contain 16% to 20% tannin which is used in making leather dark brown. The wood is also favoured for making shovels for working in the saline. The twing and leaves, used to clean the teeth, are said to be beneficial to gums, while the bark is said to be useful for tooth aches. (Salles *et al*, 2002).

In India, when the mango is green the stone extracted can be used to add acidity to certain curries and when ripe the seed removed from the woody husk may be boiled with potherbs eaten roasted, or ground to form a flour, which tends to induce constipation. The sour mango powder made from ground up green mangoes called amour is used both for seasoning and tenderizing. (Marton, 1998).

The seed fat having high stearic acid content, the fat is desirable for soap making. The seed residue after fat extraction is useable for cattle feed and soil enrichment. The dried mango flower containing 15% of tannin serves as medicinal uses such as astringents in cases of diarrhea, chronic dysentery, catarrh of the bladder and chronic urethritis resulting from gonorrhea. (Pervial, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Material Selection

Material selection can be defined as the process of choosing the right type of material in the construction of engineering structures and components. When selecting the materials used for relevant parts relating to the functions, coupled with stress condition and service life, consideration were made. The following properties were considered in selecting the materials for construction of the extractor, these are:

- Mechanical properties which include strength, toughness, stiffness, fatigue, hardness and wear resistance.
- Chemical properties include resistance to oxidation and all forms of corrosion, since the machine in question is a food processing machine.

The material selection for the construction was based mainly on:

i. Material availability: The material used were selected based on their availability such that they can be easily get for mass production at a low cost

ii. Cost of materials: The cost of material used in design and construction of machine was considered such that the machine can be made available at a cheaper price for a peasant farmer.

iii. Cost of maintenance: The cost of maintaining the material selected was considered which will reduced the cost of maintenance, the changeable parts of the machine were not permanently welded to the machine

iv. Strength of material: To avoid operational failure, the strength of the materials used was certain. These were determined by establishing data and formulae. Based on the data and formulae applied, the strength and size of parts such as central shaft, power of electric motor require, size of bearing and thickness of the sieve materials were determined. This will enable the parts to withstand stress and prevent failure.

v. Durability and Hygiene: The machine will come in contact with easily oxidizable food (liquid substance). It is therefore necessary to ensure all these parts coming in contact with the juice be made of stainless steel of appropriate strength. The use of stainless steel materials for constructing the stepped auger, shaft, perforated drum and collector will enhance the durability of the machine because of its high corrosives resistance. However, for the construction of the proto-type, ordinary mild steel was used but painted to avoid corrosion.

3.2 Machine Description

The components of the mango juice extraction machine are as follows:

i. Hopper
ii. Outer cylinder
iii. Perforated drum
iv. Decreasing pitch screw conveyor
v. Shaft
vi. Pulley and belt
vii. Bearings
viii. Machine frame

3.2.1 Hopper: The fruits are fed into the processing chamber through the hopper. It is in the form of a trapezium with the following dimensions 250mm by 250mm and based diameter of 100mmx150mm with height of 250mm.

3.2.2 Outer cylinder: It is a semi-circular drum of radius 130mm and has the hopper welded to it. At the lower end, a semi-circular hole of radius 100mm is made on it and a flat plate to its base. It is through this hole that the seed is ejected. Also, at the lower part of the cylinder a collecting funnel was attached so that the extracted juice can flow out into the container.

3.2.3 Perforated drum: The drum is perforated to have a roughened interior; it tears the fruit and the juice flow out through the holes into the collector. It is of 220mm diameter and 600mm long with end cover. It also houses the screw conveyor.

3.2.4 Decreasing pitch screw Conveyor: This is a type of screw conveyor with a variable pitch in the decreasing order with the aim of combining compression and complete extraction of juice from the mango fruit.

3.2.5 Shaft: It has the screw plate on its circumference. The shaft is of 900mm long and diameter of 20mm, 25mm, and 30mm in steps. On the shaft, a pulley was mounted, which with the help of v-belt arrangement will transmit reduced speed of power to the machine from the power source.

3.2.6 Pulley and Belt: The pulley transmits the rotary motion developed by the shaft through the v-belt. The pulleys (of the electric motor and the shaft) have diameters of 65mm and 250mm, which are different and thus, have unequal speed.

3.2.7 Bearing: The bearings were used to support and align the shaft axially. They carry the shaft load and make the operation almost frictionless. The inner diameter of the bearings is 25mm.

3.2.8 Machine Frame: This was made of 40x40mm angle iron and has a thickness of 2mm. This is the main body of the machine on which other parts were rested.

The complete assembly of the machine (extractor) is shown in figure 3.4

3.3 Mode of Operation of the Machine

When the power source (motor) is switched on, it rotates at the speed of 1440rpm and the rotational motion is transferred to the extractor through the help of the v-belt/pulley arrangement. The machine begins to rotate at the speed of 375rpm, that is, the speed is stepped down to ensure high extraction efficiency of the machine and less damage.

The hopper is then fed uniformly and ensures full load of already peeled mango was ensured. The drive conveyed the mangoes loaded in the hopper into the perforated drum and presses it against the roughened surface. Due to the nature of the screw conveyor being a decreasing pitch type, compression and extraction of the mango juice from the fruit is achieved therefore ejecting the mango seed out of the drum. The juice which is screened through the perforated drum is collected through the funnel attached to the base collector.

3.4 Design Calculations

The design of the components of this machine was based on mechanical theories and physical properties such as size, shape, volume, and density of the fruit. Lots of calculations and assumptions were also involved in determined the various dimensions selected and in construction of some of the components.

3.4.1 Determination of Density of Mango

From the work of Dolapo (1998), an experiment was carried out in two stages of ten (10) mangoes each, gotten from different parts of South-western Nigeria.

The following physical properties were obtained,

Average length of the mango fruit =8.465cm

Average breadth of mango fruit =6.520cm

Average width of mango fruit =5.995cm

Average volume of mango fruit =165.5ml

Average weight of mango fruit =161.885g

$$Density = \frac{Mass}{Volume}; \quad (3.1)$$

$$Density = \frac{161.885}{165.5} = 0.978\, g/ml$$

$$Note: 1000ml = 1litre; \qquad 1000litre = 1m^3$$

$$1 \times 10^6 ml = 1kg$$

$$Therefore, Bulk\ density = \frac{161.885 \times 10^{-3}}{165.5 \times 10^{-6}} = 978\, kg/m^3$$

From the work of Akinsolu (2000), the average width of mango seed was measured to be 15mm. This was put into consideration in determining the clearance between the perforated drum and the auger. It is also considered in the determination of pitches on the screw conveyor.

3.4.2 Hopper design

The design consideration for the hopper of the machine includes:

- Volumetric capacity
- Feeding ratio

Hopper capacity is designed to accommodate 5kg of mangoes (30 mangoes).

Calculations: Mass of mangoes = 5kg

Note 1 mango = 161.885g

30 mangoes = 30 x 161.885g = 4856.55g ≐ 5kg.

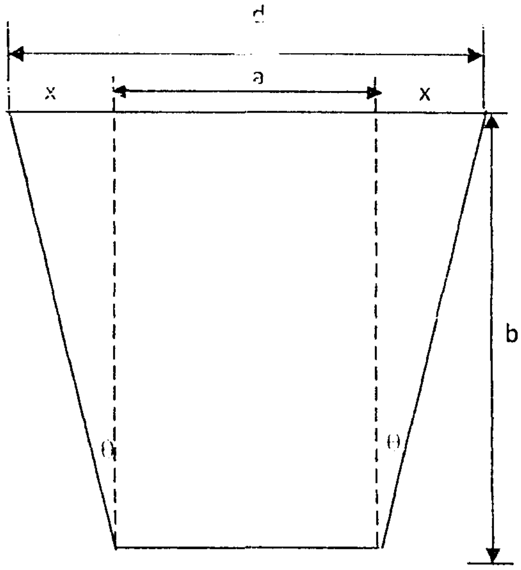


FIG 3.1: CROSS-SECTIONAL VIEW OF THE HOPPER.

$$d = a + 2b\tan\theta$$

$$\tan\theta = {}^{x}/_{b}; \quad x = b\tan\theta$$

$$d = a + x + x = a + 2x$$

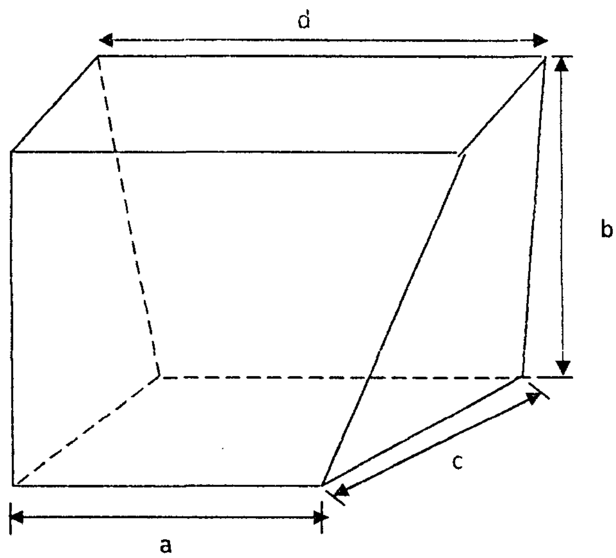


FIG 3.2: HOPPER

The volume of the mangoes which determine the volume required for the hopper is calculated from:

$$Density = \frac{Mass}{Volume}$$

Knowing bulk density of the mangoes = 980kg/m^3

$$\therefore Volume = \frac{Mass}{Density} = \frac{5.0}{978} = 0.005m^2$$

Also, cross sectional area of trapezium = $^1/_2\,(a + d)b$ (3.2)

But, $d = a + 2btan\theta$

$\therefore$ Cross sectional area of trapezium = $^1/_2\,(a + a + 2btan\theta)b$

$$= {}^1/_2\,(2a + 2btan\theta)b$$

$$= ab + b^2tan\theta$$

Volume of a trapezium = $Cross\ sectional\ area\ \times length$

$$= (ab + b^2tan\theta) \times c$$

Where: $c = length\ of\ the\ trapezium$

$a = 150mm$

$b = 250mm$

$d = 250mm$

$$volume\ of\ mango = volume\ of\ trapezium$$

$Recall, tan\theta = {}^{x}/_{b}$

$and\ x = {}^{1}/_{2}(d - a)$

$x = {}^{1}/_{2}(250 - 150)$

$= \frac{100}{2} = 50mm$

$\therefore 0.005 = \left(0.15 \times 0.25 + 0.25^2 tan\left({}^{0.05}/_{0.25}\right)\right)c$

$= (0.0375 + 0.0127)c$

$0.005 = 0.05c$

$c = \frac{0.005}{0.05} = 0.1$

$\therefore c = 100mm$

Hence, the dimensions of the hopper are

$a = 150mm, b = 250mm, c = 100mm\ and\ d = 250mm$

3.4.3 Determination of the speed of the shaft

The speed of the shaft can be determined from:

$$N_1 D_1 = N_2 D_2 \quad (3.3)$$

Where, $N_1 = rpm\ (Number\ of\ revolution\ per\ minute)\ of\ the\ motor$

$N_2 = rpm\ (Number\ of\ revolution\ per\ minute) of\ the\ shaft$

$D_1 = Diameter\ of\ the\ electric\ motor's\ pulley$

$D_2 = Diameter\ of\ the\ shaft's\ pulley.$

However, the maximum ratio permissible is 5:1 to avoid slipping of the V-bolt from the sheave. Thus, ratio 4:1 is selected.

Therefore $^{D_2}/_{D_1} = {}^{4}/_{1}$

But $D_1 = 65mm; D_2 = 260mm, but\ D_2 = 250mm$ is selected.

Hence, the diameter of the shaft pulley is $250mm$ being a standard value.

$N_1 = 1440rpm, N_2 = ?$

$D_1 = 65mm,\ D_2 = 250mm$

Therefore, $\frac{1440}{N_2} = \frac{250}{65}$

$N_2 = \frac{1440 \times 65}{250}$

$= 374.4, but\ N_2\ is\ taken\ to\ be\ 375rpm.$

Hence, the speed of the shaft = $375rpm$

3.4.4 Power requirement

The power requirement 'P' can be divided into three main parts, viz;

a) Power required in extraction, P_e

b) Power required to drive the shaft, P_s

c) Power required to drive the pulley, P_p

Taking $P = P_e + P_s + P_p$ (3.4)

a. The power required in extraction was obtained from the equation;

$P_e = Tw$ (3.5)

But $T = \frac{\pi \times d_3 \times \tau}{16}$ (3.6)

Where, $P_e = Power\ required\ to\ extract\ (W)$

$T = Torque\ (Nm)$

$d = Diameter\ of\ the\ inner\ cylinder\ (perforated\ cylinder)\ 0.22m$

$\tau = Shear\ stress\ (9090.91N/m^2)$ for extraction of mango. (Ledger, S.N, 2003).

$w = Angular\ speed\ given\ by; w = \frac{2\pi N}{60}$

$N = rpm\ (number\ of\ revolution\ per\ minute) of\ the\ shaft$

i.e. $d = 0.22m, \tau = 9090.991N/m^2, N = 375rpm$

$w = \frac{2 \times \pi \times 375}{60} = 39.27$rad/sec.

Therefore, from equation (3.4),

$T = \frac{\pi \times (0.22)^3 \times 9090.91}{16} = 19Nm$

Hence, the power required in extraction, P_e, is given by

$P_e = 19 \times 39.27 = 746.13W$

$= 0.746KW.$

b. Power required to drive the shaft

According to (Jones and Kisher, 1995) the power required to drive the shaft can be determine using the equation below:

$$p_s = \frac{(D^2-d^2)\rho g N p f l}{8000} \quad (3.7)$$

Where, $D = Diameter\ of\ the\ screw\ (0.190m)$

$d = Shaft\ diameter\ (0.03m)$

$N = Speed\ of the\ shaft\ (375rpm)$

$\rho = Density\ of\ material\ (978\ kg/m^3)$

$f = Material\ factor\ (0.5)$

$p = Screw\ pitch\ (0.18, 0.13, 0.09, 0.06, 0.04)$

$l = Length\ of\ shaft\ (0.6, 0.42, 0.294, 0.206, 0.144)$

Since the screw conveyor was designed as a decreasing pitch type, each pitch is considered individually.

i.e,$Screw\ pitch(p) = (0.6 \times 0.18 + 0.42 \times 0.13 + 0.294 \times 0.09 + 0.206 \times 0.06 + 0.144 \times 0.04)m$

$p = 0.20718m$

Therefore,

$$p_s = \frac{(0.190^2 - 0.03^2)\times 978 \times 9.81 \times 375 \times 0.20718 \times 0.5}{8000}$$

$$= \frac{13118.97}{8000}$$

$p_s = 1.64kw$

c. Power required to drive the pulley, P_p

$P_{p1} + P_{p2}$ (3.8)

But, $P_{p1} = T_{p1}W_1$ (3.9)

$P_{p2} = T_{p2}W_1$ (3.10)

Where, P_{p1} = *Power required to drive the smaller pulley.*

P_{p2} = *Power required to drive the bigger pulley.*

T_{p1} = *Torque produce by the smaller pulley.*

T_{p2} = *Torque produce by the bigger pulley.*

w_1 = *Angular speed of the smaller pulley.*

w_2 = *Angular speed of the bigger pulley*

Therefore,

P_{p1} *from the smaller pulley is given by*

$P_{p1} = T_{p1} \times w_1$ *from equation* (3.9)

And $T_{p1} = W_{p1} \times R_1$ (3.11)

Where, W_{p1} = *Mass of motor mounted pulley (smaller pulley).*

R_1 = *Radius of smaller pulley* (0.0325m)

Since,

$$Density, \rho = \frac{Mass}{Volume}$$

$$Mass = \rho \times V \quad (3.12)$$

but the volume is calculated from,

$$V_1 = \pi R_1^2 t \quad (3.13)$$

$where,\ Thicknes\ (t) = 20mm = 0.02m$

$Volume\ of\ the\ pulley, V_1 = \pi \times (0.0325)^2 \times 0.02$

$= 6.637 \times 10^{-5} m^3$

$Therefore, Mass = \rho \times V_1$

$but, \rho = Density\ of\ mild\ steel\ (7840\ Kg/m^3)$

$Mass = 7840 \times 6.637 \times 10^{-5}$

$= 0.520Kg$

$Hence, T_{p1} = 0.52 \times 9.81 \times 0.0325 = 0.166\ N/m$

$Now, T_{p1} = T_{p1} \times w_1$

$but, w_1 = \frac{2 \times \pi \times N_1}{60}$

$where, N_1 = 1440rpm\ for\ smaller\ pulley$

$w_1 = \frac{2 \times \pi \times 1440}{60} = 150.8\ rad/sec$

$but\ taking\ into\ consideration\ motor\ efficiency\ of\ 85\%$

$w_1 = \frac{85 \times 150.8}{100}$

$= 128.18\ rad/sec$

$Hence, P_{p1} = 0.166 \times 128.18$

$= 21.3w = 0.0213Kw$

P_{p2} *from the bigger pulley is given by*

$P_{p2} = T_{p2} \times w_2$, from equation x

And, $Tp_2 = Wp_2 \times R_2$ (3.14)

$Where,\ Wp_2 = Mass\ of\ shaft\ mounted\ pulley$

$R_2 = Radius\ of\ bigger\ pulley\ (0.125m)$

$Since, Density = \frac{Mass\ (Wp_2)}{Volume\ (V_2)}$

$Where, V_2 = Volume\ of\ the\ bigger\ pulley.$

And to effectively determine the volume of the bigger pulley,v_2, due to its shape. Archimedes principle was applied by which the volume of the pulley is equal to the volume of water displaced when the pulley was immersed in water. This is given as

$V_2 = 4.46 \times 10^{-4} m^3$

Mass of the bigger pulley $= \rho \times V_2$

$= 7840 \times 4.46 \times 10^{-4}$

$= 3.497$Kg

Therefore, $Tp_2 = 3.497 \times 9.81 \times 0.125$

$= 4.288\, N/m$

Now, $Pp_2 = Tp_2 \times w_2$

But $w_2 = \frac{2\pi N_2}{60}$

Where, $N_2 = 375.7m$ for bigger pulley

$$w_2 = \frac{2 \times \pi \times 375}{60} = 39.27\, rad/sec$$

Hence, $Pp_2 = 4.288 \times 39.27$

= 168.39w

=0.168Kw

Therefore, $Pp_2 = Pp_1 + Pp_2$

$(0.0213 + 0.168)$Kw

$= 0.189$Kw (Power required to drive the pulley).

Hence, the power required by the extractor machine "P"

$$P = P_e + P_s + P_p$$

$$= (0.746 + 1.64 + 0.189)Kw$$

$$= 2.575Kw$$

Since, 1hp electric motor is $0.746kw$ which is reasonably lesser than the total power requirement calculated, therefore 5.0hp of electric motor are chosen.

3.4.5 Motor Selection

Considering the power required result calculated for $2.575kw$ which is equivalent to 3.45hp, $5.0hp$ electric motor was selected for the extractor i.e. $3.73kw$.

3.4.6 Determination of belt length

The length of a belt can determine from;

$$L = \pi \frac{[d_2 + d_1]}{2} + 2c + \frac{[d_2 - d_1]^2}{4c} \tag{3.15}$$

Where, $L = length\ of\ belt$

$d_2 = diameter\ of\ bigger\ pulley\ (0.25m).$

$d_1 = daimeter\ of\ smaller\ pulley\ (0.065m)$

$c = centre\ distance\ (0.6m)$

Akinsolu (2000) the centre distance C was chosen to be 600m.

Therefore, $L = \pi\frac{[0.025+0.0625]}{2} + 2(0.6) + \frac{[0.25-0.065]^2}{4(0.6)}$

$= \frac{0.32\pi}{2} + 1.2 + \frac{0.034}{2.4}$

$= \frac{0.768\pi+5.76+0.068}{4.8}$

$= 1.717m$

The total belt length is 1717mm. Hence, a V-belt section B was selected in accordance with Osborne (1979).

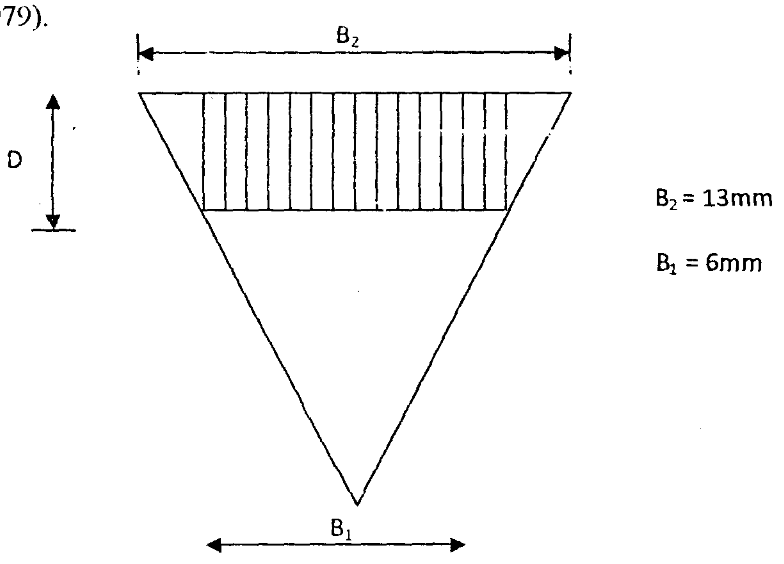


FIG 3.3: CROSS-SECTIONAL VIEW OF V-BELT

3.4.7 Angle of wrap

To determine the angle of wrap for the bigger pulley this formula can be used

$$\theta_b = 180 + \frac{2sin^{-1}(R-r)}{C} \quad (3.16)$$

Where, θ_b = Angle of wrap of bigger pulley

R = Radius of bigger pulley (0.125m)

r = Radius of smaller pulley (0.033m)

Therefore, $\theta_b = 180 + \frac{2sin^{-1}(0.125-0.033)}{0.6}$

$= 180 + 17.596$

$\theta_b = 197.6^o$

For smaller pulley, θ_s

$$\theta_s = 180 - \frac{2sin^{-1}(R-r)}{C} \quad (3.17)$$

$= 180 - \frac{2sin^{-1}(0.125-0.033)}{0.6}$

$= 180 - 17.596$

$\theta_s = 162.4^o$

3.4.8 Determination of belt speed

The belt speed, v_b, is calculated from

$$v_b = wr \quad (3.18)$$

Where $v_b = Belt\ speed\ (m/s)$

$w = Angular\ speed\ of\ the\ shaft\ or\ electric\ motor\ (rad/sec)$

$r = radius\ of\ the\ shaft\ or\ pulley\ (m)$

But, $w = \frac{2\pi N}{60}$

Using $N = Number\ of\ revolution\ per\ minute\ of\ the\ shaft\ (375rpm)$

i.e. $w = \frac{2\times\pi\times375}{60} = 39.27rad/sec$

And $r = radius\ of\ the\ shaft, \frac{250}{2}$

$r = 125mm = 0.125m$

Therefore, $V_b = 39.27 \times 0.125$

$= 4.9\,m/s$

3.4.9 Tension in belt

Using the following equations

$$\frac{T_1}{T_2} = e^{k\theta} \quad (3.19)$$

And $P = (T_1 - T_2)v$ (3.20)

Where, $T_1 = Tension\ in\ tight\ side$

$T_2 = Tension\ in\ slack\ side$

$\theta = Angle\ of\ wrap\ on\ the\ smaller\ pulley (162.4^o)\ i.e. in\ an\ electric\ motor$

$k = 0.52\ for\ v - belt$

But, $\theta\ should\ be\ expressed\ in\ radian$

i.e. $\frac{\theta\pi}{180} = \frac{162.4^{o}\times\pi}{180} = 2.83$

From the above equation

$$\frac{T_1}{T_2} = e^{k\theta}$$

$$\frac{T_1}{T_2} = e^{(0.52)\times 2.83}; \frac{T_1}{T_2} = 4.36$$

$$T_1 = 4.36T_2 \qquad (3.20a)$$

Also, from $P = (T_1 - T_2)v$

Where $P = Power\ transmitted\ by\ belt\ (3.73) Kw)$

$v = Belt\ speed (4.9\,m/s)$

i.e. $3.73 = (T_1 - T_2)4.9$

$$T_1 - T_2 = \frac{3.73}{4.9}$$

$$T_1 - T_2 = 0.761KN \qquad (3.20b)$$

By substituting the value of T_1in equation (3.20a) into $(3.20b)$

i.e. $4.36T_2 - T_2 = 0.761; 3.36T_2 = 0.761$

$$T_2 = \frac{0.761}{3.36} = 0.226KN$$

To determine the value of T_1, put the value of T_2 into equation $(3.20a)$

i.e. $T_1 = 4.36(0.226) \qquad = 0.986KN$

Therefore, total tension in belt

$$T_1 + T_2 = (0.986 + 0.226)$$

$= 1.212KN$

3.4.10 Design of screw conveyor using decreasing pitch

The screw conveyor is the main working part of the machine. The screw which must have 5 pitches of the decreasing pitch type as designed by, (jones and kisher 1995).

To get the screw configuration, iteration method has to be used. We assume a value for P(x) to get the inlet velocity and then get the remaining four (4) pitches. If the five do not add up to the total, we increase or decrease as the case may be, then start again.

In the design consideration, the physical proportion of mango fruit and the seed is considered (the length, breadth and width of the fruit and seed). This is important in order to ensure that the pitch can contain mango fruit and the last pitch is free of mango juice. Therefore, the last is ensured to be lesser than 50mm but greater than 15mm which is the mango seed size.

The design formula is given thus

$$P\langle x\rangle = \frac{4vDL}{\frac{\pi}{4}(D^2-d^2)N} \tag{3.21}$$

Where, $P\langle x\rangle = Pitch$

$v = Inlet\ velocity\ of\ material$

$D = Diameter\ of\ the\ screw(outside)0.22m$

$d = inner\ diameter\ of\ the\ screw(0.03m)$

$L = Length\ of\ shaft(0.6m)$

$N = Speed\ in\ revolution\ per\ minute(375rpm)$

Hence, applying iteration method

Assume $P\langle x_1\rangle = 0.180m$

Therefore,

$$0.18 = \frac{4 \times v \times 0.22 \times 0.6}{\frac{\pi}{4} \times (0.22^2 - 0.03^2) \times 375}$$

$$0.18 = \frac{0.5284}{13.99}$$

$$v = \frac{0.18 \times 13.99}{0.528} = 4.77\, m/s$$

$$P\langle x_2\rangle = \frac{4 \times 4.77 \times 0.22 \times (0.6 - 0.18)}{\frac{\pi}{4}(022^2 - 0.03^2) \times 375} = \frac{1.763}{13.99}$$

$$P\langle x_2\rangle = 0.126m$$

$$P\langle x_3\rangle = \frac{4 \times 4.77 \times 0.22 \times (0.42 - 0.126)}{\frac{\pi}{4}(0.22^2 - 0.03^2) \times 375} = \frac{1.234}{13.99}$$

$$P(x_3) = 0.088m$$

$$P(x_4) = \frac{4 \times 4.77 \times 0.22 \times (0.294 \times 0.088)}{\frac{\pi}{4} \times (0.22^2 - 0.03^2) \times 375} = \frac{0.865}{13.99}$$

$$P(x_4) = 0.062m$$

$$P(x_5) = \frac{4 \times 4.77 \times 0.22 \times (0.206 - 0.062)}{\frac{\pi}{4}(0.22^2 - 0.03^2) \times 375} = \frac{0.605}{13.99}$$

$$P(x_5) = 0.043m$$

However, the following pitches were chosen, 0.18m, 0.13m, 0.09m, 0.06m and 0.04m. The thickness of the plate used is 3mm distance of 0.04m and 0.03m were given at the respective ends to the first and the last pitch of the screw. The summation of the above gives 0.57m which is close to 0.6m, length of the screw conveyor.

3.4.11 Analysis of the shaft diameter

Shaft is a solid material used in transmitting power. The design of a shaft is essential so as to determine the minimum diameter, which will ensure a satisfactory strength and rigidity when the shaft is transmitting power. In the design of the shaft, force (pulley weight) acting on the shaft and the reactions sat the bearings are taken into consideration.

From. $p = T \times w$ (3.22)

But, $w = \frac{2 \times \pi \times N}{60}$

i.e. $P = \frac{2 \times \pi \times N \times T}{60}$ (3.23)

Where, $P = power\ of\ the\ electric\ motor\ (3.73KW)$

$T = Torque$

$N = rpm\ of\ motor\ (1440rpm)$

Therefore, $T = \frac{60 \times P}{2 \times \pi \times N}$

$= \frac{60 \times 3.73}{2 \times \pi \times 1440} = 0.0247KNm$

$= 24.7Nm$

But with 85% efficiency. $T = 24.7 \times 0.85$

$= 20.995Nm$

Taking the following point into consideration.

i. That the torque is transmitted in the horizontal plane

ii. The shaft is under a combined bending (due to belt tension) and torsional moment

The pulley weight can be determined from;

$$w_p = \rho v g \qquad (3.24)$$

Where, $w_p = pulley\ weight$

$\rho = Density\ of\ mild\ steel\ (7840\ kg/m^3)$

$g = Acceleration\ due\ to\ gravity\ (9.81\ m/s^2)$

Therefore, $w_p = 7840 \times 4.46 \times 10^{-4} \times 9.81 \quad = 34.3N$

$w_p = 0.0343KN$

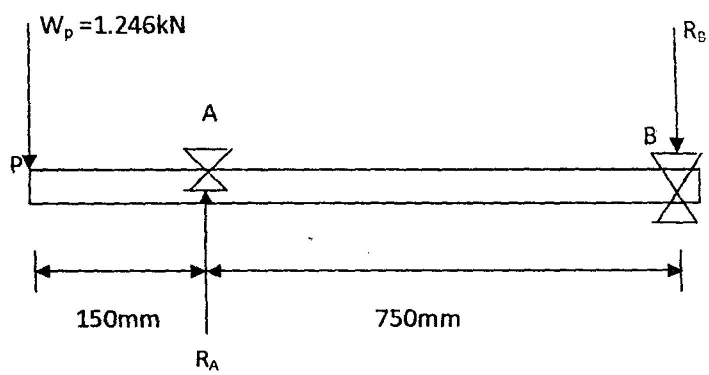
Since the weight and the tension of the pulley is acting downward, therefore the total weight on the pulley is the summation of the pulley weight and the tension.

i.e. $Total\ weight\ of\ pulley = (0.0343 + 1.212)\text{KN}$

$$W_p = 1.246KN$$

Then, the maximum bending moment can be determined as follows;

Considering the free body diagram below



Where. $C_s = Theoretical\ capacity\ (m^3/h)$

$D = Screw\ diameter\ (m)$

$d = Shaft\ diameter\ (m)$

$\rho = Screw\ pitch\ (m)$

$\emptyset = Filling\ factor$

$N = Shaft\ speed\ (rpm)$

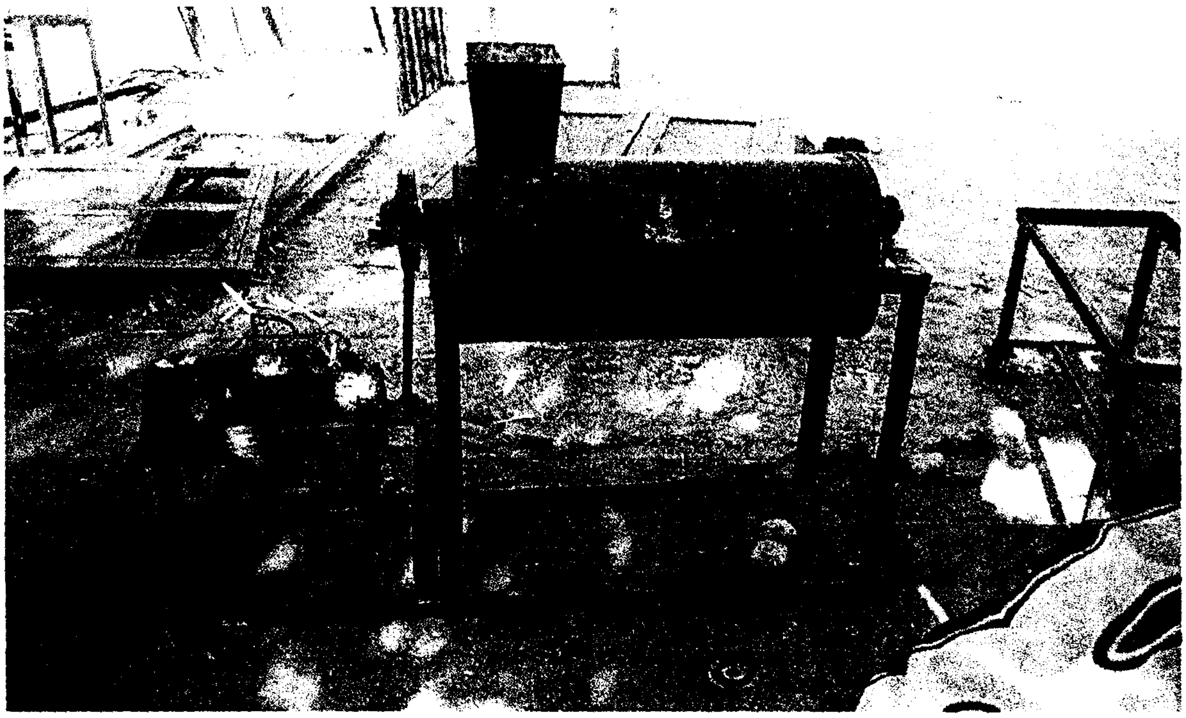


Plate 3.1: Complete Assembly of the Machine

Taking moment about point B, i.e.

$\sum M_B = 0$. taking the clockwise moment to be $(+ve)$

$$R_A \times 750 \times 10^{-3} - W_P \times 900 \times 10^{-3} = 0$$

$$0.750R_A = 1.246 \times 0.9$$

$$R_A = \frac{1.121}{0.75}, = 1.495KN$$

For a uniform or balance loading,

$$\sum V^{(+)} = 0, \;\; R_A - R_B - W_P = 0$$

i.e. $R_B = R_A - W_P$

$$R_B = 1.495 - 1.246, R_B = 0.249KN$$

The bending moment can be determined as follows;

Note that B.M at point P and B = 0

i.e. $M_P = M_B = 0$

Then the bending moment of point A,

$$M_A = -1.246 \times 0.15, M_A = 0.187KNm$$

$$M_A = 0.187KNms$$

Now, the diameter of the shaft required can be determined using the ASME code equation for solid shaft.

Recall that ASME code equation for solid shaft is given as;

$$d^3 = \frac{16}{\pi\tau_s} \times \sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2} \qquad (3.25)$$

Where, $d = diameter\ of\ the\ shaft$

$\tau_s =$

$Allowable\ combine\ shear\ stress\ for\ bending\ and\ torsional\ for\ shaft\ with\ keyway$ $(56 \times 10^6\ N/m^2$

$M_b = Bending\ moment\ (maximum)\ 0.187KNm$

$M_t = Torsional\ moment\ (maximum)\ 0.021KNm$

$K_b = Combine\ shock\ and\ fatigue\ factor\ for\ bending\ \ (1.5)$

$K_t = Allowable\ combine\ shear\ for\ bending\ and\ torsional\ (1.0)$

Hence, $d^3 = \frac{16}{\pi\times(56\times10^6)} \times \sqrt{(1.5 \times 187)^2 + (1.0 \times 21)^2}$

$= \frac{16}{\pi\times(56\times10^6)} \times \sqrt{79121}$

$= \frac{16\times281.28}{175.93\times10^6)}, d^3 = 25.72 \times 10^{-6}$

$d = (25.72 \times 10^{-6})^{1/3}$

$= 0.0295m$

$d = 29.5mm$

Therefore, the shaft of diameter 30mm was chosen for the extractor.

3.4.12 Bearing fatigue life

Given that the bearing operating under favourable condition, i.e. maintained, lubricated and utilized correctly, the life of the bearing will reach and even exceed the calculated life.

$$L_n = \frac{16667 \times a_1 \times a_2 \times a_3}{N} \left[\frac{F_B \times C_E}{P}\right]^3 (h) \qquad (3.26)$$

For simple rollers bearing where $a_1 a_2 a_3$ can be considered as a unity i.e. one then the above equation is simplified to be;

$$L_n = \frac{16667}{N} \times \left[\frac{F_B \times C_E}{P}\right]^3 (h) \qquad (3.27)$$

Where, $L_n = Life\ in\ hours$

$C_E = Extented\ basic\ dynamic\ load\ rating\ for\ the\ radial\ ball\ bearing (Newton)$

$F_B = Dynamic\ load\ rating\ adjustment\ factor\ for\ number\ of\ adjactently\ mounted$

$bearings$

$a_1, a_2, a_3, = Life\ adjustment\ factor\ for\ reliability\ ball\ bearing\ material\ and$

$applicationcondition$

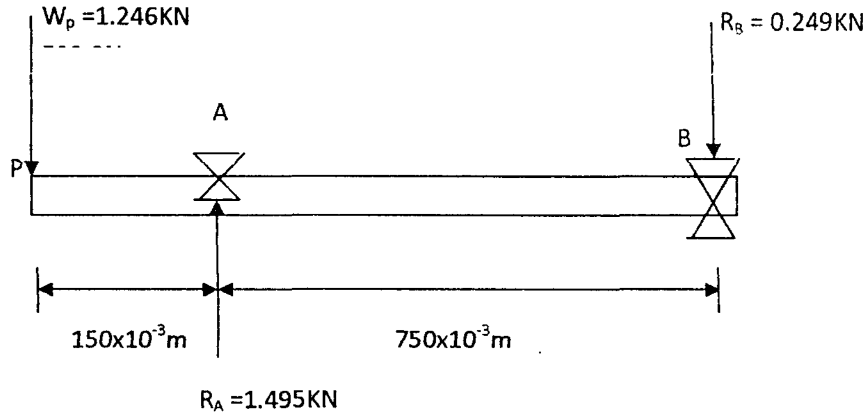
$N = Operating\ speed\ of\ the\ shaft$

P= Equivalent radial load on bearing (Newton)

From the diagram below;

Bearing fatigue life $(bearing\ P + A)$

From principal dimension table for radial ball bearing, a 56205 sealed bearing was selected, which has a bore of 25mm diameter and an outer diameter of 52mm. This is to suit the bearing application requirement and the shaft diameter.



The life (fatigue life) of the bearing can be calculated from the formula:

$$L_n = \frac{16667}{N}\left[\frac{C_E}{P}\right]^3 (h)$$

Where. $C_E = 2220lbs = 1006.975k = 9875.424N$

$P = 1480N,\ N = 375rpm$

$$L_n = \frac{16667}{375} \times \left[\frac{9875.424}{1480}\right]^3 (h)$$

$$= 44.45 \times 297.09$$

$$= 13205.65(h)$$

for bearing at P + B

$$L_n = \frac{16667}{375} \times \left[\frac{C_E}{P}\right]^3 (h)$$

$But, C_E = 9875.424N, P = 249N$

$$L_n = \frac{16667}{375} \times \left[\frac{9875.424}{249}\right]^3 (h)$$

$$= 44.45 \times 63911.15$$

$$= 2840850.62(h)$$

3.5 Procedures for testing the machine

i. The electric motor 2hp was mounted on the frame of the machine.

ii. The belt was then fitted to the both pulley.

iii. The already peeled mango of total weight 5kg was then fed into the machine through the hopper into the extraction chamber.

iv. The electric motor was plugged to the electric source and switched on.

v. The extraction chamber extracts the juice and sends the seed toward the outlet at the extreme end.

vi. Through the help of the screw, a good extraction was obtained and the extracted juice flows out through the collecting funnel.

vii. After collecting the juice, the number of seeds ejected, completely extracted and the number of mangoes that remain in the drum was determined.

viii. Lastly, the efficiency of the machine was calculated.

3.6 Method of evaluating the machine

The formula used to calculate the efficiency, throughput and the efficiency of the machine are given below.

3.6.1 Extraction efficiency (E.E)

For every experiment, the performance of the extractor was evaluated by determining the efficiency as follows:

$$E.E(\%) = \frac{A_{SE}}{A_{md}} \times 100$$

Where, $A_{SE} = Average\ number\ of\ seed\ ejected\ and\ extracted\ completely$

$A_{md} = Average\ number\ of mango\ fed\ into\ the\ drum$

But,

$$A_{SE} = \frac{T_m}{N_r}$$

Where, $T_m = Total\ number\ of\ mango$

$N_r = Number\ of\ replicatio$

3.6.2 Extractor throughput (T_p)

The throughput of the extractor machine was evaluated using the following equation.

$$T_p(kg/h) = \frac{3.6M_t}{t_s}$$

Where, $M_t = Mass\ of\ mangoes\ before\ extraction$

$t_s = Time\ used\ in\ extraction\ (seconds)$

3.6.3 Extractor capacity

The Capacity of the extractor was evaluated using the formula

$$C_s = 60 \times \frac{\pi}{4}(D^2 - d^2)\rho N\emptyset$$

CHAPTER FOUR

4.0 RESULTS, DISCUSSION AND COST ANALYSIS

4.1 MACHINE TESTING AND RESULTS

After carried out the fabrication of mango juice extracting machine, it was evaluated based on three parameters, namely:-

(i) Extracting efficiency (E.E) of the machine

(ii) Extractor throughput (T_p)

(iii) Capacity of the extractor (c)

4.1.1 EXTRACTING EFFICIENCY (E.E)

The machine was tested three times with 20 mangoes at each batch of the extraction process. The efficiency of the machine was calculated by determining the number of seeds ejected and completely extracted, the number of mangoes partially extracted the number of mangoes that remain in the drum.

The performance test data obtained is analyzed below

TABLE 4.1 PERFORMANCE TEST DATA TABLE

Replication	No. of mangoes	Seed ejected & extracted	Seed partially extracted	Seed remained in drum
1	20	13	3	4
2	20	12	4	4
3	20	13	3	4
Total	**60**	**38**	**10**	**12**

$$\text{Average number} = \frac{\text{Total number of mangoes}}{\text{number of replications}}$$

$$= \frac{60}{3} = 20$$

I.e. Average number of mangoes = 20

Now, the efficiency of the machine can be determined from:-

$$\text{E.E (100\%)} = \frac{A_{SE}}{A_{md}} \times 100$$

Where, A_{SE} = Average number of seed ejected and extracted completely

A_{md} = Average number of mangoes fed into the drum.

But, $A_{SE} = \frac{T_m}{Nr}$

Where, Tm = Total number of seed ejected and extracted completely

N_r = Number of Replication

$$\Rightarrow A_{SE} = \frac{38}{3} = 12.67$$

$$A_{SE} = 13$$

Therefore,

$$E.E\,(\%) = \frac{13}{20} \times 100$$

$$= 65\%$$

4.1.2 EXTRACTOR THROUGHPUT (T_P)

The throughput of the extractor was calculated using the following equation:-

$$T_p(kg/h) = \frac{3.6M_t}{t_s}$$

Where, M_t = Mass of mangoes before extraction (5kg)

t_s = Time used in extraction (seconds) 5 minutes

I.e. $$T_p = \frac{3.6 \times 5}{5 \times 60} = \frac{18}{300}$$

$$T_p = 0.06kg/\sec$$

4.1.3 EXTRACTOR CAPACITY

The capacity of the screw conveyor is calculated using the equation:-

$$C_s = 60 \times \frac{\pi}{4}\left(D^2 - d^2\right)\rho N\theta$$

where:-

C_s = theoretical capacity (m^3/h)

D = screw diameter (0.22m)

d = shaft diameter (0.03m)

ρ = screw pitch (0.1m using average pitch value)

θ = filing factor (assume $\theta = 0.8$)

N = shaft speed (375rev/min)

Hence,

$$C_s = 60 \times (0.22^2 - 0.03^2) \times 0.1 \times 375 \times 0.8$$

$$= 47.12 \times 0.0475 \times 30$$

$$C_s = 67.15\, m^3/h$$

$$= \frac{67.15}{60 \times 60} = 0.019\, m^3/s$$

4.2 DISCUSSION OF THE RESULTS

The mango fruit was peeled, the machine was fed with the quantity of 5kg to be extracted at the running speed of 375rpm. The time taken and the quantity extracted were daily recorded. The separation of the mango seeds, fully extracted and the partially extracted was done manually and the number of mango seeds remaining in the drum was determined. The time for extraction was 5 minutes.

After testing the machine with 5 kg of mangoes at the regular speed of 375 rpm, the efficiency of the machine was found to be 65 %, the throughput of the extractor was found to be 0.06 kg/sec and the extractor capacity was also obtained as $0.019m^3/s$

4.3 COST ANALYSIS

The global financial crisis of which Nigeria also experienced a part of, affected most, if not all the costs of the materials used in this work. The material costs listed in the table below are the costs of the material used for the construction of the machine as at December, 2009

Table 4.2: Material Costing and Analysis

S/No.	Material	Quantity	Cost (=N=)	Amount (=N=)
1	Aluminum	1 sheet	3000	3000
2	Mild steel	1 sheet	2500	2500
3	Shaft	1	1000	1000
4	Angle bar	2 ½ length	1200	3000
5	Bearing	2	600	1200
6	Bearing house	2	500	1000
7	Paint	1 liter	1000	1000
8	Thinner	1 liter	150	150
9	Bolts & nuts	8	20	160
10	Pulley	1	1200	1200
	Total			14210

Material Cost = 14210

4.3.1 LABOUR COST

Labour cost involves the cost of machining, cutting, welding and painting. It is accepted as 60% of the total material cost.

Therefore,

$$\text{Labour Cost} = \frac{60}{100} \text{x}\ 14210 = 8526.00$$

4.3.2 OVERHEAD COST

This cost includes the cost incurred during production such as transportation, lubrication, installation, testing cost, miscellaneous costs as well as consumables. The overhead cost is taken as 25% of the labour cost.

Therefore,

$$\text{Overhead Cost} = \frac{25}{100} \text{x}\ 8526 = 2131.50$$

4.3.3 TOTAL COST

The total cost of the calculation could now be said to be the sum of the Material cost, labour cost and overhead cost

Therefore:

$$\text{Total Cost} = \text{Material cost} + \text{labour cost} + \text{overhead cost}$$

$$= 14210 + 8526 + 2131.5 = 24867.5$$

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In conclusion, after testing the machine, it was found that the extraction of the juice was done effectively without crushing the seed with the juice extracted and also the efficiency found to be 65%. If carefully handled, the machine is of a great prospect to our growing economy. It was observed that the quality of mangoes fed into the machine should be much for high efficiency. The machine is easy to maintain and replacement of parts can be done with ease because the machine was made from locally and readily available materials.

5.2 RECOMMENDATIONS

Based on the results obtained after testing the mango juice extractor, the following recommendations were made:

i. The aspect of peeling the mango is still a major factor as it requires much time and might also contaminate the mango before extraction. It is therefore recommended as a research area for other student in the future.

ii. The perforations of the inner cylinder should be increased in order to allow for free flow of the extracted juice. Pulping equipment should also be incorporated to separate the juice from the fruit pulp to avoid blockage of the perforations.

iii. The length of the auger conveyor should be increased to cover about 95% of the shaft for proper juicing and easy ejection of seeds.

iv. For all parts coming in contact with the fruits, it is recommended that stainless steel could be better used in place of mild steel due to its non corrosive nature because it is a food processing machine.

v. The rotation of the auger conveyor was found to be high which affect the efficiency of the machine and the rate at which the juice is extracted. A gear speed reduction mechanism capable of giving speed output of (15.35rpm) is therefore recommended.

vi. Electric motor should be provided by the department to reduce cost on the student.

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