Design of an automated peanut butter making machine in developing countries

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Abstract

This paper is on the design of automated peanut butter making machine for a developing economy which targets small scale farmers. Many developing countries are still using traditional methods in making peanut butter for example pestle and motor while others are using hand operated machines which are laborious and slow. The demand of peanut butter is increasing but machines are manually and expensive therefore the production rate of peanut butter is low in developing economy. If peanut butter peanut is taken in small proportions chances of chronic diseases are reduced and also due to high proportion of carbohydrates in peanut butter there is gain in weight. There are three types of forces when crushing solid food namely shear, impact and compression. Rittinger, Kick and Bond laws are used to determine amount of energy needed in size reduction of solid food. . After careful analysis of current peanut butter making machines and thorough study, a solution was developed that is efficient, safe and affordable The machine grind 50-56kg per hour with minimum human involvement since the machine automatically stop if all peanuts in the hopper get exhausted. Power required to grind peanuts is approximately 1.01kW.

Key words: Automated, peanut butter, machine, design, developing nation

1. Introduction

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Groundnut (Arachis hypogaea) is an known as peanut, earthnut and ground bean and annual legume which fall into oil seed crops, groundnuts are used in many food products because of high nutrition density (Shahzad, et al., 2011). There are different types of groundnuts which are grown and these include Runner, Virginia, Spanish and Valencia. According to Gujarat Agro Industries Corporation, Peanut butter contains high percentage of protein and low calorie product that possesses high nutritional value. It is used in developing countries as a healthy alternative to dairy butter. The demand of peanut butter is increasing because is used as a substitute for milk due to increase in costs and shortage in supply of milk. Traditional methods are failing to meet the demand of peanut butter because they are laborious and slow. This project is based on the improvement of quantity and quality of peanut butter and also the efficiency of the machine through the design of an automatic peanut butter making machine that crush peanuts into paste automatically.

1.1 Background

1.1.1 Brief History of Peanut Butter Making Machine

Beacon Learning Center, 2003) states that peanut butter was first made in 1904 at war to hill wounded soldiers .Due to high nutrition density of peanut butter and low costs, people grinded peanuts into paste for making stews and porridge mostly. These factors made peanut butter to become a valuable product within the world and the demand of peanut butter increased world- wide. This raised a duty to scientist to mechanize the production of peanut butter which increased the supply of peanut butter in a short period of time. (Katz, 1997) States that initially other people used manual operated meat grinder to make peanut butter so as to feed people with poor teeth. Studies showed that peanut butter was used as a source of proteins to heal up wounds and mainly was used in battles.

1.1.2 Existing machines

There is a hand operated peanut butter which is used by small scale farmers to grind peanuts into paste. This machine is almost affordable by every small scale peanut butter producers, however this machine requires a lot of labor to operate and is time consuming. There were developments on the peanut butter making machine to increase the quantity of peanut butter by inserting an electric motor. This machine requires attention when in operation to reduce chances of failure of the machine when excess peanuts are fed into the machine. Also this machine has high processing time .Electric peanut Butter making machines are expensive. Hence designing a machine that crushes peanuts into paste automatically will cater this problem and also the machine will costs less than $300 for the affordability to almost every farmer.

1.2 OBJECTIVES

To design:

- ✓ A system that crushes roasted peanuts into paste automatically
- ✓ A system that controls the amount of roasted peanuts entering into a machine.
- ✓ A machine that meet the standards set by Standards Boards
- ✓ A design a machine that costs $200-$300

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2. Literature Review

2.1 Peanuts or Groundnuts

Groundnut or peanut and also called (Arachis hypogaea L.) is a crop with fruits produced underground or below the surface (Prasad, et al., 2011).Groundnuts originated from South America. The groundnut plant can grow to a height of 60 centimeters and can spread up to 100 centimeters, depending on variety and conditions. The plant is different in that it flowers above ground and then once pollinated, produces its fruit below the soil surface. Usually flowers are yellow in color and self- pollination occurs in plants. Most of the groundnuts are used in making peanut butter because of high nutrition values while others uses groundnut to make oils due to high content of oil in kernels. (Akcali, et al., 2006) Pointed that peanuts seeds contains approximately 43-55% oil and 25-28% proteins. There are four major types of groundnuts grown which are Runner, Virginia, Spanish and Valencia. Many of peanuts are used for making peanut butter as shown.

Table 1 Uses of peanuts

	2015/16	**% change to 2014/15**	**2014/15**	**2013/14**
Production	40.779	+2.8	39,673	41,154
Beginning stocks	2.257	-11.1	2,540	2,240
Imports	2.456	+0.1	2,383	2,383
Total Supply	45.492	+1.8	44,666	45,777
Exports	2.911	-5.6	3,085	2,885
Domestic consumption	39.683	+0.9	39,324	40,352
Food use domestic cons	19.170	+1.0	18,980	18,901
Feed waste domestic cons	3.093	+12.2	2,756	3,794
Crush	17.420	-0.95	17,588	17,657
Total disappearance	45.492	+1.8	44,666	45,777
Ending stocks	2.898	+28.4	2,257	2,540

2.2 Peanut Butter

Peanut butter is made from roasted peanuts (approximately 90%) that are grinded into spreadable paste. (Rozalli, et al., 2015).Many developing countries are using peanut butter as a source of nutrients since it has high nutrition density.

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(Griel, et al., 2004) pointed that peanut butter reduces chances of chronic diseases by 39%.Peanut butter has higher calories as compared to milk and increases energy in the body which results in high Body Mass Index. Developing countries are using peanut butter to prevent malnutrition in children (Israëls, et al., 2009). Studies proved that malnutrition results in cancer and taking peanut butter reduces chances of cancer. Heat produced during peanut butter making kills bacteria and low moisture content reduces accumulation of bacteria makes it safer to consume. Studies proved that the viscosity of peanut butter is approximately equal to 250Pa.s.

2.2.1 Stages in making peanut butter

In making peanut butter many stages are taken to produce good quality of peanut butter and these steps include roasting, grinding and mixing with other ingredients. Studies proved that to crush roasted peanuts , 1602.2N is required (Kristin McDaniel, et al., 2012) and the moisture content after roasting peanuts is approximately 2%. Depending on the thickness of peanut butter required, different types of roasted peanuts are fed into the grinding machine. The figure below shows the flow chart of how peanut butter is produced.

2.3 Principle of Operation of Electric Peanut Butter Machine

Different mechanism are used to grind peanuts, rotating plates and rotating blades are used but most of the modern machines uses rotating auger mounted on the shaft. The motor (mostly three phase motor) rotates the shaft which is mounted with blades or screws on the end thereby grinding peanuts into paste. Below the auger or blades there is a sieve which only allows the peanut butter to flow. Depending on the smoothness of peanut butter required different types of sieves are used. The shaft can be linked to the motor through belts or directly.

2.3.1 Grinding mechanism

Roasted peanuts are fed to the machine through a hopper, then the hopper directs peanuts to the screw shaft which is rotated by the motor through belts to reduce shocks on the machine. On the shaft a movable plate is mounted and there is a fixed plate with a hole at the centre which allows peanuts to enter between the rotating plate and the fixed plate. Due to roughness of the plates, friction is created which crush peanuts into paste as the peanuts are squeezed between plates and the peanut butter flows through the sieve which is usually at bottom.

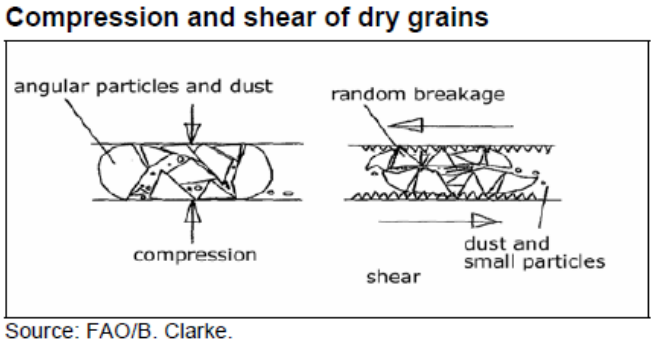

Figure 1. Compression and shear of grains

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The amount of energy required to grind the peanuts depends on the size of the peanuts. In size reduction of solid food there three different of forces exist which are shear, compression and impact (Dziki, et al., 2012). To determine the energy required for crushing and grinding food the following equation is used:

$$dE = \frac{-kdx}{x^n}$$

Where dE is the energy required to break a unit mass

X is the diameter

K, n are constants of grinding

$$E = \int_D^d -Kdx$$

Where d is particle size after grinding

D is the particle size before grinding

Different interpretation of the above equation was done by Rittinger, Bond and Kick

2.4 Problems faced by small Scale Peanut Butter producers

Many developing countries for example Zimbabwe are facing problems with existing peanut butter machines. (Mhazo, et al., 2012) Pointed out several problems uncounted by small scale peanut butter producers in Zimbabwe which includes increase in costs of new machines and spares, lack of equipment design patents and also machines are not meeting the standards set by Standard Association of Zimbabwe. Peanut butter making machines are unlicensed and also the peanut butter is of low quality and not safe to be consumed as a result some of products are banned to be sold by Standard Association of Zimbabwe. Small scale peanut butter producers are usually found in rural areas and these farmers have low income which raise a problem in purchasing peanut butter machines hence farmers they seems to look for cheaper machines which are not patented. Research proved that many developing countries are importing peanut butter machines from developed countries. Also many of these machines are failing due to overloading whereby the user feed excess peanuts and the rotating shaft later fails and also this draws more current. On these machines attention is required when operating because peanuts can be finished inside the hopper and the machine will run which causes failure on the machine and also the bill of electricity will increase.

2.4 1 Good characteristics of peanut butter machine

- Grinding at least 40 KG / hour of peanuts
- Absorbs shocks and vibrations
- Grind all types of peanuts

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- Produces smooth peanut butter

3. Methodology

The purpose of this design is to create an affordable peanut butter making machine that is more efficient and that require minimum human involvement. Demerits from other existing peanut butter making machine will be used to create some of the technical specifications that will help the researcher in attaining the objectives.

Power required=1.1KW

Auger speed=150r.p.m

Output Capacity=56kg/hr

Bulk density of peanuts= $300kg/m^3$

Plate diameter= $100mm$

Auger diameter $=12\times4 \ =48mm$

Work Index of peanuts $=13.17KJkg^{-1}$

Weight $=40kg$

Hopper holding Capacity $=10kg$

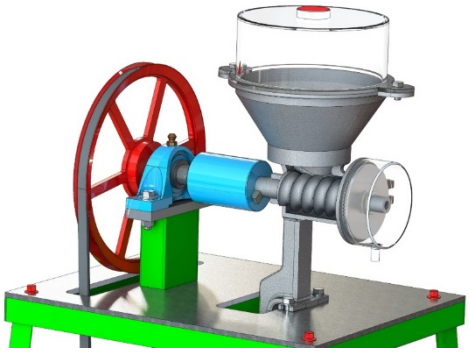

Figure 2 Internal view of peanut butter making machine

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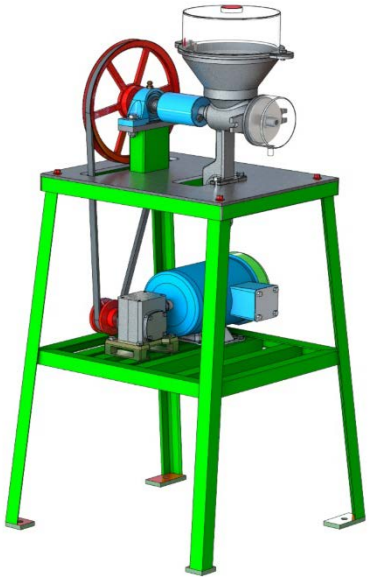

Figure 3 peanut butter making machine

4. Results and discussion

After performing calculation it was found that the machine grinds 56kg per hour with total power of 1.1kw.To reduce maintenance costs 1.5HP air fan motor was selected. An experiment to determine moisture content of roasted peanuts was done and it was observed that to have quality peanut butter 2% moisture content is required. Using bond's equation the amount of energy required to crush roasted peanuts is $57.13KJkg^{-1}$.Amount of energy required depends on the moisture content, size of peanuts and also type of peanuts. To connect shafts muff coupling was used since it is relatively cheap and easy to maintain. V belts were used to reduce shocks and it was found that the maximum tension in the belts is 1.23KN. SKF deep groove radial bearing was selected with life of 11889.265235hours.For maximum grinding of peanuts 100mm stainless plates were selected and these plates resist wear and corrosion.

4.1 Automation

SMT client software is used for automation. The machine regulates amount of peanuts entering into machine from the hopper. Mass sensors check the amount of peanuts entering into the machine and there is feedback to control peanuts. The program is shown on appendix F. After pressing the power button I02, the motor (M01) starts to rotate providing current to the machine. This provide current to the magnet on the regulating mechanism (T01) and the solenoid is attracted to the magnet allowing peanuts to enter into the machine for 20s.The output is shown by Q01. Then the current stops to flow into the magnet for 60s (T01) and the mechanism closes for 60s allowing peanuts to be grinded and the cycle repeat. When there are no peanuts in the machine for 5 minutes there is negative feedback to electric

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motor and the motor automatically stops. When there is emergency, emergency button (i03) is pressed, there is no current flowing and the machine stops.

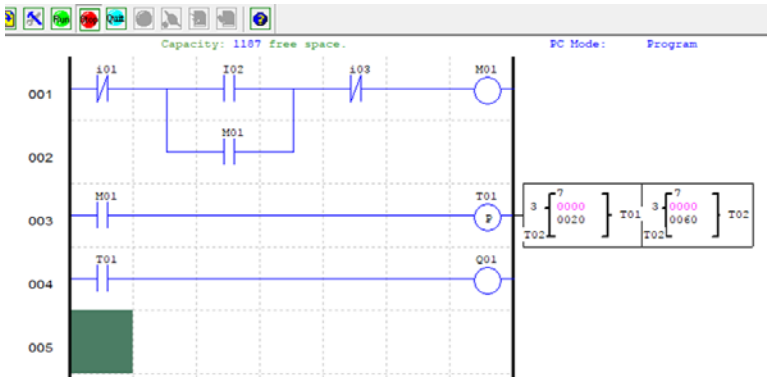

Figure 4. How the system will work with automation

5. Recommendations and conclusion

The purpose of this project was to design automated peanut butter making machine. The machine was successful designed and all the objectives were met. As compared to other existing machines, the machine is almost affordable to almost all small scale farmers that are in the business of making peanut butter. Also the machine serves time when making peanut butter since the machine can be operated while doing other jobs and the control system regulate the amount peanuts entering into the machine. To reduce costs and supporting local business locally available materials were used to during designing. All types of peanuts can be grinded using this machine and also it cushion the vibration hence the machine is stable. When there is no electricity the machine can be operated manually hence there is continuous production of peanut butter.

5.1 Safety and precautions

There are rotating components on the machine for example belts and pulleys, maximum care is needed when operating the machine for example removing of loose clothes. The machines also operates at high voltages therefore wiring should be regularly checked and replaced. In case of emergency there is an emergency button with a red color mainly and after pressing this button the machine automatically stops.

5.2 Maintenance

After using the machine, plates and auger should be disassembled for cleaning with running water to avoid contamination of peanut butter .Moving parts are prone to wearing for example pulley and plates , therefore these parts should be inspected and replaced. Blanching of peanuts is difficult and laborious to small scale farmers hence there is need of mechanism that blanches peanuts and blowing out removed materials together with foreign particles and then blanched peanuts are grinded. Manually packing of peanut butter requires a lot of labor, contaminates peanut

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butter with dirty and also reduces the quality of peanut butter, therefore a mechanism that automatically pack peanut butter is recommended.

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Biographies

Benjamin Moyana is a final year student at the University of Zimbabwe where he is studying Mechanical Engineering. After completing his advanced level at Nyanga High School, he started to develop his interest in engineering by studying various science projects. Benjamin aspires to pursue a career in condition monitoring and also in renewable energy to have a clean source of energy. To gain basic knowledge he decided to study condition monitoring on energy storage. During his spare time he enjoys playing soccer as it helps him in developing team work which is a key issue at work.

Dr. Tawanda Mushiri received his Bachelor of Science Honors Degree in Mechanical Engineering (2004-2008) and a Masters in Manufacturing Systems and Operations Management (MSc. MSOM) (2011-2012) from the University of Zimbabwe, Harare, and a Ph.D. from the University of Johannesburg, South Africa (2013-2017). He also obtained a Certificate with Siemens in Programmable Logic Controllers in the year 2013 where he worked with SCADA and PLC Programming. His doctorate involved fuzzy logic and automated machinery monitoring and control. Currently, he is a Senior Lecturer and Senior Research Associate at the University of Zimbabwe and University of Johannesburg, respectively. In the past (2012-2013), he has also lectured at the Chinhoyi University of Technology, Zimbabwe, lecturing mechatronics courses. He has also been an assistant lecturer for undergraduate students at Chinhoyi University of Technology, tutoring advanced manufacturing technology, robotics and machine mechanisms.

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