A VACUUM FRYER FOR "GREENSHELL" MUSSELS MEAT

by

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ABSTRACT

The Appropriate Technology Center of the Department of Agricultural Engineering, College of Agriculture, Central Philippine University, Iloilo City, in collaboration with the Assosasyon sang Magagagmay nga Mangingisda sang Roxas City (AMMARO), had carried out a design and evaluation of a vacuum fryer for frying "greenshell" mussels meat. The project was carried out from May 15, 2002 to November 29, 2002.

The machine has a frying chamber having a diameter of 0.60 m and a height of 1.2 meter. This chamber is made of 1/8-in. thick stainless steel plate to prevent salt corrosion. The lower portion of this chamber is enveloped by another cylinder with a diameter of 0.8 m and a height of 0.7 m which serves as the heating chamber for the fryer. Inlet and outlet pipes are provided for both chambers for loading and unloading of oil. An exhaust pipe is also provided for the heating chamber to automatically release any pressure developed in the chamber during operation. An LPG burner is utilized to heat the oil. It is placed directly beneath the heating chamber to supply the heat needed for frying. Two vacuum tanks were used to generate the required vacuum pressure for the frying chamber. These tanks create vacuum while the water is transferred from one tank to the other.

Performance evaluation showed that the machine uses 160 liters of frying oil and 60 liters of heating oil. A vacuum pressure of up to 15-in. Hg can be generated by the system within 5 minutes. The temperature of the frying oil can be elevated to a level of 130 within 2 hours of continuous firing using the LPG burner. One to two kilos of "greenshell" mussels meat can be satisfactorily fried within 5 to 6 minutes. The products produced are crispy and less oily. Frying recovery of the product averaged at 32%. Electrical power and fuel consumption averaged at 1.27 kW and 1.06 kg per load, respectively.

The initial investment required for the vacuum fryer is P205,000.00. The computed cost of producing vacuum fried green shells meat is P129.96 per kilogram. Assuming a P150.00 cost per sack of "greenshell" mussels, a recovery of 8 kilos of "greenshell" mussels meat per sack, a frying capacity of 15.36 kg/day, and a selling price of P700.00 per kilo of the vacuum-fried product, the total net income that can be derived from the operation is P508,253.18 per year. The return on investment is 247.9% while the benefit cost ratio is 4.27. The computed payback period is 0.40 year.

INTRODUCTION

Vacuum frying is a recently developed technology for frying foods. It is used mainly in western countries, like the USA and Europe, to obtain good quality fried food. The method basically is done by frying the product into deep oil below atmospheric condition, i.e. below 14.7 pound per square inch (psi). Its advantages are: (a) the freshness of the flavor is retained in the final product, (b) there is less shrinkage in the textural characteristics of the product, (c) less depletion of nutrient in the product, (d) the smoke point of frying oil can be avoided during frying operation, (e) shorter frying time needed, and (f) less oil is consumed by the product during frying. The only disadvantages of this method are the high investment cost for the machine since the unit is usually imported,and the limited frying capacity per unit size of the machine.

In 1998, the Department of Agricultural Engineering, College of Agriculture, Central Philippine University, Iloilo City started the research and development on vacuum fryer in collaboration with the government sector and the industry. The first attempt was made when the Bureau of Fishery and Aquatic Resources (BFAR) of the Department of Agriculture Regional Office No. 6, through the Jamandre Industries, Inc., had carried out a modification of the DOST Vacuum Fryer using LPG as source of heat instead of kerosene. The machine can successfully fry squid-ring product with good eating quality and storability. However, the machine requires longer preheating time of about 4 hours before it can do frying due to the large amount of oil used for heating and frying. Moreover, the moisture leaving the product contains certain amount of salt that causes excessive corrosion to the machine parts, especially at the rotary vane pump that requires intensive maintenance and frequent repair of parts.

In the middle of 2002, the need for a local design of vacuum fryer for frying "greenshell" mussels in order to meet the demand for export of this product, improvement of the design of vacuum fryer was carried out in collaboration with the AMMRO in Roxas City.

Objectives of the Study

The general objective of the study is to design and evaluate the performance of a vacuum fryer for frying "greenshell" mussels meat. The specific objectives are:

1. To design a vacuum fryer that can be fabricated using locally available materials;
2. To evaluate the performance of the vacuum fryer in terms of operating pressure and temperature, frying capacity, frying recovery, oil-product ratio, electrical input power and fuel consumption per load, and quality of fried products; and
3. To make a cost-return analysis of frying "greenshell" mussels meat using the machine.

REVIEW OF LITERATURE

So far there are only few studies that were carried out in line with the vacuum frying of food products. Most of the studies reviewed were conducted in the United States and in some research institutions in Asia and Europe. Below are some of the researches reviewed from Internet as well as from books and catalogues.

Moreira of the Department of Biological and Agricultural Engineering at Texas A&M conducted a study on vacuum frying of junk food. She found out that vacuum fried junk food has lower oil content, less vitamin loss, and higher overall quality compared with control method. Together with steam drying, she noted that vacuum frying are two alternative methods of drying that yield a healthier and high quality product, i.e. nice color and texture, lower oil content, and less destruction of food's naturally occurring vitamins. She emphasized that frying at high temperatures creates more oil adsorption and greater vitamin loss, resulting in a less healthy product. Vacuum frying, according to her, can be done at a lower temperature resulting in a lower oil adsorption and less vitamin loss. Moreover, she recommends that vacuum frying process is also ideal for frying delicate food such as fruits. Fruit that is vacuum fried will produce lighter color as compared with traditional frying which tends the sugar in the fruit to turn dark. (http://www.foodservice.com/news_homepage_expandtitle_fromhome.cfm?passid=1671)

Moreira and Garayo conducted a test of vacuum frying potato chips to produce low oil content product at oil temperature of 118 to 144 °C and vacuum pressure of 3.115 to 16.661 kPa. They found out that oil temperature and vacuum pressure had a significant effect on the drying and oil absorption rates of the chips. Potato chips fried at lower vacuum pressure and higher temperature had less volume shrinkage. Hardness value of the product increases with increasing oil temperature and decreasing vacuum levels. Moreover, vacuum fried potato chips had more volume shrinkage and were slightly harder and lighter in color than potato chips fried under atmospheric condition. (http://ift.confex.com/ift/2002/techprogram/paper_10613.htm)

Krupanyyamat and Bhumiratana carried out a study of vacuum frying vegetables. Pumpkin slices with dimension of 25 x 55 x 1 mm were subjected in various pressures, oil temperature, and frying time. They found out that the color intensity of the product is dependent on temperature. The higher the temperature used, the higher product color intensity is obtained. Lowering pressure can increase the degree of starch gelatinization and slightly decrease oil content and moisture content. According to them, low pressure and low temperature frying conditions improve product quality acceptation such as texture, color, oil content, moisture content, and nutritive value. (http://www.kmutt.ac.th/organization/Engineering/Food/t011y94.html)

Akoh and Reynolds of the University of Georgia stated that deep-fat frying enhances the sensory properties of fried food, however, repeat use of frying oils produces undesirable constituents that may pose health hazards and lead to quality and economic loss to the processors.

Yan and Chen conducted a study of determining the effect of introducing microwave heating on the oil adsorption of deep frying instant noodle. They found out that oil adsorption of fried noodle can be reduced by introducing microwave heating during frying process whether simultaneously or stepwise procedure. (http://ift.cpmfex.com/ift/2002/techprogram/paper_13663.htm)

In the study of Kawas and Moreira they found that frying oil temperature did not affect the total oil content of tortilla chips. Oil absorption was observed for tortilla chip during cooling rather than during frying. Also, particle size distribution significantly affect oil absorption. Fine particles absorbed more oil than chips made of coarse particles. (http://www.confex.com/ift/99annual/abstracts/4016.htm)

Velez-Ruiz et. al. found that at oil temperature of 130 to 150 °C, a noticeable effect on chicken characteristics was observed during frying process. The average shrinkage in length of 25 to 32% and in width of 27 to 29 % were observed.

According to Agriculture Technology Information of India, fat has a relatively high melting point and is solid at room temperature, whereas the oils are liquid in room temperature. Refined oil, on the other hand, is oil further processed by pressing and solvent extraction processes. The smoke point temperature of fats and oil is the temperature at which smoke come continuously from the surface of the fat or oil during heating. (http://www.indiaagronet.com/indiaagronet/food%20Technology/Fat%20 and%20oils.htm)

There are several kinds of oil that can be used for vacuum frying. The kinds of oil that is suitable for frying operation is highly affected by its smoke point. Berthold-bond enumerated the smoke point value for the different kinds of oil as follows: (a) unrefined canola oil – below 225 °F, (b) unrefined sunflower oil – below 225 °F, (c) unrefined corn oil - below 320 °F, (d) refined canola oil - below 400 °F, (e) refined peanut oil – below 450 °F, and refined avocado oil – below 520 °F. On the other hand, for the coconut oil which is locally available, the tables on smoke point of various oils indicated that the smoke point of coconut oil is below 350 °F it is slightly higher with that of unrefined corn oil of 320 °F. (htpp://www.goodeatsfanpage.com/collectedinfo/oilsmoke point.htm)

According to Christian Chefs Fellowship Chart for oils, a coconut oil is described as heavy, nearly colorless oil extracted from fresh coconuts. It is used primarily in blended oils and shortenings. Moreover, it is used primarily in prepared, processed, and packaged foods. (http://www.christianchefs.org/chart/oil.htlm).

METHODOLOGY

Design Plan Preparation

Before making the design of the vacuum fryer, actual visit and inspection of the existing machines were conducted together with the representatives from AMMARO in Roxas City. The vacuum fryer which was previously designed for the Bureau of Fisheries Region VI Office for frying squid ring and the original machine that was installed in Roxas City were visited.

After all the criteria were set, a conceptual design of the machine was prepared. Computations for the diameter and height of frying and heating chambers, diameter and length of pneumatic cylinder, oil heating time, LPG fuel consumption per loading cycle, and the pumping time necessary to generate vacuum were made. From the computation, a fabrication drawings were prepared.

Fabrication of the Machine

The fabrication of the machine was done at Dennis Welding Shop in Jaro, Iloilo City. During fabrication, regular visits were conducted to ensure that the machine is well fabricated according to the design and revision agreed both by the Designer and the Shop Supervisor. Leak tests were also conducted for the frying and heating chambers to ensure that the machine is properly welded and that no oil leakage is observed when it is operated.

Performance Evaluation

Preliminary test runs were carried out to determine parts that need to be modified and to orient the operator, assigned by AMMARO, in operating the machine. Burner setting, temperature build up, pressure generated, and procedural steps of operation were carried out until final setting of the machine was made.

The performance evaluation of the machine was carried out by conducting series of tests using 1 to 2 kg of freshly prepared "greenshell" mussels meat.

During the test, the Fuji Weighing Scale having a capacity of 10-kg was used to measure the weight of freshly prepared "greenshell" mussels meat before and after frying. A spring scale was also used to measure the change in weight of “greenshell” mussels meat before and after it was removed from the shell including the amount of LPG fuel consumed during frying. The time required to heat oil, to generate vacuum, to fry samples, and to operate the machine in one load were determined using a stop watch. Heating and frying oil temperatures were determined using SENSE bimetallic thermometer (200 C). A vacuum pressure gauge (0-29 in. Hg) was used to measure the vacuum pressure generated in the frying chamber before dipping the samples in the heated oil. Measurement of input voltage of the motors was done using Hew volt meter

(0-300 Volt) and a Yokoyama ammeter (0-20 Amp) was used to measure the input current to the motors.

During the performanc evaluation, the following data were gathered:

1. Vacuum Pressure Generated by the Pump
2. Time Required to Generate and Recharge Pressure
3. Temperatures of the Frying and the Heating Oil
4. Heating Time of Oil
5. Weights of Whole and “Greenshell” Mussels
6. Weights of Fresh and Fried "Greenshell" Mussels
7. Weight of LPG Fuel
8. Frying Time
9. Input Voltage and Current
10. Physical Appearance

After all the data were gathered, the following parameters were analyzed:

1. Frying Capacity - This is the amount of "greenshell" mussels meat subjected to the machine per load.
2. Frying Recovery – This is the percentage amount of dry matter retained after the product is subjected to the machine.
3. Oil-Product Ratio (O-P Ratio) – This is the ratio of the weight of oil used to the weight of product subjected to frying operation.
4. Electrical Input Power per Load – This is the amount of electrical power input per load at the air compressor and at the water pump.
5. Fuel Consumption per load - This is the amount of LPG fuel consumed per load.
6. Quality of Fried Products – This refers to the quality of fried “greenshell” mussels meat based on the oiliness and crispiness of the product.

Operating and cost-return analysis of using the machine was also carried out to determine the economic advantgae of using the vacuum fryer.

RESULTS AND DISCUSSION

Description of the Vacuum Fryer

The Vacuum Fryer, as shown in Figure 1, is a locally-fabricated machine designed for frying "greenshell" mussels meat in a heated oil at a relatively high temperature and vacuum condition. The design specifications of the various machine components are given in Table 1.

As shown, the machine basically consists of: (1) frying chamber, (2) heating chamber, (3) burner, (4) pneumatically-operated dipper and lifter, (5) vacuum tanks, (6) water storage tank, and (7) pressure pump.

Basically, the frying chamber is where the product is fried. It is made of 1/8-in. thick stainless steel cylinder having a diameter of 0.6 m and a height of 1.2 m. It holds the oil inside and is used to accommodate the frying basket. A swing-type door is provided for the frying chamber to load and unload the product during operation. It is made completely sealed to prevent air to enter the chamber during pumping in order to generate enough vacuum pressure during frying.

The basket inside the frying chamber is made of ¼-n. stainless steel screen mesh that holds the product during frying. The basket with the product inside is dipped into the oil through a lever actuated by a pneumatic cylinder. A pressure gauge and a bimetallic thermometer are provided for the frying chamber to measure the vacuum pressure inside the chamber as well as the temperature of the oil. The frying chamber can hold 8 to 10 containers (20 liters/container) of coconut oil.

Table 1. Design Specifications of the Vacuum Fryer.

Frying Chamber	0.6 m ϕ x 1.2 m H - stainless steel 1/8-in. thick plate
Heating Chamber	0.8 m ϕ x 0.7 m H – stainless steel 1/8-in. thick plate
No. of Frying Basket	2 units stainless steel (1/4-in. mesh screen)
Size of Frying Basket	0.25 m ϕ x 0.3 m high
Vacuum Tank	Two (2) units - 0.60 m ϕ x 1.22 m high – 1/8 in thick MS plate
Pump	¾-hp PEDROLLO pump
Water Storage Tank	82-gal capacity
Burner	LPG Three-burner with 11 kg LPG tank
Air Compressor	¼-hp VESPA Air Compressor
Pneumatic Cylinder	1-in. ϕ x 0.6 m stainless steel cylinder

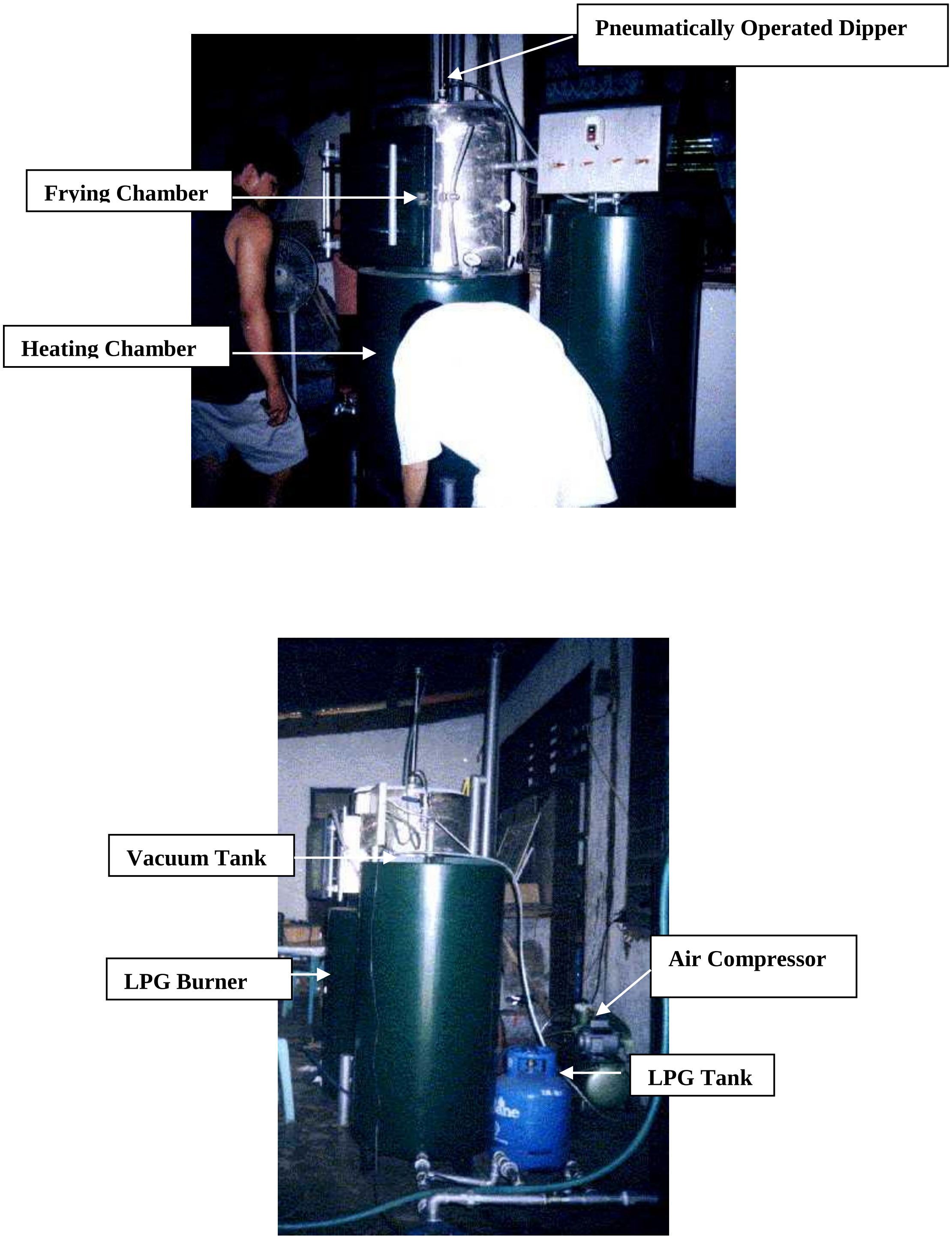

Figure 1. The Vacuum Fryer Showing its Various Components.

The heating chamber encloses the lower portion of the frying chamber. It is also made of 1/8-in. thick stainless steel plate having a diameter of 0.8 m and a height of 0.7 m. Heat generated in the heating chamber is transmitted to the frying chamber with the use of oil. This chamber is made to hold about 2 to 3 containers of oil and is enough to reduce the time required to preheat the frying chamber. Similarly, this chamber is welded properly to prevent oil leakage. Inlet and outlet pipes, with 1-in. diameter, are provided for the chamber to load and unload oil. A two-inches diameter exhaust pipe is also provided for the chamber to automatically release any pressure build up in the chamber. A bimetallic thermometer is also used to measure the temperature of the oil during operation.

A three-burner industrial-size LPG burner was used to supply the heat needed for frying. It is directly placed beneath the heating chamber. The amount of heat supplied into the fryer is regulated by three-gas manifold directly coupled to the gas regulator and the hose. An 11-kg LPG tank is used as storage gas tank for the fryer.

The pneumatically-operated product dipper and lifter is a locally-fabricated cylinder made of stainless steel materials. It has a diameter of 1 inch and a length of 0.6 m. This assembly is responsible for the upward and downward movements of the frying basket during operation. The movement of the cylinder lever is controlled by gas manifold positioned on top of the vacuum tank. The compressed air that causes the lever to move is supplied by a ¼-Hp VESPA air compressor.

The vacuum tanks are large cylindrical tanks coupled directly to the frying chamber in series. The tanks create vacuum while the water is transferred from one tank to the other tank by the pump. These tanks are made of 1/8-in. thick mild steel plate having a diameter of 0.3 m and a height of 1.2 m. Braces are provided for the tanks to ensure enough strength to overcome resistance from vacuum pressure. A ¾-hp PEDROLLO high-pressure pump was used to generate the needed pressure for the tanks. Pressure is generated by pumping water at the lowest portion of the tank and is discharged to the other tank at the uppermost portion. Ball valves control the direction and flow of water in the tanks.

Operation of the Machine

The machine operation is started by heating the oil inside the frying chamber below oil smoke point temperature, i.e. below 150° C for most cooking oil. This is done by igniting the gas from the burner at full opening of the gas valve for about 2 hours. When the required temperature is reached, the water pump is switched ON to start generating vacuum in the two tanks. During this process, water is transferred from the first tank to the second tank, and then to the third tank. The ball valve connecting the frying chamber completely controls the flow of air to assure that the product is below atmospheric condition before dipping into the oil. After the desired reading at the vacuum gauge is achieved, the product is then dipped into the oil and consequently re-open the ball valve to create vacuum condition inside the frying chamber. The moisture that evaporates from the product is sucked and transferred from the frying chamber to the vacuum tanks. After few minutes of frying the product, the pneumatic cylinder is activated to lift the product from the oil. The ball valve is then opened to release vacuum pressure and to equilibrate the pressure inside the chamber to remove the product. The same procedure is followed for the succeeding operations until all the samples are completely fried.

Samples used for frying were freshly harvested "greenshell" mussels to minimize producing a product having bad odor and taste. They are then thoroughly washed and cleaned before placing into a boiling water for cooking. After cooking the samples, they are removed from the container to separate the meat from the shell. The meat is transferred to a colander to remove excess water before vacuum frying.

Test Operating Conditions

The machine performance was evaluated after it was completely installed at the PSPC Dayao Campus in Roxas City. However, prior to final testing and commissioning of the machine, series of test runs were made to obtain the best operating condition for the machine.

Figures 2 and 3 show the operating performances of the air compressors used for the pneumatic system as well as the performance of the vacuum generating system of the machine. As shown, the air compressor requires about 5.5 minutes of continuous operation until the pressure of about 70 psi is reached. Reduction in the pressure was observed during operation while the pneumatic system is operated to dip into and lift the product from the frying chamber. Since the air compressor is operated by automatic switch, there was no problem experienced on pressure loss during operation. On the other hand, the vacuum generator also took about 3 minutes to generate vacuum of about 9-in. Hg and 6 minutes for a vacuum pressure of about 13-in. Hg. In order to achieve a desired vacuum pressure of 15-in.Hg, the vacuum generator should be ran for additional few more minutes.

Table 2 shows the operating conditions and results of the tests of the machine for three trial runs using freshly prepared "greenshell" mussels meat. As shown in the first trial run, at an oil temperature of 135° C, a vacuum pressure of 15-in.Hg and at 5-minute dipping time, one kilogram of "greenshell" mussels meat was properly deep fried in the vacuum fryer containing less amount of oil. The final weight of vacuum fried "greenshell" mussels meat obtained was 0.350 kg. In the second trial run, at an oil temperature of 119° C, a vacuum pressure of 13-in.Hg and at 5-minute dipping time, two kilograms of "greenshell" mussels meat was properly vacuum fried. However, it was observed that the vacuum-fried sample is slightly oily compared with those obtained in the first trial run. The final weight of the sample obtained after frying was 0.650 kilogram. In the third trial run, at oil temperature of 129° C, 14-in. Hg vacuum pressure and at 6-minute dipping time, 1.75 kg of "greenshell" mussels meat was successfully deep-fried in the machine. Similarly, the vacuum-fried samples have less amount of oil same as with those in the first trial run. The final weight of samples obtained after frying was 0.50 kilogram.

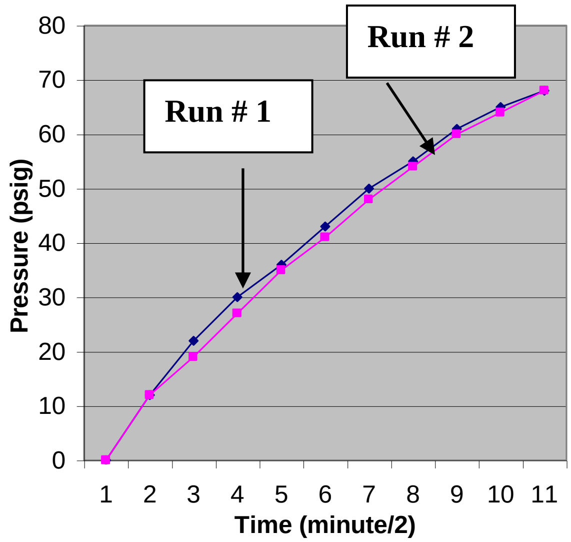

Figure 2. Performance Curve of VESPA Air Compressor.

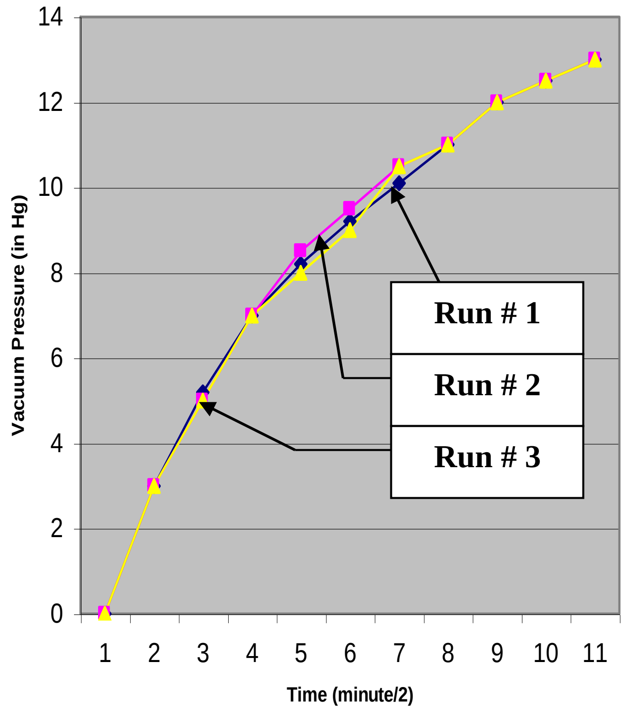

Figure 3. Performance Curve of Vacuum Generator.

Table 2. Operating Conditions and Test Results of the Vacuum Fryer.

Parameters	Trial Run		
	1	2	3
Frying Oil Temperature *	135 °C	119 °C	129 °C
Heating Oil Temp *	155 °C	138 °C	154 °C
Vacuum Gauge Pressure	15-in. Hg	13-in. Hg	14-in. Hg
Dipping Time	5 minutes	5 minutes	6 minutes
Initial Weight of Samples	1.00 kg	2.00 kg	1.75 kg
Final Weight of Samples	0.35 kg	0.65 kg	0.50 kg
Physical Appearance After Frying	Crispy, Less Oil, Good Taste and Odor	Crispy, Slightly Oily, good Taste and Odor	Crispy, Less Oil, Good Taste and Odor

* At 60 liters heating oil and at 160 liters frying oil

Heating oil temperature was found slightly higher from oil temperature by 19 to 25 degree Celsius. Moreover, all samples where found crispy and have a good taste and odor.

During the performance testing of the machine, it was observed that there was slight change in the temperature once the product is dipped into the oil. This can be attributed to the loss of heat in the oil as it is transmitted into the product. Also, the pressure reading at the vacuum gauge is gradually reduced with time while the samples are dipped into the oil as a result of the mass transfer of evaporated water from the product to the surrounding space. It was also observed that samples subjected in a higher vacuum pressure and higher oil temperature produce vacuum-fried samples that are less oily. Moreover, the smaller the amount of samples used during vacuum frying, the better is the quality of the vacuum fried product as indicated by the lower percentage amount of oil present in the sample.

Figure 4 shows a comparison of samples before and after frying. Note that vacuum-fried samples retain the shape of the product after it was subjected in the fryer. They were observed to be crispier than samples dried in atmospheric frying.

Operating Performance of the Machine

The operating performance of the vacuum fryer is based on its frying capacity, frying recovery, oil-product ratio, electrical power input, and the fuel consumption per load. Table 3 shows the operating performance of the machine based on the results of the tests carried out for the three trial runs.

Figure 4. Samples Before and After Vacuum Frying.

As shown, the frying capacity of the machine per load in the first, second, and third trial runs were 1.00, 2.00, and 1.25 kg, respectively, giving an average frying capacity for the machine of 1.42 kg of "greenshell" mussels meat per load. After frying the samples, the frying recoveries were obtained with 35.00, 32.5, and 28.6 percent of the original weight for the first, second, and third trials, respectively, with an average frying recovery of 32.02%.

The oil-product ratio obtained from the machine averages to 120.2. This parameter is important to ensure that there is no significant heat reduction during frying once the product is dipped into the oil. As shown, the computed oil-product ratio obtained for the frying machine is 156.8, 78.3 and 125.4, for the first, second, and third run, respectively.

Table 3. Operating Performance of the Vacuum Fryer.

Trial Run	Frying Capacity (kg/load)	Frying Recovery (%)	Oil/Product Ratio* (Dmls)	Electrical Power Input (kW)	Fuel Consumption per Load (kg LPG/load)
1	1.00	35.00	156.8	1.25	0.90
2	2.00	32.50	78.3	1.02	1.10
3	1.25	28.60	125.4	1.54	1.20
Average	1.42	32.03	120.2	1.27	1.06

* Coconut oil density = 0.923 kg/liter

The average electrical power input obtained for the three runs was 1.27 kW. The value ranges from 1.02 to 1.54 kW for the three runs. Also, the LPG fuel consumption per load averages to 1.06 kg. For the first, second, and third runs the fuel consumed were 0.90, 1.10, and 1.20 kilograms per load, respectively, with an average of 1.06 kg/load.

Economic Analysis

Table 4 shows the operating cost analysis of the machine. The total investment cost requirement for one complete unit of the vacuum fryer is P205,000.00. This includes the frying and heating chamber, the vacuum generating tanks and pump, the pneumatic system and the air compressor, and the LPG burner and gas tank unit.

The total fixed cost for the machine is P279.98 per day that includes depreciation, interest on investment, repair and maintenance, and insurance. The machine was assumed to have a total life span of 7 years with a salvage value of 10%. The interest on investment is 24% while the repair and maintenance is 10% of the investment cost. The insurance is 3% of the investment cost.

For the variable cost, the total cost incurred is P1,700.96 per day. It was assumed that the machine is to be operated by two persons at P200.00 per day, 8 hours per day operation. The cost of one tank LPG is P320.00 and is good for two days operation. The combined cost for electricity for the pump and for the air compressor is P60.96 per day, which was obtained from the average power consumed of 1.27 kW for 8 hours and from the power cost of P6.00 per kw-hr. Operation is 15 min per batch at 1.5 kg per load. Oil consumption is P30.00 per liter at 180 liters per week, 5 days operation per week.

At a frying capacity of 15.36 kg per day of vacuum fried “greenshell” mussels meat and the total cost of P1,980.94 per day, the cost of frying a kilogram of product is P129.96.

Table 5 shows the cost-return analysis of frying “greenshell” mussels meat in the machine. The assumptions made are as follows: (a) operating period of the machine is 20 days per month for 3 months in one year, (b) cost of “greenshell” mussels is P150.00 per sack, i.e. 8 kg of meat can be produced out of one sack of “greenshell” mussels, and (c) selling price of vacuum fried “greenshell” mussels meat is P700.00 per kg in export market.

Based on the computation for the given assumptions, the yearly net income that can be derived from the machine is P508,253.18. The computed return in investment is 247.9%. The investment for the machine can be paid back within 0.403 year of operation. Benefit cost ratio is 4.27 which means that per every peso investment a return of P4.27 could be derived.

Table 4. Operating Cost Analysis of the Vacuum Fryer.

Investment Cost (IC)	P 205,000.00
Fixed Cost (P/day)	
Depreciation [a]	72.21
Interest on Investment [b]	134.79
Repair and Maintenance [c]	56.16
Insurance [d]	16.85
Total	279.98
Variable Cost (P/day)	
Fuel [e]	160.00
Labor [f]	400.00
Electricity [g]	60.96
Oil [h]	1,080.00
Total	1,700.96
Total Cost (P/day)	1,980.94
Frying Capacity (kg/day)[i]	15.36
Operating Cost (P/kg)	129.96

[a] Straight line method at 10% salvage value and 7 years life span.
[b] 24% of investment cost
[c] 10% of investment cost
[d] 3% of investment cost
[e] P320.00/tank
[f] Two (2) laborers at P200.00 per day at 8 hour per day
[g] Electric load of 1.27 kW for 8 hours at P6.00/kw-hr
[h] P30.00/li of oil at 180 li/week
[i] At 32% product recovery

Table 5. Cost-Return Analysis of the Vacuum Fryer.

Investment Cost	P205,000.00
Fixed Cost	279.98
Variable Cost	1,700.96
Total Operating Cost	1,980.94
Net Income	508,253.18
Return on Investment	247.9%
Payback Period	0.403 year
Benefit-Cost Ratio	4.27

Assumptions:

1. Operating period per year is 20 days/month for 3 months.
2. Cost of “greenshell” mussels per sack is P150.00 at 8 kg meat output/sack.
3. Export price of vacuum fried “greenshell” mussels meat is P700.00/kg.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study, the following were concluded:

1. The machine is a simple and low-cost technology for frying "greenshell" mussels meat;
2. The machine can be fabricated using locally-available materials and labor;
3. The use of high-pressure water pump combined with vacuum and atmospheric tanks can successfully generate the required vacuum pressure needed in vacuum frying in the fryer;
4. The locally-fabricated pneumatic cylinder out of stainless steel material and hard rubber gasket can successfully be used for the vacuum fryer;
5. The industrial-type LPG burner can sufficiently supply the heat needed for vacuum frying;
6. "Greenshell" mussels meat can be successfully vacuum fried in the machine;
7. The higher the oil temperature and the vacuum gauge pressure, the lesser is the amount of oil obtained in the product after vacuum frying;
8. The lesser the weight of samples used for frying, the better is the quality of the vacuum-fried samples; and
9. The machine is advantageous in terms of BCR, ROI, and PBP if the products are exported.

To further improve the design and operation of the machine, the following are recommended for further study:

1. Redesign the pneumatic system in such a way that it can be easily operated to automatically dip and lift the product;
2. Redesign the vacuum-generating tank using two large capacity tanks instead of multiple small tanks to minimize the use of several ball valves that complicate the operation of the machine.
3. Replace the existing water pump with a larger size pump to provide sufficient power in generating vacuum pressure. This may also prolong life span of the pump.
4. Carry out testing using shrimp, crablets, squid, and other food products to increase utilization of the machine hence making it more economical;
5. Pre- and post-treatment of the product before vacuum frying should be explored to improve product quality and price;
6. Oil filtering device should be added into the system to recycle the use of oil hence minimize the cost of using oil; and
7. Further refinement on the design and fabrication should be done to make the unit commercially attractive and saleable.

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