International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 12, 2019, pp.-8650-8655.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

DESIGN AND DEVELOPMENT OF COCONUT MILK EXTRACTOR

MOHAN L.* AND TITO ANAND
Department of Food Engineering, Indian Institute of Food Processing Technology, Thanjavur, 613005, Tamil Nadu Agricultural University, Coimbatore, 641003, India
*Corresponding Author: Email - mohanlenin1994@gmail.com

Received: June 03, 2019; Revised: June 24, 2019; Accepted: June 25, 2019; Published: June 30, 2019

Abstract: A machine was designed and developed for coconut milk extraction and its performance was evaluated at IIFPT, Thanjavur, Tamil Nadu. The milk extraction efficiency was found to be 78.27%. The milk yield was tested with three different nozzle clearance of 2, 3, 4 mm and rotational speeds of 40, 50 and 60 rpm. Finding saying that, the percentage of coconut milk yield was higher at the point of combination of the nozzle clearance of 2 mm with the rotational speed of 40 rpm which yielded about 49.03% of coconut milk. The lowest coconut milk yield of 33.38% was analyzed during the point of combination of the nozzle clearance of 4 mm with the rotational speed of 60 rpm. Both lower and higher percentage of coconut milk yield were having a significant difference (p<0.05) with other results. The experiment shows that the increase in rotational speed of the motor resulted in decrease in the milk yield. It was also showing that the average milk yield started to decrease while increasing the nozzle clearance (mm). Thus, our major research finding saying that, lower rotational speed and nozzle clearance result to the higher amount of coconut milk yield. The performance evaluation indicates the values of 30.52 kg/h and 0.041kWh/kg-grated coconut for average feed rate (FR) and Specific energy consumption (SEC) for the designed coconut milk extractor.

Keywords: *Coconut milk, Extraction, Design and development, Efficiency, Yield, Nozzle clearance, Rotational speed*

Citation: Mohan L. and Tito Anand (2019) Design and Development of Coconut Milk Extractor. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 12, pp.- 8650-8655.

Introduction

Coconut is one in all the foremost valuable gifts of nature to man. Each a part of a coconut has its own use or applications. It is typically referred to as "Tree of Heaven", "Tree of Abundance", "Tree of Life" and "Kalpavriksha". Botanically, the Coconut may be a flowering plant and belongs to the order 'Arecaceae', family 'Palmae' and the species is known as 'Cocos nucifera Linn'. Coconut milk is a most important ingredient for food, source of oil, and raw material for pharmaceuticals. In order to minimize the extensive laborious involvement in the extraction of coconut milk, high cost of the devices and energy needs hence the driving force for this study. This study was thus carried out to design, fabricate and evaluate the coconut milk extractor for coconut milk production [12].

MATERIALS AND METHODS

Design of machine components

Design of Hopper

The hopper is trapezoidal in shape. The inlet diameter of the hopper should be the size of the area loading into the cylinder from the hopper which was determining to be 85 mm. The outlet dimension of the hopper was estimated at three times that of inlet, which is 260 mm [9].

Volume of Hopper, V_h

To determine the volume of the hopper, the following equation [3] is used,

$$V_h = \frac{1}{3}\left(\frac{b_1^3 - b_2^3}{b_1 - b_2}\right) h \qquad (2)$$

Where,

b_1 = length of larger part of the frustum = 260 mm

b_2 = length of smaller part of the frustum = 85 mm

h = Height of frustum = 160 mm

V_h = 5169333mm^3= 0.005169m^3

Hopper Capacity, H_c

To determine the hopper capacity[3], the following equation is used.

The angle of the feed hopper wall is considered to be 30°.

$$H_C = \rho V \qquad (3)$$

Where

ρ = Density of coconut meat sample 352 kg/m³.

V= Volume of the hopper = 0.005169 m³

$$H_c = 2Kg$$

Design of the Screw geometry

The screw conveyor is the important unit in the design of the expeller unit. American Society of Agricultural Engineers (ASAE) engineering says that the pitch of the flighting of auger conveyors must be in between 0.9 and 1.5 times the flighting outside diameter. Hence, the first pitch of the decreasing pitch was taken to be equal with the outside diameter of the screw shaft; P_s = D_s = 143 mm (assumption). Iteration method was used to find out the decreasing order of the pitches. A value is assumed to first pitch (P) in order to obtain the inlet velocity (v) and the remaining pitches by iteration method [9].

Calculation of area of the shaft threads

The area of the shaft threads is calculated as follows

$$Area\ of\ the\ shaft\ threads = \frac{\pi(D^2 - d^2)}{4} \qquad (4)$$

Where, the assumed diameter of the shaft (d) = 125 mm, diameter of the shaft with thread (D) = 143 mm. The area of the shaft threads is 3.789 X 10^{-3}m^2

The volume of coconut meat gets crushed at the first pitch of the shaft 143 mm when it is fully covered with coconut meat is calculated as,

Volume at entrance = 3.789 x 0.14 x 10^{-3}

= 5.3046 x 10^{-4} m^3

The compression ratio of 1:4 was found to be efficient for the complete compression of grated coconut meat. Hence, the ratio was taken to be equal to 1:4

Hence the pitch length at exit = 143/4 = 35mm
Volume at exit = 3.789 x 0.03 x 10^{-3}
= 1.13 x 10^{-4} m^3

Design of the screw thread

The length of the screw thread, L was found by using Pythagoras rule is the square root of the sum of squares of the circumference, C is the diameter of the shaft and P is the Pitch of the screw,

$$L = \sqrt{C^2 - P^2} \qquad (5)$$

Circumference of 125 mm diameter shaft = π x d
=393 mm

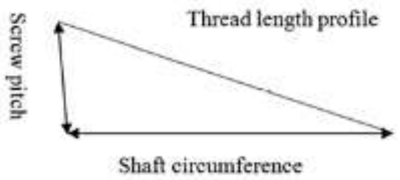


Fig-1 Generation of thread profile

From Pythagoras theorem,

$$L_1 = \sqrt{(393)^2 + (140)^2} = 417\ mm$$
$$L_2 = \sqrt{(393)^2 + (110)^2} = 408\ mm$$
$$L_3 = \sqrt{(393)^2 + (75)^2} = 400\ mm$$
$$L_4 = \sqrt{(393)^2 + (35)^2} = 395 mm$$

The following table represents the length of the thread profile used for the different pitches

Table-1 *Summary of thread lengths for different pitches*

Pitch (mm)	Thread length (mm)
140	417
110	408
75	400
35	395

The raw material inlet velocity can be calculated from;

$$v = \frac{P_s x \frac{\pi}{4}(D_S^2 - d_S^2)N}{4DL} \qquad (6)$$

Where; P_s is the screw pitch, D is the outside diameter of screw, d is the inside diameter of screw, L is the length of the screw shaft, and N is the shaft speed. Given that P_s= 143 mm, D= 143 mm, d= 125mm, L= 393 mm.

Therefore, Inlet velocity of raw material $V = \frac{14 x \frac{\pi}{4}(143-125) x 60}{4 x 143 x 393}$
= 0.53 mm/s

Design of Helix angle (Pitch angle)

The angle of pitch (helix angle), α, which is in relation with diameter and lead given by the equation[16];

$$\alpha = tan^{-1}\left(\frac{p}{\pi Ds}\right) \qquad (7)$$

where; P = Mean pitch of the screw (lead) = 98mm, α = 12.3°

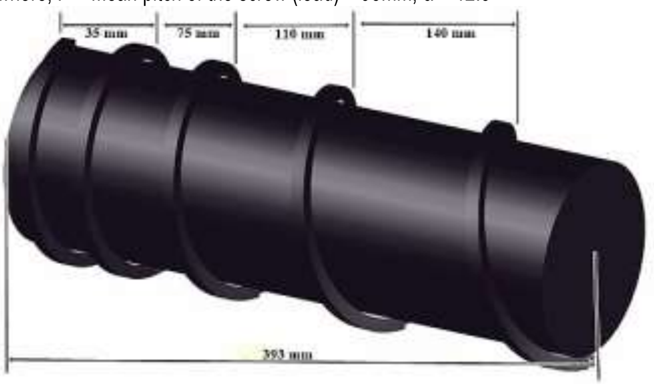


Fig-2 Designed screw press for coconut milk extractor

Design of the Barrel (Press cage)

On the middle section of the barrel cage, milk outlet sieve is made with double mesh size of 1 mm and 3 mm. The cake outlet zone is kept slightly far from the milk outlet zone due to the high-pressure application in the cake outlet zone which leads the small holes to filled with the compressed cake.

The clearance of 2 mm is provided between the screw thread and the barrel's internal wall. Hence, barrel's inner diameter is calculated as

$$D_I = D + 2C \qquad (8)$$

Where; D_I is the barrel's inner diameter, D is the diameter of the screw (143 mm) and C is the clearance between the barrel's internal wall and the screw thread (2 mm). D_I = 147 mm.

The barrel's outer diameter was calculated by the equation,

$$D_I = 0.95\ D_0 \qquad (9)$$

Where, D_0 is the outer diameter of the press cage in mm.

$$D_0 = 154.7\ mm$$

The thickness of the barrel was determined thus:

$$t = D_0 - D_I \qquad (10)$$

Where, t is the thickness of the barrel in mm. t = 7.7 mm. Therefore, a stainless-steel mesh of diameter 147 mm and thickness 10 mm was selected for the press cage of the extractor.

The Pressure of the Barrel

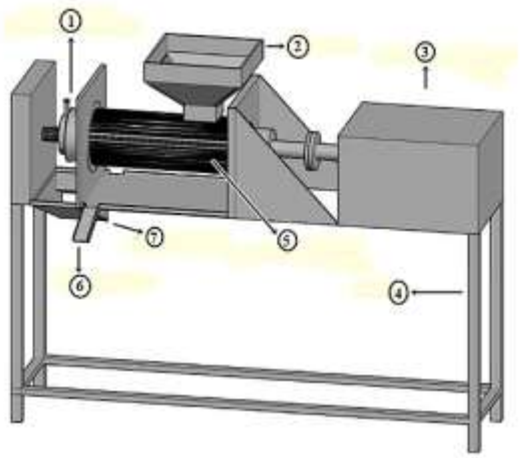
The following equation is used to determine the pressure that can be withstood by the barrel [9];

$$P_b = \frac{2t\delta_a}{D_i} \qquad (11)$$

Where, P_b = pressure to be withstood by the barrel, δ_a = allowed stress ($0.27\delta_0$), t = thickness of barrel (10 mm), D_I = inside diameter of barrel (147 mm) and δ_0 = yield stress of stainless steel (215 N/mm^2). Hence, P_b= 7.8 Mpa. This describes that the pressure that the barrel can withstand 7.8 Mpa is higher than the pressure developed by the screw thread for milk extraction 0.31 Mpa [1]. Therefore, the barrel will withstand the expelling pressure without bursting.

Finalized design of coconut milk extractor

The isometric view of the coconut milk extractor is presented in [Fig-1]. The unit consists of four section; the feeding section, extraction section, power section and the frame. The feeding section consist of hopper; the extraction section consists of the worm shaft, the perforated barrel and the conical restrictor; the power section consists of a geared motor while the frame section serves as a support for the unit on which all other sections were mounted.



1. Conical nozzle, 2. Hopper, 3. Geared motor, 4. Stand, 5. Screw press, 6. Cake Outlet, 7. Milk Outlet

Fig-3 Isometric view of coconut milk extractor

The hopper helps as a holding container for grated coconut from which the coconut milk was to be extracted. The screw shaft crush, press and convey the grated coconut which comes from the hopper and squeezed out milk from the grated coconut. The milk then drains into the tank placed just below the vessel.

Main body

The main body contains three parts. They are screw shaft, vessel and hopper. They are described as follows.

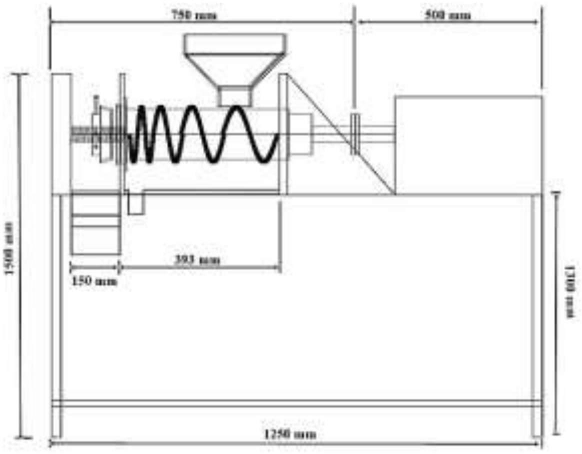


Fig-4 Front view of coconut milk extractor

Screw shaft

The grated coconut is compressed by two ways. By the continuous feeding of the coconut meat into the system, the first way of compression will occur. Newly fed coconut meat compresses the meat which are already present in the system. The second way of compression takes place between the vessel's inside surface and the screw shaft's inside surface. As the depth of the screw thread decreases continuously, the distance between the thread surfaces decreases, so as a result the coconut meat volume reduces, and the coconut milk is drained out. The screw shaft will be rotating inside the vessel. Between the vessel and the screw shaft, there will be a clearance of 3 mm. To avoid the meats penetrating between the outside diameter of the screw shaft and the inside surface of the vessel, the small clearance is necessary. In such a case, the required torque becomes higher due to the frictional force increases between the screw shaft and the vessel. To apply more pressure on the meats the screw shaft pitch will be reduced down the vessel. At the maximum screw thread depth, the grated coconuts are fed inside the hopper. The swept volume of each turn decreases as the coconut meat pass through the screw. Due to high pressure, the coconut milk is separated from the compressed meat. As cake has no fluidity property, it continues to the screw shaft end and drained out as cakes. The cone will be connected to the end of the last thread on the shaft which allows the cake to drain out between the screw shaft and the vessel surface. By adjusting the cone from the longitudinal direction, the gap size of the cake drainage can be increased or decreased. The residual milk content of the cake becomes lower, when the gap size is smaller, it is because the compressed coconut meat is applied higher pressure. The summary of thread lengths is given in [Table-1].

Fig-5 Developed screw press for coconut milk extractor

Vessel

A larger rectangular cut is made on the vessel (barrel) which allows the coconut meat from the hopper into the starting of the screw shaft where the screw thread pitch is maximum. It has two vessels made of holes of 3 mm and 1mm all around from which the coconut milk drains out into the tank. Since, no theoretical considerations were made to fix the size of the holes, it was fabricated based on conceptual design. On the vessel's mid zone, the pressure of the cake is not very high, and the coconut milk can easily pass through the holes. That's the reason why the milk drainage zone is kept slightly far from the cake outlet zone. The pressure that the barrel can withstand 7.8 Mpa which is higher than the pressure developed by the screw thread for milk extraction 0.31 Mpa [1].

Milk collecting tank

Here the compressed coconut milk is drained and collected in the storage containers. It is placed below the vessel to collect the milk. Since, no theoretical considerations were made to design the collecting tank, it was fabricated based on conceptual design.

Choke

By changing the axial displacement of the choke on the shaft forward and backward, the maximum pressure and the cake thickness can be altered. Due to which, the amount of cake out of the cone is adjusted hence the maximum amount of coconut milk can be extracted. Since, no theoretical considerations were made to design the choke, it was fabricated based on conceptual design.

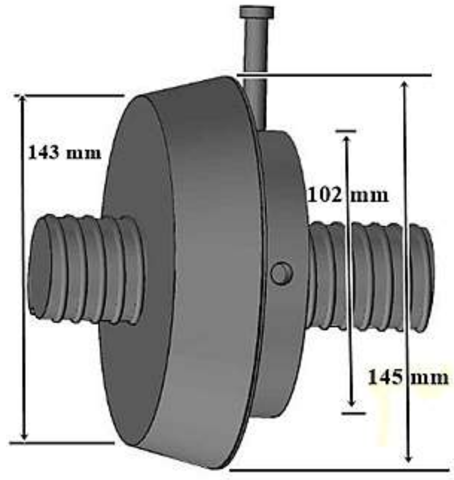


Fig-6 Conical choke

Hopper

The hopper is used to carry the grated coconut into the screw press. As gravitational force is enough for feeding, it does not require any energy. It is mounted on the top vessel and kept as a stationary part. The volume of the hopper and the capacity was designed to be 0.005169m^3 and 2 kg.

Drive system

The total power requirement of the screw press was found out to be 0.604 kW. Hence, 1hp three phase geared motor was selected to extract the coconut milk. The motor shaft will be connected to the pressing shaft. The rpm can be controlled by using variable frequency drive (Invac AC drive model 13AC101).

Material Selection and Component Fabrication

Different process where followed in the fabrication of the coconut milk extractor. The processes include marking out, machining, cutting, drilling, joining and fitting. Different number of workshop tools and machines are used for the fabrication process. They are scriber, steel rule, compass and centre punch, treadle operated guillotine for cutting and arc welding and stainless-steel welding for joining were used. It took about two months to complete the various components and finally assemble to form a complete unit. The biggest challenge came during assembling the different parts into a one unit. Different parts demanded some modifications like grinding to enable them to fix into one unit. The stand was made of mild stainless steel one-inch angle beam, which is joined by arc welding process. The stainless-steel round rod with the diameter of 125 mm is taken with the length of 800 mm. The middle portion of 400 mm is allowed for placing the screw thread. The one side of the Stainless-steel shaft of 200 mm is drilled in the lathe and allowed as a plain shaft with 350 mm diameter. This plain shaft is then allowed to join with 1 hp three phase geared motor of 0.75 kw having the motor rotation speed of 1404 rpm. The gear reduction ratio of the motor is 1:23 resulting in 62 rpm at the end of the shaft. Variable frequency drive of model 13AC10M (Invac AC drive) is connected to geared motor which helps to alter the speed of the shaft.

Table-2 The effect of physical parameters of screw press on processing time and milk yield

No	Nozzle Clearance (mm)	Speed (rpm)	Trail 1 Milk yield (%)	Time taken (minutes)	Trail 2 Milk yield (%)	Time taken (minutes)	Mean Milk yield ± SD	Mean time taken (minutes)
1	2	40	49.51	7.4	48.54	7.4	49.03 ± 0.68^a	7.4
2	2	50	49.02	7.15	49.02	7.2	49.02 ± 0.00^b	7.17
3	2	60	47.32	6.25	48.25	6.36	47.78 ± 0.65^c	6.30
4	3	40	44.05	6.42	45.59	6.45	44.82 ± 1.08^a	6.43
5	3	50	43.27	6.23	43.84	6.21	43.55 ± 0.00^b	6.22
6	3	60	43.52	6.19	42.67	6.20	43.09 ± 0.00^c	6.19
7	4	40	39.42	5.52	40.12	5.43	39.77 ± 0.49^a	5.47
8	4	50	40.53	5.48	38.57	5.37	39.55 ± 1.38^b	5.42
9	4	60	32.02	5.35	34.74	5.21	33.38 ± 1.92^c	5.28

Note: Results showing the means of two trails with standard deviations.
Values in the same row and sub table not sharing the same subscript are significantly different at p< .05 in the two-sided test of equality for column means.

Another end of the S.S shaft of 200 mm is drilled in the lathe to form a 4 mm squared threads in the shaft. Both sides of the shaft are hold by mild steel square frame of 300 x 300 mm dimension. The screw thread was provided by joining the heated 20 mm Stainless steel square rod and welding in the screw shaft in a different pitch sizes of decreasing order. The conical nozzle was fabricated in the lathe with the inner diameter of 102 mm and the outer diameter of 140 mm. The screw barrel consists of top consist of a top portion and a bottom portion. On the top portion of the barrel, the hopper which serves as a holder for holding grated coconut meat with the larger part length 260 mm and the smaller part of the frustum length 85 mm. It was fabricated in stainless steel 304. Screw barrel is made of two stainless steel mesh of thickness 2 mm with the holes of 3 mm which is combined with another stainless-steel mesh of thickness 1 mm with 1mm holes. The coconut milk collecting tank is made up of stainless steel of 400 x 300 mm dimension. The cake outlet section is provided at the end of the conical nozzle with the dimension of 150 x 125 mm which is fabricated in stainless steel.

Method of Evaluation and Statistical Analysis

Selection and Preparation of test materials

Matured Coconuts were purchased from a local market at Thanjavur with an average weight of 423.08±52.02 gram and an average moisture content of 43.74±1.15% (w.b). The coconuts were cleaned, cut and then grated by using electric coconut scrapper available at incubation center of IIFPT, Thanjavur. The machine was run at no load in preparation for the experiment.

Design of experiment

Three different experimental setups were carried out with combinations of different parameters in order to determine the effect of independent variables like speed, nozzle clearance on dependent variable milk yield. Treatment of the coconut milk extractor was carried out at different nozzle sizes of 2, 3, 4 mm and three different speeds of rotation at 40, 50, 60 rpm using 3 x 3 factorial experimental design with twice replication. The resulted data was analyzed using two- way ANOVA (SPSS 12) by Univariate with Tukey's Multiple Range test to indicate the differences among means (p<0.05) expressed as Mean ± Standard Deviation (M± Standard Deviation (M±SD) [11].

Table-3 Experimental setup

Setup 1	Setup 2	Setup 3
N2- ω40	N3- ω40	N4- ω40
N2- **ω**50	N3- ω50	N4- ω50
N2- **ω**60	N3- ω60	N4- ω60

ω-rotational speed in rpm, N is nozzle size in mm

Evaluation of the system

The constructed coconut milk extractor was tested to evaluate its performance in the extraction process. Materials required include weighing balance, measuring cylinder, grated coconut meat, milk receiving container and cake receiving container. One kilogram of each combined treatment from grated coconut meat was filled into the feeding hopper and pressed by the screw press with nozzle sizes of 2, 3, 4 mm and with rotational speed of 40, 50 and 60 rpm. The coconut milk was weighed and percentage of milk yield was calculated using the formula [2]:

$$Milk\ yield\ (\%) = \frac{m_0}{m_s} x\ 100$$

Where: m_0 – weight of milk extract, m_s of sample.
The Milk extraction efficiency of the press is given by the following formula,

Calculation of milk extraction efficiency

Milk extraction efficiency was calculated using the formula adopted from [5]

$$MEE = \frac{AMY}{TMY} x \frac{100}{1}$$

Here, MEE is the milk extraction efficiency of the press (%), AMY is the actual milk yield (g) and TMY is the theoretical Milk yield (g), TMY is the coconut milk content (CMC (%)) multiplied by weight of sample (g).
A study showed that the total lipid content (%DM) found in the mature coconut meat is found to be 62.64% [13], which is considered for the theoretical milk yield (TMY) in order find the extraction efficiency of the extractor.

Calculation of feed rate and specific energy consumption

Finally, 20 kg of grated coconut were taken and divided into 4 samples of 2, 4, 6, 8 kg each [5]. Each sample's pressing time was recorded with the stop watch. Since the hopper capacity is only 2 kg, the feed material inlet is constantly metered.
i) The screw press feed rate was calculated using the following equation [5]

$$FR = \frac{WS}{APT} x \frac{100}{1}$$

Here, FR is the feed rate of the screw press (kg/hr), WS is the weight of the sample(g), APT is the average processing time per sample (h).
ii) The specific energy consumption for each sample is calculated by the following equation [5].

$$SEC = \frac{PR\ x\ T}{WS}$$

In the above equation, SEC is the Specific energy consumption of the screw press (kWh/Kg- sample), PR is electric motor power ratings (0.75 kW), T is the time taken to complete a process operation.

Results and Discussion

The effect of physical parameters of screw press on milk yield

The average percentage of coconut milk yield which was expelled using screw press extractor with various nozzle clearance and rpm is shown in the [Table-2]. Based on result [Table-2], it says that, the percentage of coconut milk yield was higher at the point of combination of the nozzle clearance of 2 mm with the rotational speed of 40 rpm which yielded about 49.03% of coconut milk. The lowest coconut milk yield of 33.38% was analyzed during the point of combination of the nozzle clearance of 4 mm with the rotational speed of 60 rpm. Both lower and higher percentage of coconut milk yield were having a significant difference (p<0.05) with other results.

Effect of speed on coconut milk yield

The experiment shows that the increase in rotational speed of the motor resulted in decrease in the milk yield. It had showed a pattern of decrease in milk yield percentage at 40 rpm to 60 rpm of rotational speed. This is most probably related to the time of pressing process. The result was supported by a study [14] where the barrel's pressure gets decreased when the screw speed gets increased while

Table-4 Performance evaluation of the developed extractor

Sample No.	Sample mass (kg)	Processing time (minutes)	Feed Rate (kg/hr)	Specific Energy Consumption (kWh/kg)
1	2	7.4	27.02	0.0462
2	4	15.2	26.3	0.0475
3	6	18.5	32.43	0.0385
4	8	22	36.36	0.0343
Average			30.52±3.86	0.041kWh/kg±0.01

pressing canola and the amount of oil is residual cake gets increased while increasing speed. Another study result [4] showing that, increasing the speed of rotation of the screw resulted in the reduction of residence time, hence the time required for the maximum amount of oil draining from the seeds also get reduced. [7] used Jatropha seeds for oil extraction optimization study with a screw press. In this study, two different screws with two different press cylinders were tested using three different nozzles and three different rotational speeds (low, medium and high). The highest oil recovery was 89.4% (w/w) and obtained at the lowest rotational speed [7]. Therefore, the result indicated that rotational speed of 40 rpm is seemed to be the best speed for give optimum pressure to produce optimum percentage of milk yield. The effect of nozzle clearance and speed on milk yield if shown in the [Fig-7].

Fig-7 Developed Coconut Milk Extractor

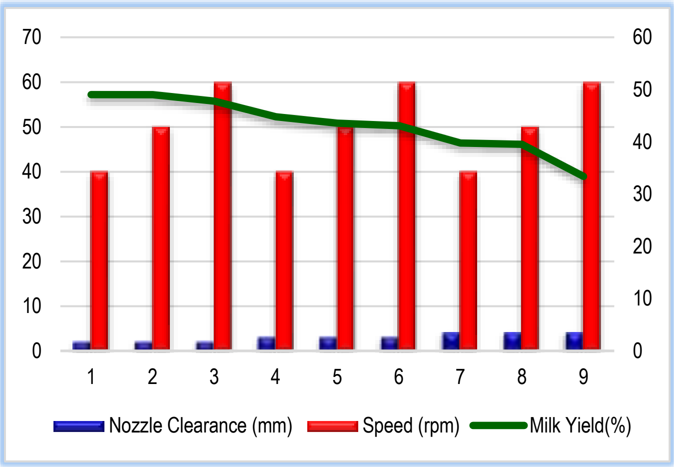


Fig-8 Effect of nozzle clearance and shaft speed on coconut milk yield

Effect of clearance of on coconut milk yield

It was showing that the average milk yield started to decrease while increasing the nozzle clearance (mm). It had showed a pattern of decrease in milk yield percentage at 2 mm to 4 mm of nozzle clearance. This is mainly due to the result of decrease in pressure for extracting process. It was studied [8] that pressure is responsible for breaking the cell walls of the seeds and for releasing more oil from the seeds. Similar supporting result was obtained by a study, [6] where the maximum yield of oil was recorded at the lower nozzle clearance size of 6 mm in the screw press with a rotational speed of 45 rpm. Also observed that the yield of oil from groundnut increases with a reduction in clearance [10]. The size of the nozzle might add pressure to the seed which thus promote heat to be produced by the result of the collision between the shaft screws and the seeds and also between the seeds themselves [4]. Thus, their study showed that the nozzle clearance does influenced the production of oil yield.

Effect of time on milk yield

From the [Table-2] it was showing that the time required for processing grated coconut started to decrease with increase in nozzle clearance and rotational speed. The highest processing time of 7.4 minutes was recorded to get the maximum milk yield of 49.03%. The lowest time of 5.28 minutes was recorded to get the minimum milk yield of 33.38%. This is mainly due to the result of increase in material flow rate with larger nozzle clearance. It results in lower processing time due to which minimum yield of extraction in obtained. This statement was supported by [4] saying that increasing the speed of rotation of the screw resulted in the reduction of residence time, hence the time required for the maximum amount of oil draining from the seeds also get reduced. It was also supported by [15] which stated that, the clearances have larger effect on the mass flow rate, the enlargement of clearances will bring larger leakage amount.
Thus, this result does support the result analyzed from this experiment saying that, lower rotational speed and nozzle clearance result to the higher amount of coconut milk yield.

Performance evaluation of the developed extractor

Calculation of feed rate and specific energy consumption

The optimized screw press combination for maximum milk yield is adopted for finding the other performance indices like feed rate and specific energy consumption. The results of the screw press extractor feed rate (FR), specific energy consumption (SEC) from the different experiments is shown in the [Table-2]. The results indicate the values of 30.52 kg/h and 0.041kWh/kg-grated coconut for average feed rate (FR) and Specific energy consumption (SEC).

Calculation of milk extraction efficiency

A study showed that the total lipid content (% DM) found in the mature coconut meat is found to be 62.64% [13], which is considered for the theoretical milk yield (TMY) in order find the extraction efficiency of the extractor.
The milk extraction efficiency of the press is given by the formula [5],

$$MEE = \frac{AMY}{TMY} x \frac{100}{1} = 78.27\%$$

Here, MEE is the milk extraction efficiency of the press (78.27%), AMY is the actual milk yield (49.03%) and TMY is the theoretical Milk yield (62.64%).

Summary

A machine was designed and developed for coconut milk extraction and its performance was evaluated. Findings indicate that screw press with straight and variable pitch inner shaft is simpler, more effective and generate more pressures compared with other designs of screw presses. The selection of the screw press with straight and variable pitch inner shaft can reduce initial and maintenance costs, and easy to clean and maintain. The conical type choke mechanism and drilled holes type milk drainage system were selected due to simplicity and cost considerations. The milk extraction efficiency was found to be 78.27%.

Conclusion

A machine was designed and developed for coconut milk extraction and its performance was evaluated. The milk extraction efficiency was found to be 78.27%. The milk yield was tested with three different nozzle clearance 2, 3, 4 mm and rotational speeds 40, 50 and 60 rpm. It says that, the percentage of coconut milk yield was higher at the point of combination of the nozzle clearance of 2 mm with the rotational speed of 40 rpm which yielded about 49.03% of coconut milk. The lowest coconut milk yield of 33.38% was analyzed during the point of combination of the nozzle clearance of 4 mm with the rotational speed of 60 rpm. Both lower and higher percentage of coconut milk yield was having a significant difference ($p<0.05$) with other results.

Application of research: To the coconut farmer, the result of the study may motivate them to produce more coconut because the demand of coconut in the market will increase which tends the price of coconut also may increase. The people engaged in food business, they may able to afford the low-cost coconut milk extractor which make their work easier and faster which make their business to expand resulting to increase their income. The enterprising people may find interest in fabricating this low-cost coconut milk extractor.

Research Category: Food Process Engineering

Acknowledgement / Funding: Authors are thankful to Department of Food Engineering, Indian Institute of Food Processing Technology, Thanjavur, 613005, Tamil Nadu Agricultural University, Coimbatore, 641003, India

***Research Guide or Chairperson of research: Dr Tito Anand**

University: Tamil Nadu Agricultural University, Coimbatore, 641003, India

Research project name or number: MTech Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Indian Institute of Food Processing Technology, Thanjavur, 613005

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Ethical Committee Approval Number: Nil

References

[1] Bako T., Awulu J.O. and Garba A.J. (2017) *American Journal of Modern Energy*, 3(6), 136-145.

[2] Beerens P. (2007) *Eindhoven University of Technology. Ministerio de Ambientey Energía MINAE (2007) "Plan Nacional de Biocombustibles". Costa Rica.*

[3] Eric O., Franklin D.J. and Holbrook L.H. (1982) *Machinery handbook (21ed.). New York.*

[4] Evangelista R.L. (2009) *Industrial Crops and Products*, 29(1), 189-196.

[5] Evangelista R.L. and Cermak S.C. (2007) *Journal of American Oil Chemists' Society*, 84, 1169-1175.

[6] Ezeoha S., Akubuo C., Odigboh E. and Arallo M. (2017) *Nigerian Journal of Technology*, 36(2), 636-642.

[7] Harmanto A., Hendriadi E., Rahmarestia M. and Wiyono J. (2009) *Indonesian Journal of Agriculture*, 2(1), 35-40.

[8] Karaj S. and Müller J. (2011) *Industrial Crops and Products*, 34(1), 1010-1016.

[9] Khan L. and Hanna M. (1983) *Journal of Agricultural Engineering Research*, 28(6), 495-503.

[10] Khurmi R.S. and Gupta J.K. (2008) *A textbook of machine design (6 ed.). New Delhi.*

[11] Olayanju T. (2003) *Trop. Sci*., 43, 181-183.

[12] Pallant, J. (2005) *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows (Version. In: Allen & Unwin Pty, crow's Nest, Australia.*

[13] Punchihewa P. and Arancon R. (2006) *Coconut: Post harvest operations. Asian and Pacific Coconut Community.*

[14] Santoso U., Kazuhiro K., Ota T., Tadokorob T. and Maekawab A. (1996) *Food Chemistry*, 57(2), 299-304.

[15] Vadke V.S. and Sosulski F. (1988) *Journal of the American Oil Chemists' Society*, 65(7), 1169-1176.

[16] Yan D., Kovacevic A., Tang Q., Rane S. and Zhang W. (2017) *Journal of Mechanical Engineering Science*, 231(24), 4617-4634.

[17] Zehev Tadmor, Costas G. Gogos (2006) *Principles of Polymer Processing. Hoboken, New Jersey*, ISBN: 978-0-471-38770-1.