Design Fabrication of an Improved Portable Vegetable Slicing Machine

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Abstract- ***This Project covers the design and manufacture of an improved portable vegetable slicing machine within available materials; it operates automatically with a self-loading rotary motion principle. It is designed to slice the leaf vegetable to about 7mm width. The reliability of the improved concept to be developed was based on simple gear train arrangement which can operate easily without negative slip. So it was selected for fabrication. The result of this project will go a long way to help in the development of a commercially viable leaf vegetable slicing machine that would be affordable to every user.***

Indexed Terms- ***Design, Fabrication, Portable Vegetable Slicing Machine***

I. INTRODUCTION

Vegetable is the term used to denote any member of the plant kingdom (culturated herbaceous) of which any part especially its leaves or roots, is taken savoury frequently, with meat or fish. Even though the term vegetable is a collective term for other plants such as tomatoes, carrots, eggplant, okra, pumpkin leaves and water leaf etc., it is worthy to mention without equivocation that other fruit plant scan also be classified as vegetable by a large majority of people to who they are native. This underscores the difficulty involved whilst attempting to define the word vegetables (Oxford Dictionary).

Vegetable provides mankind with essential health protective vitamins and minerals on the ground that the long term herbaceous portion is the part eaten. Leafy vegetable mostly used as food are oval, irregular in shape with a leathery surface and as such have to be shredded or sliced before it is ready for eating. As a special class of food eaten by both man and animals vegetable are increasingly becoming of more importance not only in Africa but also in the world at large. This is as a result of the under enumerated:

a. Admittedly, vegetables production is labour intensive with little input beyond seed and seedlings. Their high yields however, makes their production more viable compared to those of other crops such as yams, plantains etc. Vegetable production provides earning for people living in the rural areas such as producers, and traders of vegetables.
b. Vegetable is comprised of lots of nutrients that cannot be synthesized by animal by virtue of the fact that they absorb and minerals from the soil directly. Example of such nutrients are calcium, potassium, magnesium, manganese, cobalt, sodium, carotene including other varieties of nutrients too numerous to mention.
c. Abundance and low cost of vegetable: Vegetable by virtue of the reasons outlined in (a) above are relatively abundant in large quantities at some seasons of the year. This is due to the fact that weather variations do not have much influence of vegetable out put. Equivalent amount of vegetables in terms of nutrients supplies are considerably cheaper compared to that of meat or fish.

In addition to the above, several other factors such as religious beliefs as in the case of Buddhist, Hindus and even the Seventh day Adventist and also the risk of contaminated meat such as infected pork etc. and fish capable of passing on diseases to mankind makes vegetable important for consumption. Studies in Europe and America has fingered chemicals used in treating meat on large scale forms especially clembuterol, dietitesbestro (DES) including doses of antibiotics in promoting the spread of resistant strains of bacteria to man and increasing the risk of contracting various forms of cancer.

Vegetables can also be used as herbs for medicinal purposes. This has culminated into its continues cultivation on the ground that it can be cheaply cultivated. This has made vegetable cultivation in Europe, America and African to be very important in this contemporary world.

II. PROCESSING VEGETABLE

The conventional method employed for preparing vegetables is old as the earth and it is still commonly used by most of each other with the aid of a sharp knife on a chopping board. This process is tedious, dangerous and unhygienic. It is most times done by vegetables sellers annually. Although it is easier for the end user, it has many draw backs listed below:

a. The same chopping knife and chopping board is used for all the vegetable the trader slices and often times, wood chips maybe seen in the mass of the vegetables sliced.
b. The need for speedy slicing often makes the sellers to sustain injuries themselves in the process no matter the level of caution, since the knife is usually very sharp and may not be making the same stroke of cut. This will lead to the probability of spreading diseases due to the cut from the seller.
c. Large proportion of vegetables could be chopped at a time at a given time if its demand increases due to manually means of chopping.

III. THE NEED FOR VEGETABLE SLICING MACHINE

The increase rate of vegetable consumption and the advent of globalization coupled with the economic consequences of free trade and market economics has made the commercialization of materials, goods and services near inevitable.

It is a well-documented fact that the situation of Africa in the tropics makes it a repository of abundant plant and animal life forms. Its adversity of plant forms is thus virtually unmatched by that of any other continent. This raises the spectre of the need to export this amazing variety of vegetables to other continents. The strict codes of ethics maintained by regulating bodies in Europe and America makes the use of vegetables slicing machine indispensable for processing vegetables more efficiently and hygienically. The need for freshness in food, the high fiber content of vegetables, their high nutrient content and relatively low costs makes vegetables useful as relief materials to those war torn areas of the world, a situation where this vegetable slicing machine could be of immense help. In the home however, the hygiene conscious mother, single man, or students or house wife would find vegetable slicing machine of great importance for providing a clean vegetable food; certainly, efficient way of slicing vegetables for home use. Thus the underlying concept of this study is to provide a portable leaf vegetable slicing machine for home use, vegetable sellers in markets that will provide time efficient, hygienic, stress free means of processing vegetable for uses.

Putting the forgoing discourses into cognizance, it is worthy to mention at this junction that this study was borne out on the ground that due to inconclusive attempts to build a workable self-loading vegetable slicing machine in the past, this study primarily aims to improve on the design and manufacture of one previously done. In view of the pre-going, this study is confined to testing and analyzing the prototype manufactured previously. The identification of its inherent faults, and the rectification of those faults shall go a step further in making the new prototype a good success. It is aimed at rectifying the flaws in the previous one done and in the new prototype, I tested extensively the efficiency, suitability and reliability of the new improved vegetable slicing machine to be built. Moreover, ideas and concepts as to how this machine can be mass produced for commercialization is considered in this study.

IV. OBJECTIVES OF THE STUDY

The primary aim of this study is basically an attempt to use some of the theoretical knowledge gained during my sojourn in the University of Benin to create something of importance to the general public and to fill a gapping need. Having attempted a thorough research into the nature, composition, constituents advantages of incorporating vegetables into human diet, the amazing discovery is that significant advantages exists in pursuing a vegetable slicing machine that could be manufactured with

locally sourced materials. To this end, the aims and objectives of this study includes:

i. To provide a locally designed and manufactured prototype of a portable self loading vegetable slicing machine
ii. To compile and present the compelling evidence on the significant advantage of a vegetable based diet.
iii. To provide a cheap and reliable way of processing vegetables
iv. To provide a portable vegetable slicing machine that is affordable to users
v. To provide a vegetable slicing machine that can process vegetable in large quantities within the shortest time

V. METHODOLOGY

This machine was designed and fabricated locally using available materials. I made use of two parallel shafts wherein the circular cutting part was machined out of the shaft. The two shaft, one of which is powered by electric motor with the aid of a gear it drives the second shaft. The two shaft are meshed in such a way that they rotate to their common centre, which enables them to shear the leaves.

VI. LITERATURE REVIEW

The importance of using vegetable machine cannot be over emphasized due to the presence of high loads of vitamins and minerals that it contains. There is therefore need to for a leaf vegetable cutting machine to be produced for the aim of cutting/slicing. To this end, a marked survey and research was conducted in southern Nigeria metropolis including the breath of the University of Benin to ascertain the improvement on the previously made vegetable slicing machine in order to critically analyze and look thoroughly at areas in which it has some drawback and improve on it.

From previous research data however, it was discovered that there is no leaf slicing machine in the Nigeria market. The closest attempt in the market is a multipurpose blender that is used for slicing other types of vegetables such as carrots, cabbage, cucumber etc. Moreover, the only leaf vegetable slicing machine ever produced by the Department of Mechanical Engineering in the University of Benin lacks some basic characteristics capable of attracting its future mass production and safety factors such as its size and weight has made it so discouraging for some home users, so also the arrangement of its cutting chamber. These machines were made in the aforementioned department during the 1999/2000 and 2002/2003 academic sessions; hence they need improvement. Again here, they need improvement on the ground that they are marred with certain flaws. Hence this present study will focus on the related concepts closest to obtaining a leaf vegetable slicing machine, to analyze the concept of the design and the limitations to obtaining the desired slicing machine.

VII. THE ROTATRY BLADE FRUIT VEGETABLE SLICER

This machine slices vegetables like carrots, cabbage etc. that are not compressible. It is also capable of blending vegetables which can be interchanged to suit a desired cut, a collector for a sliced fruits, a hopper for feeding in the vegetable, the power compartment and the blending compartment.

VIII. MULTIPURPOSE BLENDER

PRINCPLE OF OPERATION

The vegetables are fed in the proper hopper, as the blade rotates (fig 1), the sharp edged groove with an opening into the collector slices the vegetables that are fed through it to fall into the collector. After the slicing process is completed, the hopper is removed as is the blade and the sliced vegetable is poured out. The blades are interchangeable and are in many forms to suit a desired cut, like for chopping okra, carrot etc.

LIMITATIONS OF THIS MACHINE

The multipurpose slicer is useful only for fruity vegetables such as okra, carrot and cabbage etc. that are not compressible i.e. they are rigid. But for leafy vegetables that are not rigid, it cannot be used because:

1. An additional force will be required to force down the vegetable to meet the blades
2. The vegetables might slide during the surface of the blade and this stop the rotation of the blade.

3. Leaf vegetable thickness is very small so it needs a support to be placed or arranged before shearing or cutting could take place.

REVIEW 2

The first attempt on the reciprocating vegetable slicing machine was developed in the department of Mechanical Engineering, University of Benin during the 1999/2000 academic session. The machine was comprised of the following:

a. The hopper
b. The conveyor
c. The Cutter/slicer mechanism
d. The collector

PRINCIPLES OF OPERATION

The vegetables are fed directly into the machine through the hopper as the fall into the conveyor by the force of gravity. As the conveyor rotates continuously, the vegetables in it are transferred into scissors type reciprocating cutting disc, consisting of a fixed knife edge to slice the vegetables. The sliced vegetables then fall to the collector, under the action of gravity.

LIMITATION OF FIRST ATTEMPT

The factors that made the first attempt to fall below the expected performance are considered thus:

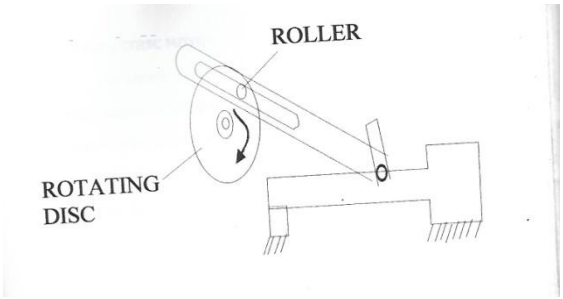
1. Conveyor
2. The reciprocating cutting mechanism
3. The electric motor
4. General

CONVEYOR

The motion of the conveyor belt was continuous such that when cutting was taking place, vegetables were still being fed to the cutter mechanism, causing an unregulated quantity of vegetable admitted for cutting per a slice. To overcome this set back, an intermittent conveyor mechanism was chosen to be the appropriate system to admit vegetable to the cutter in a regulated manner to achieve the slicing required per cutting motion.

THE RECIPROCATING CUTTING MECHNISM

The reciprocating cutting mechanism used in the first attempt was a scissors type reciprocating mechanism shown/depicted in figure 2



As can be from the diagram above, as the disc rotates, the roller slides along the groove of the moveable knife edge to move it up and down in a reciprocating manner. The set back here was the angular clearance. Space through which vegetables are admitted for slicing is shown in figure 2. It is obvious that vegetables are not conveyed properly into the slicing mechanism at equal pace. Since one side of the clearance is wider than the other side. To overcome this set back, a mechanism that could produce a uniform cut had to be designed.

ELECTRIC MOTOR

The electric motor used for the machine has a high power rating compared to the overall power requirement of the designed machine, thereby causing vibrations in nearly all part of the machine and failure of some parts and materials used. Generally, the materials used for the cutting mechanism were not properly hardened (heat treated) and are not stainless steel which may add some rust to the vegetables being sliced due to wear of the roller in the disc as a result of friction generated between the roller and slot of the sliding movable knife.

REVIEW 3

ANOTHER MACHINE STILL EXAMINE CRITICALLY

Is the stationary vegetable slicing machine. This machine was in the department of Mechanical Engineering, University of Benin. The cutting process is done when the via the movable blade. The cutting process is done when the movable blade is pressed downward as the vegetables are being fed into the machine manually.

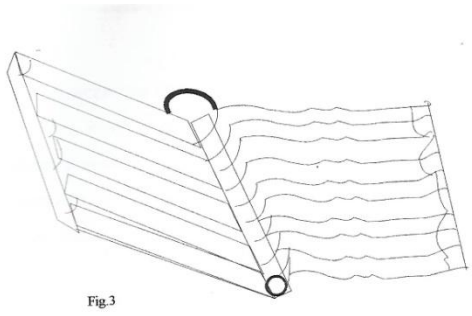


Fig.3

LIMITATION OF THE OPERATED VEGETABLE SLICER

1. The blades are fixed and not replaceable
2. The vegetables are manually fed into the machine
3. The shearing action of the machine is not uniform since all the blades fixed do not have the same force applied on them at he same time.
4. The blades were not made of highly corrosion resistant materials. This also a limitation to its use.

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CONCEPTUAL DESIGN

The design methodological concept approaches solving the identified problems in the previous machines that have been designed in the department and other ones available which have some drawback. Hence, choosing an appropriate concept and designing for a modification using the acceptance concept. The improved portable vegetable slicing machine would also be tested and comparison made with the previous design. Thus, a machine which should have a reorientation of the cutting mechanism like the paper shredder was chosen. The entire cutting system will be so arranged that the paper to its arrangement. However, the problems inherent in the machine earlier produced are:

CONCEPT 1

1. A one toothed gear mechanism: this concept has a one toothed gear meshing with a multiple toothed gear as shown;

(diagram of fig 4)

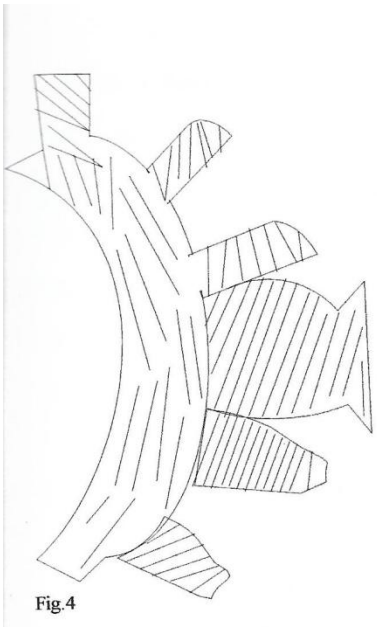


Fig.4

The one toothed gear concept

a. One toothed gear
b. Multiple gear

Critically observing the operation of this two meshing gears; the one toothed gear stands as the driver and the multiple gear is driven. The idea was to attach the multiple toothed gear to the conveyor so that as the one tooth gear meshes with the driven, it turns it then disengages for a while. However, from the consideration of wear and the stresses induced at the root of the tooth, a one toothed gear meshing is not feasible.

2. Conveyor (Belt) Mechanism: The length of the transfer of the vegetable along this line before cutting is some more that the vegetables are not cut instantaneously. A situation like this poses a problem on the ground that some vegetables may fall to the side of the conveyor.
3. The concept of the fixed movable blade manually operated cutting machine was looked at critically but there was no movable part except the point of support and it could be improved upon only in terms of the quantity of blades used.

(fig 5 diagram here)

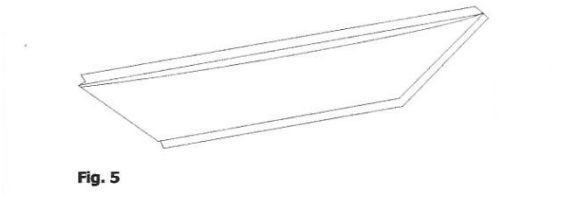
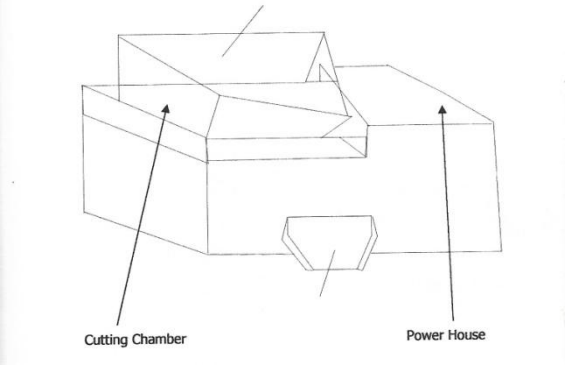


Fig. 5

Both concept one and two do not produce the improved type leaf vegetable slicing machine needed. However, concept one seems more plausible bearing in mind the difficulty to be encountered in manufacturing it and its weight. Although, the concept one is chosen but it has to be improved upon. The new concept evolve utilizes two shaft rotating counter clockwise towards a common center as they are aligned using a gear train. The cutting operation of these two shafts can be seen when they rub each other as the shredding of the vegetable takes place.

(fig 6 showing the concept evolved should be placed here)



DESIGN SPECIFICATION

This involves the various requirements which the design must meet. It is usually the basis on which the design concepts and the detailed design are based. The design specification provides more specific and quantitative information about the machine to be designed. Therefore, the design specifications of portable leaf vegetable slicing machine are discussed in the subheadings below:

a. MACHINE PERFORMANCE

The portable leaf vegetable machine is expected to slice a maximum of 10kg of leaf vegetable in a minute. However, the leaf to be sliced should be pre-washed, pre-selected to avoid stone or sticks combining with the vegetables during slicing.

b. POWER REQUIREMENT

The power requirement for this machine should be 0.5 horse power. This is based on the experimental analysis carried out on the specimens transmission in terms of efficiency.

c. POWER SOURCE SELECTION

Presently, there are two available options, electrical and internal combustion engine. The choice in this case reflects how readily available the source is. One may be compelled to choose electric motor because it is always available in the market. It is important to consider the availability of electricity in the operating vicinity.

Internal combustion engine, once available serves in any part of the country whether urban or rural. All that is required is the availability of fuel. For the fact that electricity is readily available compared to internal combustion engines, electric motor has been chosen for this machine.

d. ENVIRONMENT

The most important component to be considered in this are the cutting disc and the cutting shaft, hopper because they are the parts that come in contact with the food material. Hence the machine should not be operated in an acidic environment to avoid corrosion of the cutting disc since they come in contact with the food material. Therefore, the choice of materials for the components reduces the effect of corrosion on the stainless steel which is least attacked by corrosion is recommended for the shaft and disc while mild steel for the other parts.

e. RELIABILITY

The machine should not require a sliced operator. Moreover, the machine should be simple so that the maintenance would require little or no skill. All the parts should be accessible so that fault anywhere can be easily detected and repaired immediately. Thus, less time will be wasted in maintenance and it will cost little to maintain, since the operator can always have access to any part that needs repair. It is expected that the machine should be able to compete effectively with any other similarly available in the market.

f. SIZE AND WEIGHT

The total weight of the machine should be 12000k. this massive weight is primarily to maximize vibration and to provide the necessary stability required by the machine. The machine is expected to be about 600mm high, 450mm wide and 560mm long.

g. LIFE SPAN

The machine should effectively work for about six years, thus its active life with little maintenance. However, this life span depends on many factors. These include:

1. Working hours per day
2. Method of handling
3. Exposure to environmental effect
4. Effective maintenance when necessary
5. Fabrication process

It is pertinent to mention at this junction that for the machine to be able to work effectively for a maximum of six years, the conditions for which the machine is designed must be observed; for instance, the machine is not designed to slice other types of vegetables like carrot, garden egg or any other type of vegetable that it is not meant or designed for. Additionally, the machine should not be kept under severe environmental effect.

h. COST

From the breakdown of the market prices of some of the components, it is estimated that the cost of the machine should not exceed N14, 500.00.

PRELIMINARY DESIGN

EXPERIMENTAL ANALYSIS

In this work, I considered improving on a portable vegetable (leaf) slicing machine for domestic and market use, capable of slicing all types of leaf vegetables such as pumpkin, squash, marrow, bitter leaf, green vegetables, water leaf, hospital leaf etc.

Due to variation in sizes (dimension) of the above mentioned materials and also to design a machine that would be able to slice those leaves perfectly in shred form, I carried out experimental analysis by applying the weight to a knife in a bid to cut the various vegetable leaves, the depth of cut, length of cut were recorded. Hence the shear stress of various vegetable leaves was determined and the weight applied was also recorded.

The result of this analysis unveiled that the minimum average depth of cut was 0.123mm, which was the depth of cut for hospital leaf and the maximum average depth of cut was 0.620mm which was the depth of cut for water leaf.

HOSPITAL LEAF

Weight of cut = 3.5kg

Cutting force = 3.5 x 9.81 = 34.34N

Average depth of cut = $\frac{0.1 + 0.15 + 0.12}{3}$

SN	Depth of Cut	Width of Cut
1	0.1	63
2	0.15	62
3	0.12	63

Cross Sectional Area

=0.123 x 63

= 7.77mm

Shear Stress = 34.34/7.77

= 4.42mm2

WATER LEAF

Weight = 4kg

Shear Force = 4 x 9.81

= 39.24N

SN	Depth of Cut	Width of Cut
1	0.6	17
2	0.56	18
3	0.7	16

Average depth of cut

$$\frac{0.6 + 0.50 + 0.7}{3}$$

= 0.62mm

Width of cut = 17mm

Cross Sectional area

0.62 x 54mm^2

Shear Stress = 39.24/10.54

=3.72mm^2

IMPACT EXPERIMENT

In order to determine the power requirement of the machine, I carried out impact experiment aimed at determining the maximum force required to slice leaf vegetables. However, before experiment commenced, we had to determine the hardest of the vegetables to be sliced. Taking the hospital leaf, the experiment was performed using a sharp knife raised at a particular height, while certain mass was placed on top, meanwhile, the vegetable to be cut were placed at the bottom and the knife is directed to fall on the vegetables. The experiment was performed more than three times on different leaf vegetables and their results is shown below:

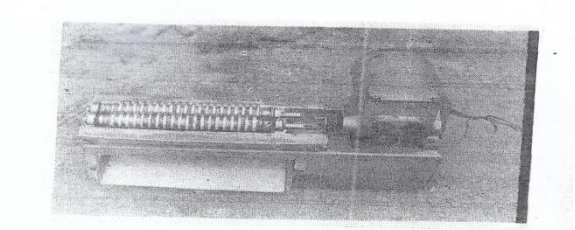


fig.8

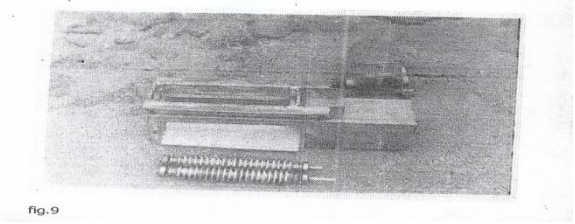


fig.9

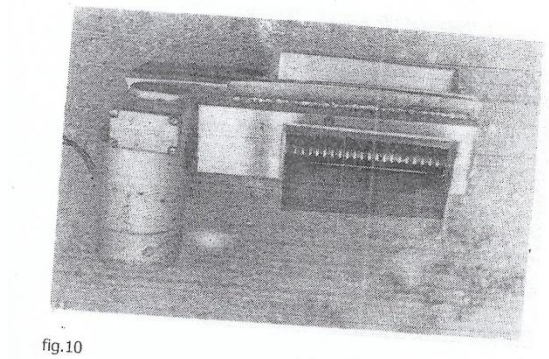


fig.10

HOSPITAL LEAF

Depth or height for cut = 0.123mm

Depth or the height of cut for water leaf = 0.62mm

$$thus: \sqrt{2gh}$$

V =$\sqrt{2\ x\ 9.81\ x\ 0.123}$

= 1.5534m/s

From the experimental analysis, the mean height depth for water leaf is

= 0.62mm

Thus: V = $\sqrt{2\ x\ 9.81\ x\ 0.62}$

= 3.49m/s

The potential energy is converted to Kinetic Energy, hence the time taken to cut the vegetable is assumed to be 2/100, = 304.54/s.

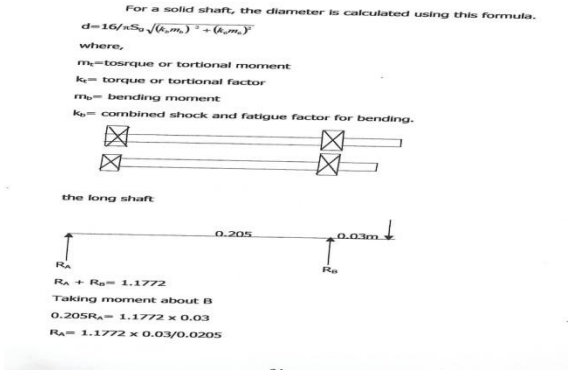
An electric motor of power rating 1200watts i.e. with a safety factor of 4, can be used.

1kw = 1hp = 0.75kw

Hence, for the machine, a single phase of 0.5 hp is used

P = 0.5 x 750 = 375watt.

DETAIL DESIGN, RESULTS AND DISCUSSION



R_A = 0.15N

R_B= 1.1772-0.15

R_B= 1.0272N

Moment at A= 0.15 (0.205 + 0.03)

= 0.152 x 0.235

moment at B= 1.0272 x 0.03

= 0.0308Nm

Power = force x speed

Force=

Speed= $\frac{2\pi x100}{60} = 10.47 rad/s$

d radius of gear box shaft = 9/2 = 4.5mm

= 0.0045

speed = 10.43 x 0.0045= 0.018m/s

force= 375/0.018 = 20,833.3N

Torque on cutting shaft

= 20,833.3 x 0.02

= 416.67Nm

∴ M_t= 416.67Nm

After the completion of the machine, the following procedure was adopted in testing the machine. Having ensure that all components were tightly coupled, the electric motor was attached to the shaft through the gear was switch on and the machine was operated for 20minutes. My major observation was the cutting disc rotation, which was as a result of the improper seating bearing. This was rectified immediately. This was followed by the testing of how the cutting disc cut when over loaded with vegetables; the disc will be dragging while some vegetables are being cut. The faith of the cutting disc was dragging as a result of the vegetables not well fed into the cutting chamber through the hopper, and this was corrected as well.

However, when the machine was tested with the maximum capacity, the hopper could not hold, it worked satisfactorily. Hence from this result, the output produced shows that out of 5 of bitter leaf loaded into the hopper, 49 were obtained after slicing. Based on this, the efficiency was calculated to be 80% i.e. Output/Input x 100 = efficiency; 4/5 x 100 = 80%.

Similar test was carried out for the other vegetables leaf like water leaf, pumpkin leaf etc. and similar results were obtained. From these findings, one can safely posit that the machine exhibits satisfactory performance.

RECOMMENDATIONS ANDCONCLUSION

This study was not very easy because I encountered a lot of inconsistencies and draw backs in the course of trying to make it a reality. During the course of this study, I was faced with some problems such as:

1. Constant power fluctuations and failures which debarred me from carrying out my operations, hence leading to delays in supposed time of completion of this study.
2. High cost of materials drained my purse of my hard earned money. Meaning to say that money to purchase appropriate materials was not readily available and this delayed the completion time of this study.
3. Some of the vital parts and materials required for this study were not readily available in the local scrap market nearby me. Hence it took a long time to fabricate them out.

SOLUTIONS

1. Availability of materials
2. Reduction in price of raw materials
3. Constant power supply
4. Proper planning to save

RECOMMENDATION

Fresh research work on this project should be geared towards modifying the cutting/slicing disc with PVC material to save cost and time of manufacturing the shaft.

CONCLUSION

Although the task of completing this study was not easy as earlier mentioned, the usefulness of this machine cannot be over emphasized. The design and construction of this project has added another feather to the overgrowing technological advancement of Nigeria. This study has enabled me to apply my theoretical and practical experiences required during my university days into practice. It is my hope that technologically, at the indigenous level, this machine

will go a long way to slice all forms of vegetables available in Nigeria including other parts of the world. This machine is highly recommended for both domestic and commercial purposes as it saves time and produces a better output. The production of this machine, if enlarge and embarked upon will alleviate the problem faced by leaf vegetable sellers in the market places, hence increase their sales output.

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