AVAHAN: A Journal on Hospitality and Tourism
12 (1) 2024, 60-66
http://www.publishingindia.com/avahan/

Analytical Study on the Production Capacity of Soybean Grinding Machine for Producing Tofu

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Abstract

Taho and tofu are common snacks that are available nationwide, and also a good source of protein. The machine used for grinding varies based on the nature of the producer. Small local enterprises utilize a custom-made grinding machine that is made up of two grinding stones enclosed in a cast iron that is connected to a shaft which is connected to a motor through a belt drive. The main objective of this study is to develop a machine that could increase the production of small factories from twenty (20) kilograms to 30-50 kilograms of grinded soybeans by increasing the speed of the motor without generating much heat in the process that could affect the quality of the soymilk produced. This was achieved by using the principle of a hammermill instead of grinding stones, in which the extraction process undergoes pulverization instead of compression. Test results had shown that the machine could grind 5-10 kilograms of soaked soybean in less than 10 minutes. The use of motor control increases the functionality and user-friendliness of the machine. The prototype is presented to thirty (30) evaluators to determine its performance. The performance of machine is evaluated by 30 evaluators and obtained the mean score of 4.53 which means Excellent. This concludes that the soybean grinding machine had managed to achieve on increasing the production and the use of food grade stainless steel that have a high corrosion resistance which prevents contamination and also improves the quality of the machine.

Keywords: Taho, Soybean, Grinding Machine, Hammermill, Grinding Stone

Introduction

Taho and tofu are common snacks that are available nationwide. Tofu or bean curd is a popular food in Asian countries. It is a soy food with a gel-like texture and has a lot of nutritional value mostly protein [Mohamed, Radwan, Elashhab & Adly, 2015). It is a cheap and satisfying snack that costs a minimum of ₱10 or more depending on the size. Commonly taho vendors prepare their products before dawn and sell it the next morning, this results in taho being considered as an option for breakfast for most Filipinos (Estrella, 2014).

Soybean and its components are valuable raw materials for the food and feed industries in the Philippines. Processed soybeans turns into various food products such as soymilk and tofu or soybean curd (Taho & Tokwa). The by-product of oil extraction is commonly used as the main source of protein for feeds by the livestock industry. Using the acid hydrolysis method, it is also the major ingredient for making ordinary soy sauce (toyo). Soybean oil is used for both food and industrial applications (Enicola, 2009).

It has been proven that eating soybean on a regular basis in any form has many health benefits. The presence of a major phenolic phytochemical, isoflavonoids, is what makes soybean such a healthy legume (McCue & Shetty, 2004).

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With these problems, the researchers proposed a machine that remove the use of grinding stones to extract soymilk from the soybeans. The design of the constructed machine was based on the principle of a hammermill, wherein the extraction undergoes pulverization instead of compression. This will remove the heat produced because of friction which could result in loss of flavor or bad taste of soymilk. Additionally, the machine also had a clog removing mechanism to eliminate the manual cleaning of the machine in case of clogging. The machine was fabricated using food-grade stainless steel material. The general objective of the study is to develop a Soybean Grinding Machine that will improve the volume of the production and to improve the aesthetic quality of the machine by using food-grade stainless steel materials, specifically the study aims to: (1) Design a prototype with the following features: (a) It is made up of food-grade stainless-steel material. (b) It has a feed hopper that consists of an auger conveyor to transport the soybean to the steel drum. (c) It has a permanent magnet to collect metals that could otherwise destroy the hammers inside the steel drum. (d) It has a two-hinge door to prevent misalignment that results from frequent opening and closing and a water pump that sprays water in the perforator if clogging occurs. (2) Construct the prototype as designed. (3) Test and improve the prototype. (4) Evaluate the performance of the prototype in terms of functionality, aesthetic, workability, durability, economy, safety, and salability.

Research Background

Soybean becomes a major part of the diet in South Asian countries. The style of cooking in these countries advertises the world on how soybean can be consume in various forms like bean curd, miso, soy sauce, and tempeh. As stated in studies, the soybean contains high protein and vitamin content but low in calories, carbohydrates, and fats, and is entirely free of cholesterol (Ajay & Genistein, 2009).

Different Products Produced by Soybean and Process of Production

Soybeans and the products made from it have long been associated with health food. It is acknowledged that soy foods are low in saturated fat and contain no cholesterol. Most notably, soybeans are sources of isoflavones compounds that may help promote bone health. However, the nutritional value of any given soy food can vary greatly depending on how it was processed. It can be soymilk, tempeh, tofu or taho which are the famous snacks in the Philippines (Berkeley, 2016).

Soymilk

One of the most important traditional beverages that are consumed widely in Asian countries, including China, Japan, Korea, Singapore, and Thailand is soy milk. Not only inexpensive but also a convenient source of high-quality proteins. Soy milk possesses a balanced nutrient combination, which is similar to cow's milk, but free from cholesterol, gluten, and lactose (China National Standardization Committee of Light Industry, 2008).

Tofu

Tofu is a soybean food composed principally of protein and oil. It is growing rapidly in popularity in the West. The bulk of the soybean crop is still used for animal feeds and oil, the use of whole soybeans for human consumption is increasing steadily. Originating in China over a thousand years ago, tofu is made by curdling soymilk so that its proteins become coagulated. The resulting soy curds are pressed to cut into the sliceable cake (Shurtleff, 1982).

Taho

Tahô is a Philippine snack food made of fresh soft/silken tofu, arnibal (brown sugar and vanilla syrup), and pearl sago (similar to pearl tapioca). This staple comfort food is a signature sweet and can be found all over the country. Through early records, it is evident that tahô traces its origin to the Chinese douhua. Prior to the Spanish Colonization, Chinese were common traders with the natives, influencing Philippine cuisine (Mang Pedro Food Products (Director), 2013).

Process and Techniques Used in the Philippines

Wet grinding and milk extraction are the major process steps involved in soymilk production (Liener, 1994). Dehulled soybean was pre-soaked in water for 3 hours at room temperature. The moisture content of fully hydrated soybean reached ~58%. Wet grinding of hydrated soybean was carried out with mixer grinder, stone grinder and colloid mill which revealed that particle size had a profound effect on the protein recovery in the extracted milk with a maximum recovery of 89.3%.

Horizontal-axis stone mill, a close relative of the vertical-axis mill that is also widely used. The stones grind more slowly than the vertical axis mill which keeps the puree from overheating and also keeps the price of mill lower. The beans are gravity fed from a hopper and simultaneously drawn in between the stones through a 4-inch-diameter hole in the rear stone by a small screw impeller (Shurtleff & Aoyagi, 1976).

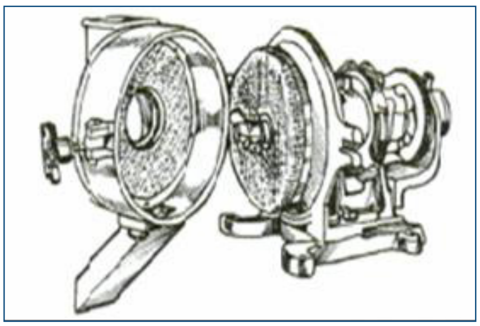

Fig. 1: Horizontal Axis-Stone Mill

Vertical-axis stone mill, this mill is faster and takes less space than its horizontal counterpart. Soaked soybeans placed in an overhead hopper fall down through a hole (eye) at the center of the stationary upper stone (the bed stone) and are forced toward the periphery by the centrifugal force of the lower revolving runner stone. The faces of the two stones come closer and closer together at their periphery where most of the fine grinding takes place (Shurtleff & Aoyagi, 1976).

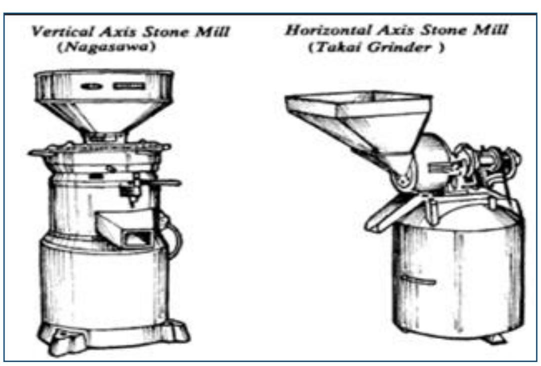

Fig. 2: Vertical Axis-Stone Mill

Hammermill is similar to a disintegrator except that the blades spin on a horizontal axis. It has been used in tofu and soymilk production. The various machine come in some sizes that are smaller and less expensive. They have a sizing screen that goes only 220 degrees around the circumference of the blades (Shurtleff & Aoyagi, 1976).

Fig. 3: Hammermill

Disadvantages of Grinding Stones

Heat treatment is the most known method used to reduce any anti-nutritional factors present in raw soybeans and other pulses. The mechanism by which the heat inactivates these anti-nutritional factors is known as "denaturing" (Rackis, Wolf & Baker, 1986). If a protein source overheats, its amino acid availability, in particular, that of lysine, drops. Furthermore, inadequate treatment reduces the oxidizing stability of the fat contained within the soybeans (Kouzeh-Kanani, Van Zuilichem, Roozen & Pilnik, 1981).

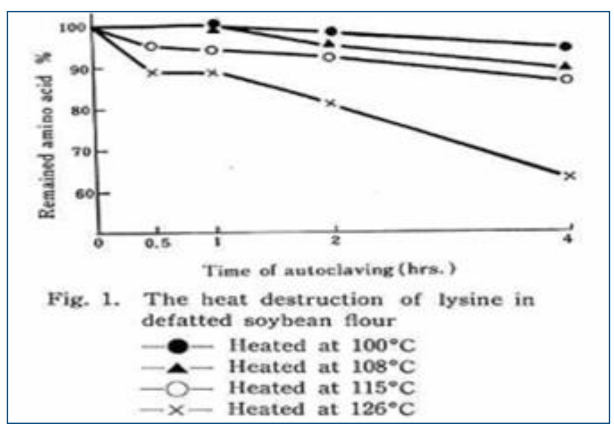

Fig. 4: Lysine Protein Loss

The heating process also has many advantages in the nutritional point of view, namely, expulsion of the anti-nutritional factors in soybeans and development of the digestibility of soybeans. But overheating causes massive denaturation of soybean protein and destruction of amino acids. This results in decreasing the digestibility of the protein with the enzymes in the fermentation process and decreases the quality and nutritional value of products (Stillings & Hackler, 1965).

Research Design

Conceptualization

Based on the foregoing problems, concepts and theories, and findings of related literature, studies presented, and insights taken, a conceptualization of prototype is developed.

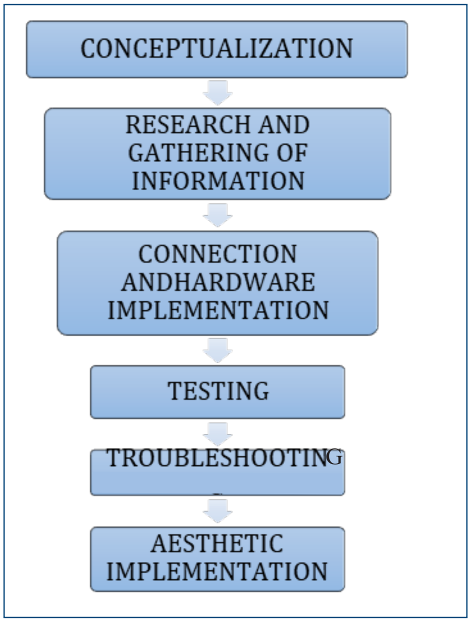

Fig. 5. Research Process of Soybean Grinding Machine

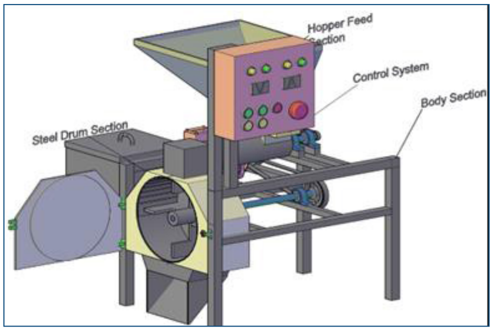

Fig. 6. Isometric View of the Soybean Grinder

Fig. 6 shows the isometric view of the soybean grinder including its labels of the four main sections of the machine.

Research and Gathering of Information

The research and information gathering are vital elements on the development of the prototype. Important information and data in using of the hammermill were conducted through a thorough systematic approach.

Development of Block Diagram

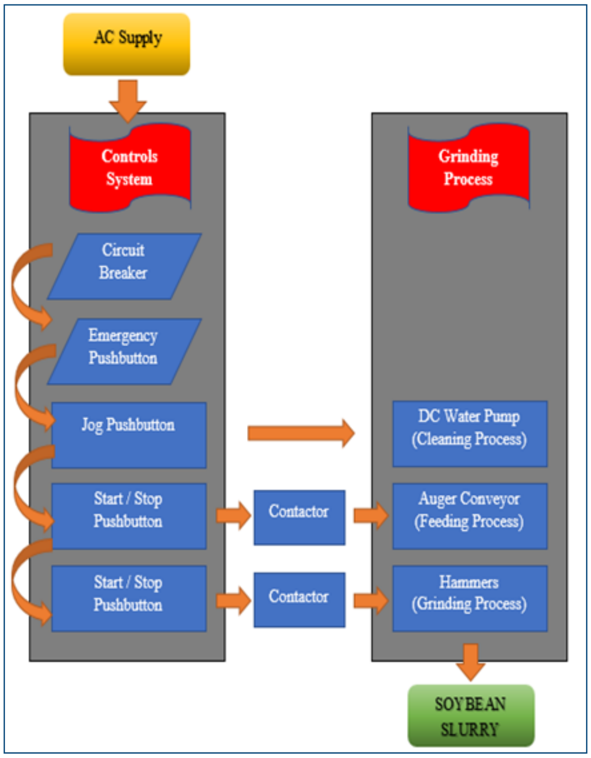

Fig. 7: Block Diagram of the Soybean Grinding Machine

Connection and Hardware Implementation

After the conceptualization of the design of the prototype, the hardware implementation was conducted. There are four main section of the machine, 1) Control system which is the one responsible for controlling the motors and other electrical devices in the machine, 2) Hopper which includes a feed controller, auger conveyor, and a magnetic separator, 3) Steel drum which is responsible in grinding the soybeans, 4) Body which holds all the components of the machine, this is where the two ac motors and a single dc motor are placed.

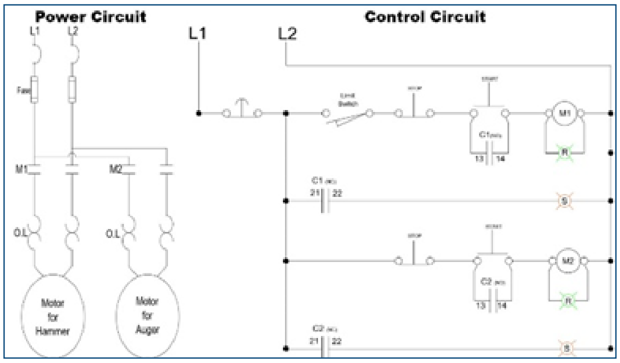

Fig. 8: Schematic Diagram of Soybean Grinder

Fig. 8 illustrates the schematic diagram for the two motors of the soybean grinder. The motors for hammers and screw conveyor both utilize the across the line magnetic starter connection.

Testing

To ensure that the project is working properly the following tests was conducted: capacity test and efficiency test. The following instruments was used during the test: weighing balance to measure the mass of the output materials and stopwatch to record the time spend at different tests.

Troubleshooting

The troubleshooting procedure is dependent on the testing procedure. In troubleshooting, the not so satisfying result got from testing are being analyzed then be corrected. Every possible way just to make the results more satisfying must be taken into consideration.

Aesthetics Implementation

Fig. 9 shows the isometric view of the soybean grinding machine indicating its four major sections, the control system, body section, hopper feed section and steel drum section. The machine is constructed using food-grade stainless steel that is corrosion resistant to prevent contaminants in mixing with the soybeans.

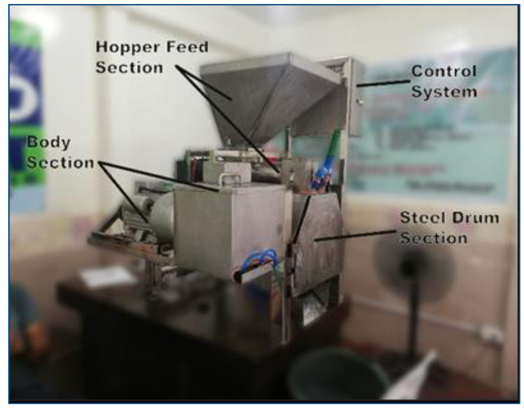

Fig. 9: Actual Prototype

Results and Discussion

In order to evaluate the performance of the prototype several tests has been made. And these were follows:

Capacity Test

The purpose of this test is to determine the number of soybeans the machine could grind in a specific amount of time. The machine must be able to grind 5-10 kilograms of soaked soybean per batch in 10 minutes without overloading the motor. The test is conducted by using a fixed amount of water approximately 10L of water per 5 kg of soaked soybeans. *Note that 1L of water is equals to 1kg (Jatav, 2018). After grinding, the total weight is measured, and the amount of water used is subtracted to the total weight, the result is then considered as the total output.

Table 1: Capacity Test Table

Trial	*Time (min)*	*Input (Kg) Soaked Soybeans*	*Ampere Rating (A)*
1	10 min	5 kg	5A
2	10 min	10 kg	7A
3	10 min	15 kg	10.5A

Table 1 shows the result of the capacity test of the soybean grinding machine. The test consisted of three trials with a constant time of ten minutes and a varying input of 5, 10 and 15 respectively on each trial. The hopper of the machine could only hold 5 kg of soybeans.

On trial 1 exactly 5 kg of soaked soybean is grinded with a grinded output of 4.3 kg, during the grinding process it reaches a maximum current of 5A. On trial 2 the process is done only this time 10 kg of soaked soybean is input to the machine. The resulting grinded output is 9.2 kg, during the grinding process the motor reaches the full load current of the motor which is 7A. Finally, on trial 3 15 kg is inputted to the machine. Unfortunately, with the time limit of 10 minutes the machine did not manage to successfully grind all the 15 kg. After 10 minutes the grinded output is measured resulting in 9.6 kg. The motor reaches up to 10.5A which is extremely dangerous for a 1 HP single phase AC motor.

The capacity test concluded that the machine could grind and handle up to 10 kg of soaked soybeans in 10 minutes or 60 kg in an hour without overloading the motor. This also means that the machine can grind more than the average of 21 kg of grinding output in a typical small taho factory.

Efficiency Test

The purpose of this test is to determine the efficiency of the machine to grind soybeans. In this test three trials were conducted with different capacity each trial and the input and output will be recorded. The following formula will be used to compute the grinding efficiency: Crushing efficiency = Mass of output material/mass of input material (Mohamed, Radwan, Elashhab & Adly, 2015).

Table 2: Efficiency Test Table

Trial	*Input (Kg) Soaked Soybeans + Water*	*Output (Kg) Soaked Soybeans + Water*	*Effeciency*
1	2 kg + 4.5L	6.27 kg	0.96
2	2 kg + 4.5L	5.97 kg	0.92
3	2 kg + 4.5L	6.27 kg	0.96
Average	2 kg + 4.5L	6.17 kg	0.95

Table 2 shows the result of the efficiency test of the soybean grinding machine. The three trials on this test all have a 2 kg input of soaked soybeans, the test is conducted the same way as the capacity test but only 4.5L of water is used per 2 kg of soaked soybeans. In trial 1, 6.27 kg of grinded output is measured resulting in 0.96 efficiency, while in trial 2 only 5.97 kg of grinded output is measured resulting in 0.92 efficiency. Finally, in trial 3 after grinding 2 kg of soaked soybeans the grinded output is 6.27 kg resulting in 0.96 efficiency. After calculations the total mean of the grinded output is 6.17 kg, this means the total efficiency of the machine when grinding a batch of 2 kg of soaked soybeans is 0.95.

The efficiency test concluded that the machine can grind soaked soybeans efficiently with an average of 0.95. This means when grinding there is only a few numbers of soaked soybeans that stayed inside the machine, which is although grinded it does not exit the hammermill screen. This is mostly due to the wrong size of hammers inside the hammermill.

Conclusion and Recommendation

Conclusions

Based on specific objectives and the results from the evaluations conducted, it is concluded that;

- The machine is working properly according to the design.
- The machine is easily controlled using pushbuttons and light indicators.
- The machine has multiple safety features like circuit breaker and a limit switch that could prevent accidents.
- The machine is capable of grinding up to 30 kilograms of soaked soybeans in less than an hour based on tests conducted.
- The machine is functional and user-friendly, during the evaluations the respondents have given an excellent descriptive rating with a total mean of 4.53.

Recommendation

The following recommendations is given by the evaluators to further improve the project.

- Reduce the size of the machine if possible.
- A finer output is necessary to maximize profit.

- Converts the blades or hammers to be adjustable to control whether the output is coarser of finer.
- Fix the connection of water inlet.

Acknowledgement

The authors would like to thank all the people that extended their help in the completion of this study to the faculty of Electrical Engineering Technology Department, to our classmates, friends and most of all to our parents for their support and encouragement.

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