

## DEVELOPMENT OF A PROTOTYPE OF SCREW PRESS FOR THE COLLECTION OF OIL FROM SEEDS OF CASTOR AND JATROPHA

Keyll Carlos Ribeiro Martins; *kmartins@ifma.edu.br*<sup>1</sup>  
Pires, Hellen Cristina Silva; *hellen\_pires@hotmail.com*<sup>1</sup>  
Viana, Luciano Galvão; *luciano.eng.mec@gmail.com*<sup>1</sup>  
Lídia Santos Pereira Martins; *lidiamsp@gmail.com*<sup>2</sup>  
Silva, Lorenni Evren Matias da; *lorennievren@yahoo.com.br*<sup>1</sup>  
Rodrigues, Jean Robert Pereira; *jrobert@ifma.edu.br*<sup>1</sup>

<sup>1</sup>Department of Mechanical and Materials, Federal Institute of Education, Science and Technology of Maranhão, Avenue Getúlio Vargas, 4, Monte Castelo – CEP 65000-000, Sao Luis, MA, Brazil

<sup>2</sup>Department of Chemistry and Biology, State University of Maranhão, University City Paulo VI - Tirirical Avenue S/N, Tirirical - CEP 65055-970 - Sao Luis, MA – Brazil

**Abstract.** *This paper discusses the construction and testing of a system of continuous mechanical pressing to extract vegetable oil from seeds of castor and jatropha. Currently, the scientific literature concerning the design of an extrusion press is not presented accurately. For develop the prototype the physical variables were understood and applied in this study to facilitate the design of the project. The study made it possible not only the design of the prototype, but also in establishing a methodology for sizing this type of equipment based mainly on the control of two parameters: the compression ratio and pressure drag. The first parameter is related to reduced passage area available for seed. The second is related to seeds subjected to pressure along the cylindrical chamber. The analysis of these physical characteristics of the project allowed to discuss their structural dimension to enable their CAD model and subsequent construction, assembly and testing.*

**Keywords:** *Oilseed; Vegetable oil; Pressing*

### 1. INTRODUCTION

The extraction plant for generation of biodiesel are promising because, when compared to the use of fossil fuels, their use reduces the emission of CO<sub>2</sub>, SO<sub>x</sub> and hydrocarbons released to the environment and therefore there is the qualitative and quantitative reduction in pollution levels environment. Is therefore a market growing rapidly (FERRARI et al., 2005).

The national biodiesel program, with the obligatory 2% mixture with petroleum diesel, generated an increase in demand for vegetable oils, a key raw material for the production of this renewable fuel. Small rural communities are currently supplying oil seed, constituting only a small part of the government. To increase the participation of these communities in a program option that allow farmers the extraction of vegetable oils in their properties, mechanical presses continuous are used (PIGHINELLI, 2007). The availability of large areas for planting, scientific knowledge, and manpower make Brazil a country ready to receive investments for the production of vegetable oil.

The use of vegetable oils in internal combustion engines dates back to the early use of the diesel engine itself, as long as the internal combustion engine was invented by Rudolph Diesel, knew that it could operate it with vegetable oils, because in 1896, Diesel designed his first engine with efficiency ranging from 26% and tested it with oil, alcohol, and in 1900, with vegetable oils (OLIVEIRA, 2004). For economic reasons, because of their higher cost and lower availability compared to the petroleum products, the use of vegetable oils as a source of fuel was completely abandoned for a while. However, the increase in oil prices, which started in 1973, generated a new global consciousness about the production and consumption of energy, especially when originating from non-renewable, such as fossil fuels (KÖRBITZ, 1999).

There are three main methods used for extraction of oil, with possible variations or even combinations of these processes: batch hydraulic pressing, pressing mechanical continuous (expeller) and solvent extraction. Among the processes of extracting mechanical pressing is seen as continuing the process more efficient in oil extraction and has been replacing the hydraulic presses (WEISS, 1983). As for the efficiency of the process, the result is well below that achieved by the traditional method of solvent extraction, being directly affected by the initial conditions of the grains, such as moisture content and temperature, and constructive aspects of the press, as its design axis and the camera (PIGHINELLI, 2008).

The screw press within the system of small plants vegetable oil production presents itself as the most advantageous system. The system of continuous screw pressing of oilseeds is characterized today as a practical, functional and inexpensive to obtain oils and is an activity highly recommended for small communities of farmers. It is simple construction, easy maintenance and operation are not needed with highly qualified technical professionals for its use (COSTA, 2008). The research on this subject are being taken aiming the continuous improvement of the process. The

mechanical continuous press is a simple and adaptable to various types of oil and in a short space of time, allows installation in small farms and use of byproduct (pie) as fertilizer or animal feed (SINGH and BARGALE, 2000).

The efficiency of this type of process is also affected by the initial conditions of the grains, such as moisture content and temperature, cooking processes and heating of the grains before pressing, and construction aspects of the mechanical press, as its axis and sizing of chamber compression. Added to this, studies also show that the variation of moisture content of seeds through physical, chemical or hydrothermal pretreatment resulted in an increase of 50% to 80% in rates for oil from various oilseeds (SINGH and BARGALE, 2000).

This work aimed at the development, construction and testing of a prototype system of mechanical pressing to extract vegetable oil. Operating principles and parameters of the extraction process to dealing with this type of equipment have been studied to understand the physical and dimensional variables that could provide direct or indirect influence on efficiency or income of such a process of mechanical extraction. Initially samples were used for seeds of jatropha, and castor oil then. The formulation of such a prototype project aimed at obtaining a low-cost manufacturing and ease of operation that meets the needs of small farmers in the state of Maranhão, and could serve to use in research laboratories.

## 2. SEMENTED OIL

The plants that are considered promising for the production of biodiesel must have their actual technical capabilities evaluated and its side effects as the utilization of byproducts and, in light of that diagnosis, model production, considering the characteristics of regionalization, to define which technology is applicable, and especially those aspects related to quality of biodiesel.

### 2.1 Jatropha

The jatropha (*Jatropha curcas* L.) belongs to the family Euphorbiaceae, the same castor bean, is characterized by its ruggedness, it is drought resistant and less susceptible to pests and diseases. It is a species native to Brazil and can be grown in areas with less fertile soils and climate unfavorable to the majority of traditional food crops, such as in semi-arid region. Its seeds are rich in oil and have desirable characteristics for the production of biodiesel (MELO, 2006).



Figure 1. Planting Jatropha



Figure 2. Seeds of Jatropha (with shell and shelled)

In these seeds the percentage of oil is about 37.5%. This species is not being exploited commercially in Brazil, but is an oleaginous plant viable for obtaining biodiesel because it produces at least two tons of oil per hectare, taking three to four years to reach productive age, which can extend for 40 years.

### 2.2 Castor

The castor bean (*Ricinus communis* L.) is a plant belonging to the Euphorbiaceae family, the same as cassava and rubber. It probably originated in Africa or India, and now cultivated in several countries, with India, China and Brazil, in order, the world's largest producers. The main product of the castor bean is its oil, which has unique chemical properties that make it unique in nature: it is the fatty acid ricinoleic which has large predominance in oil composition (90%) and has a hydroxyl (OH) which gives it properties such as high viscosity, chemical and physical stability and solubility in alcohol at low temperature (EMBRAPA, 2010).



Figure 3. Planting Castor



Figure 4. Photos of castor seeds

Besides the wide application in chemical industry, the castor bean is important because of its tolerance to drought, making it a viable culture to the semi-arid region of Brazil where there are few agricultural alternatives. However, this culture is not unique to semi-arid region and is also planted with excellent results in various regions of the country.

Castor oil can be extracted through various ways, among which the most used and also the simplest stand out pressing extraction discontinuous and continuous, and pressing combinations of continuous solvent extraction.

Castor oil has hundreds of applications within the chemical industry, being a versatile raw material with which to make several reactions leading to various products. Its main applications are for the manufacture of greases and lubricants, inks, varnishes, foams and plastics for various purposes. (EMBRAPA, 2010).

### 3. PRESSING PROCESS IN A SCREW PRESS

The literature on the design of screw presses reveals that most of the knowledge related to the design and development of this type of equipment belongs to the holders of large manufacturers in industrial scale production systems. Thus, the correct approach to projects is the combination of screw extrusion theory with practical experience. While the theory of extrusion is not fully developed, there is no substitute for practical experience (CHRIS RAUWENDAAL, 1991).

The extrusion press consists of an auger mounted on an axle suspended by conical bearings. The axis of the extruder has the same rotation center of the cylinder to which it is confined (Ademola, 2003). The turning of the screw (propeller shaft) is responsible for advancing the material inside the cylindrical chamber, turning the seeds into a mass flow, comprising a substrate seed and vegetable oil, which by action of the axis configuration is reduced in your area crossing. This bottleneck to the mass flow is responsible for oil extraction plant, according Fig. 5.

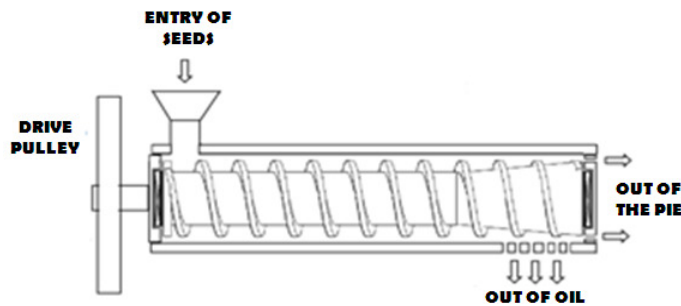


Figure 5. Schematic representation of the working principle of a screw press.

The vegetable oil in the form of oil globules, first, is contained in the cells of oleaginous seeds, along with other components such as proteins, cells and cell nucleus. These are involved in the membrane of the cell wall. In Fig. 6 you can see a representation of the micro-cell section of a seed of canola. The rotation of the auger creates axial and radial forces on the seeds that lie within the inside of the cylindrical chamber. The pressure put seed breaks the cell walls and releases the oil globules. In Fig. 7 arrows indicate the stresses acting on the mass flow of between two fillets thread and direction of movement restrictions caused by movement of the auger. The force that causes pressure in the chamber is the component that is in the direction of material advance which can be seen in Fig. 8.

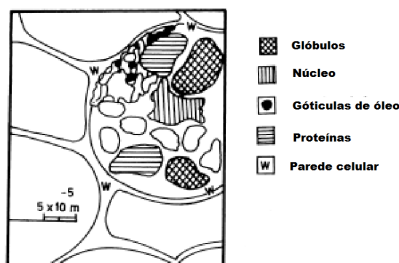


Figure 6. Micro-cellular Section.

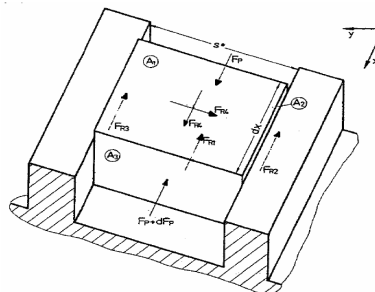


Figure 7. Tensions mass flow.

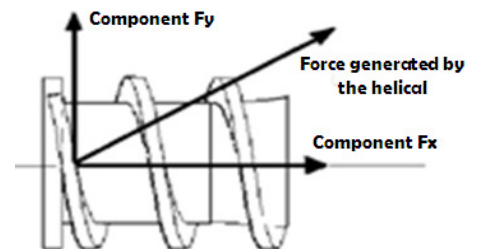


Figure 8. Forces generated by rotation of the auger

A model widely used for the extraction process is a model of continuous compression zones, see Fig 9. In this model the length of the cylindrical compression chamber is divided into three areas: zone diet, zone and compression zone plugs (VARD, 1976).

In the first area, the seeds are inserted into the compression chamber. The transport of seeds in this area is responsible for the initial start of the oilseed crushing and elimination of air contained within the chamber. Its main function is to ensure the homogeneity of mixing oil and solid to be passed to the next zone. In the compression zone, the mass begins to be pressed due to the gradual restriction of the movement promoted by varying the diameter of the auger. This reduction in available area for the passage of the seeds results in strangulation of mass flow and, consequently, the separation of vegetable oil. In the third area, closures, the passage of material is minimum. Only the pie and a small quantity of oil is still present in the mass flow. After that point, the oil flows through these holes in the bottom of the cylinder and the substrate is discharged at the far side of the cylinder (ADEMOLA, 2003).

Another important principle to be considered in the design of extrusion presses is the equation of the relationship between the quantity of material entering and compression applied on it, see Fig 10. The rate of compression of screw worm auger is the relationship between the volume of material displaced by action of the rotating section and the volume of food moved in the area of closure (SINGH and BARGALE, 2000).

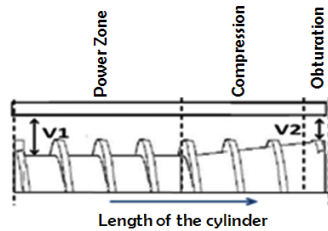


Figure 9. Representation of process model based on the mechanical pressing areas of compression.

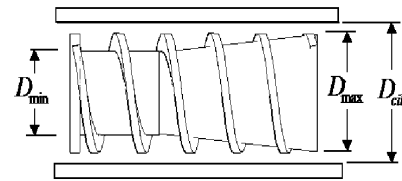


Figure 10. Representation of the compression ratio

In practice, we use compression rates higher than the theoretical rates to arrive at an acceptable level of oil obtained as a way to compensate the losses suffered in the rotation and torque of the shaft during the extraction process.

## 4. MATERIALS AND METHODS

### 4.1 Scaling, equations of operation and materials used

The study prepared for the sizing of the auger was aimed at obtaining the maximum extraction efficiency of the extrusion press to be obtained by varying only the mechanical parameters of the process. In this sense, the work pressure and compression exerted on the seeds were the parameters used for the Auger project. The main focus of this phase of the research was the systematization of a design methodology suitable for the development of such prototype.

The following table shows all nomenclature involved in the equations of operation.

**Table 1. Definition of nomenclature used in the equations for sizing of the mechanical press**

Nomenclature			
$D_{cil}$	Inner diameter of the cylinder	$D_1$	Diameter of drive pulley
$D_{max}$	Maximum diameter of the shaft	$D_2$	Lower intermediate pulley diameter
$D_{min}$	Minimum diameter of shaft	$D'_2$	Larger diameter idler pulley
$l$	Length Auger	$D_3$	Pulley diameter of the helix axis
$l_{con}$	Length of the conical shaft	$Pot_{nec}$	Engine Power
$\alpha$	Angle of the cone axis	$T$	Torque
$\beta$	Angle of the screw thread	$N$	Rotational speed of the motor
$h$	Thread pitch helicoid	$Ne$	Rotational speed of the auger
$A$	Cross sectional area	$R_c$	Compression ratio
		$P$	Work pressure

In General, power and speed provided by the drive shaft to generate torque which gives rise to the rotating helix, which in turn creates a force acting on seeds. A component of this force acts in the same direction of mass flow within the compression chamber, dividing the length of the contact area of the shaft leading finally to work pressure. According to Singh and Bargale (2000) a compression ratio of 10:1 is sufficient to perform the extraction process. Based on this initial value is possible to use the relationship given by Eq. (1) to define possible values for the diameter of the cylinder to the maximum diameter of the cone axis and its minimum diameter.

$$R_C = \frac{D_{cil}^2 - D_{min}^2}{D_{cil}^2 - D_{max}^2} \quad (1)$$

After defining the diameter of the shaft and the jacket of the chamber, the total length of the auger should be sized so as to ensure the efficient grinding the seeds on the gradual extraction of oil. The extent of the feeding zone should allow a good homogenization of the seeds that formed the mass flow (pie and substrate). The extent of the compression zone, when related to the minimum and maximum diameter of the tapered portion of the shaft, is responsible for the formation angle of the tapered portion of the helix. A small angle of inclination when combined with a good compression ratio, enables a gradual compression of mass flow. Thus the conical part of this should have a length of approximately 50% of the total length of the tapered shaft. As a result, we calculate the slope of the tapered portion to be used in calculating the length of the helix Eq. (2).

$$tg\beta = \frac{1}{2} \frac{d_{\max} - d_{\min}}{l_{con}} \quad (2)$$

It was pre-defined a methodology for calculating the size of the initial prototype of the auger as a function of compression ratio, the method was developed to perform calculations related to the pressure to be exerted on the seed to achieve the extraction process. This pressure depends on the force generated by the drive shaft and the cross-sectional area closures in the area. The calculation of the cross-sectional area is obtained by Eq. (3):

$$A_{\text{sec}} = \frac{\pi(d_{\max}^2 - d_{\min}^2)}{4} \quad (3)$$

The calculation of the pressure of work has as its starting point the values of power and speed of work provided to the press auger extruder (ADEMOLA AND ADEKOYA, 2003). The calculation of the torque generated in the auger is obtained by Eq. (4):

$$T = \frac{Pot_{nec}}{\omega} \quad (4)$$

The data, when used in conjunction with the value of minimum diameter of the shaft, allow to define the force acting on the shaft and its component that acts in the direction of displacement of mass along the length of the compression chamber. The values of the force generated by the rotating helix and its component can be obtained using Eq. (5) and (6).

$$F = T \times \frac{2}{d_{\min}} \quad (5)$$

$$F_x = F (\cos \alpha) \quad (6)$$

Soon the pressure applied on the seeds is obtained by Eq. (7):

$$P = \frac{F_x}{A_{\text{sec}} (\cos \alpha)} \quad (7)$$

Study the effect of the calculation method has been tested using the dimensions of prototypes developed in other work related to the design and construction of extrusion presses. Using the dimensions of the prototype developed by Bargale in 2000, data were obtained for theoretical work pressure and compression ratio of 19,75 MPa and 9,48, respectively. Already using the dimensions of the prototype developed in 2003 by Ademola, theoretical data were obtained for pressure and compression ratio of 17,35 MPa and 3,7 respectively. The theoretical results obtained for the two works can be seen in Tab. 2

Table 2. Application of the methodology of sizing screw press using dimensions obtained in other studies related to the design of prototype press extruder.

Pot <sub>Nec</sub> (kW)	Ne(rpm)	T(N.m)	Fcosq (N)	A <sub>sec</sub> (m <sup>2</sup> )	Dmin (m)	Dmax (m)	Dcil int (m)	[Re]	P(Mpa)	DATA
5.600	96,00	557,042	25.246,550	0,001278	0,042	0,058	0,060	9,480	19,754	BARGALE, 2000
1.500	90,00	159,155	12.176,050	0,000702	0,025	0,039	0,043	3,700	17,357	ADEMOLA, 2003

Since, both prototypes, achieved its objective in performing the extraction of oil from oilseeds becomes possible to assume that the design methodology developed can be used to accomplish the design of a prototype of a screw press



with similar principle, operation and transaction. It was then mounted a second table with the possible dimensions for the prototype of the shaft. To drive the equipment used was a three-phase asynchronous electric motor with power of 2.2 kW and operating speed of 1710 rpm.

According to the work of VADKE (1988), low rotation speeds produce greater efficiency in the extraction process. It was necessary, the development of a transmission mechanism capable of adjusting the rotation of motor output to the rotation for more efficient extraction. The transmission system is built on the use of four pulleys of aluminum, shown in Fig 11.

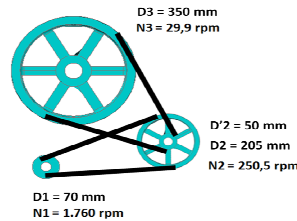


Figure 11. Representation of transmission system used to reduce the rotational speed of the auger against the firing of the electric motor.

With the relationship of transmission to the drive system, it is possible to establish the values of compression ratio and pressure from the data related to the dimensions of the auger, his speed and his power of work. The Tab. 3 shows the configuration of the prototype press extruder to be built.

Table 3. Data from the prototype press extruder obtained from the sizing methodology.

Pot <sub>Nec</sub> (Kw)	Ne (rpm)	T(N.m)	Fcosq (N)	A <sub>sec</sub> (m <sup>2</sup> )	Dmin (m)	Dmax (m)	Dcil int (m)	[Rc]	P(Mpa)	DATA
2205	29,31	718,396	31234,627	29869,822	0,046	0,055	0,0555	17,452	41,839	PROTOTYPE

#### 4.2 Determination of Materials

The material used in this mechanical press is an a priori decision; it is necessary to calculate the mechanical elements. This is an application that does not leave many possibilities. It must be a material with high hardness to resist wear and low oxidation to prevent contamination of the extracted oil. Thus we decided to use a SAE 1045 steel, that is a high-strength steel to the action of shear force, and temperature imposed by heating the cylinder wall. The following properties shown in table 4:

Table 4. Properties of 1045 steel

Properties	1045 Steel
Resistance limit (minimum)	58 kgf/mm <sup>2</sup>
Yield Strength (minimum)	30 kgf/mm <sup>2</sup>

#### 4.3 Process Modeling in CAD and manufacturing

After defining the dimensions of the prototype of the screw press, we begun the modeling in CAD and manufacturing processes and assembly. From the measurements of each component was mounted the three-dimensional model shown in Fig.12.

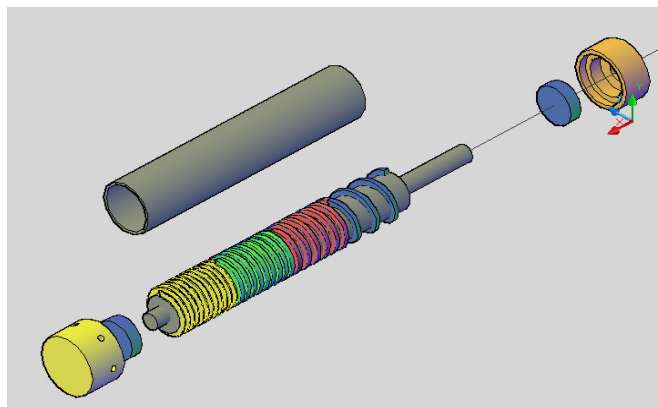


Figure 12. CAD modeling of the cylindrical chamber compression of the prototype of the screw press.

During the study of the main methods used for manufacturing an auger we found a wide variety of manufacturing processes and screw axle configurations. In the search for more practical and economically viable stood out, in order of importance, the machining on a computer numerical controller (CNC Module), industrial machining on a lathe and finally forming the hot in a prefabricated tapered shaft. The second case was selected because of the unavailability of a technique of CNC machine. The axis of the screw press was machined SAE 1045 steel according to the dimensions in the design of manufacturing shown in Fig. 13

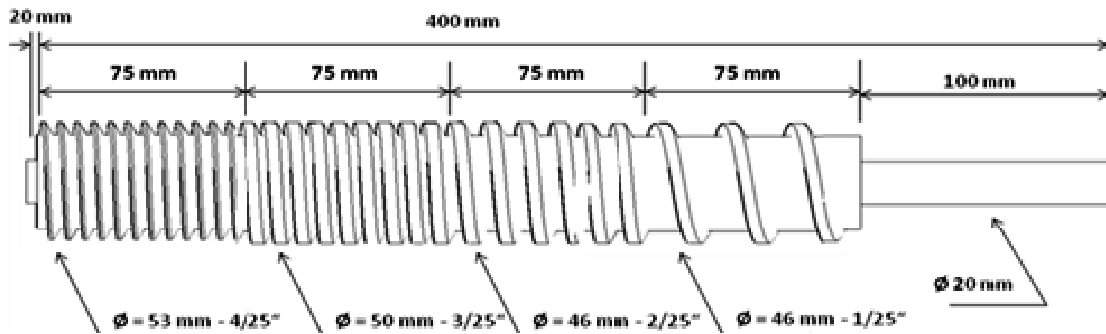


Figure 13. Production drawing Auger built in SAE 1045 steel.

After construction of the shaft, the shirt of the compression chamber was machined from a galvanized steel pipe. They were then machined into SAE 1045 steel brackets that support for the bearings supporting the shaft. The representation of the design and fabrication of the supports of the shirt is found in Fig. 14. The extension shaft was used with point coupling drive pulley. A support structure of the compression chamber and motor drive was built then.

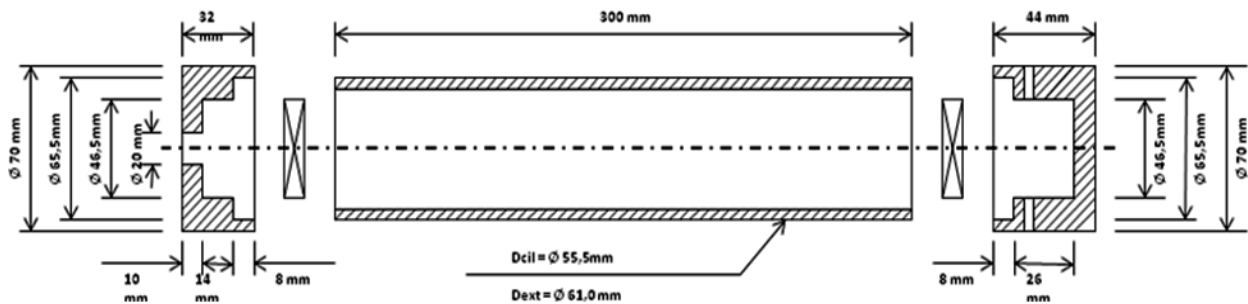


Figure 14. Design of the manufacture of SAE 1045 steel supports and the cylinder liner galvanized steel.



Figure 15. Photo of the prototype of the screw press.



Figure 16. Photo of the prototype of the screw press with support.

Table 5. Dimensions and technical information of the prototype of the screw press.

Dimensional Parameters	Dimensions
Total length of shaft (mm)	400 mm
Length of helix (mm)	300 mm
Length of feed section (mm)	150 mm
Length of compression section (mm)	140 mm
Length of section plugs (mm)	10 mm
Outside diameter of the cylinder (mm)	61 mm
Inner diameter of the cylinder (mm)	55,5 mm
Outer diameter of helix (mm)	55 mm

Operating Parameters	Dimensions
Power drive motor	2,2 kW
Rotation of the drive motor	1.710 rpm
Rotational speed of the shaft	29,31 rpm
Compression ratio	
1st stage compression	1,66 : 1
2nd stage compression	2,14 : 1
Total Compression Ratio	3,60 : 1

## 5. TESTING AND ANALYSIS

For the tests, were acquired the seeds to pressing the seeds of jatropha in local commerce and castor bean seeds directly from the plantations, where the latter needed to work was drying and peeling to obtain the seeds.

It was expected with this test verify that the prototype would be capable of dealing with four specific goals related to this initial stage of research: Ability to perform the crushing of the seed evenly generating pie; Ability to perform the transport of mass flow consisting of oil and substrate along the compression chamber; Ability to perform the separation between oil and the substrate; And finally, capacity to generate vegetable oil suitable for use both in research related to biodiesel production as the production of oils lubricants. The care of these items enable the prototype to the second stage of research, where the influence of mechanical parameters was studied, along with the influence of aspects such as moisture content of samples and methods of preparation of the seeds before extraction.

### 5.1 Tests with jatropha

The seeds of jatropha were shelled and weighed, with the selected sample approximately 300 grams. Then the samples were inserted at the entrance of the press. The press would rotate the auger in 29.31 rpm, with a pressure drag of approximately 41.8 MPa. The pressing process lasted about 25 minutes elapsed between the start of the test with the activation of the equipment and the end of the test with disabling the prototype.

### 5.2 Tests with castor

The castor bean seeds were dried, shelled and weighed, with the selected sample approximately 172 grams. They were then placed at the entrance of the press. After about three minutes elapsed transmission system stopped working due to a slack in the belt and, with the accumulation of material in the compression chamber caused a crash, being necessary to stop the test to adjust the belt. The pressing process lasted about 15 minutes elapsed between the start of the test with the activation of the equipment and the end of the test with deactivation of the prototype.



Figure 17. Castor in the drying process



Figure 18. Peel of seeds of castor



Figure 19. Seeds of the castor

In both tests, the samples deposited at the entrance of the equipment were not completely sucked into the compression chamber. The amount of seed added to the input format of the feed zone apparently are the possible causes for this phenomenon. It was necessary to manually force remaining seeds into the chamber. With the seeds of jatropha, eight minutes after the test, the material expelled by the action of rotation of the auger starts flowing in small quantities by the vents below the cylinder. This material is presented as a mixture between substrate seed and vegetable oil. After 15 minutes of output of material, the 25 minute test ends, with no further changes present, the equipment was turned off. Now with samples of castor oil, this process begins with five minutes of testing, performing the same way: as a homogeneous mixture. When disassembling the compression chamber of the press noted that over 70% of the samples included in the mechanical press still was among the fillets Auger featuring two stages of homogeneity. In the feed zone



of the press, it was still possible to identify some parts of castor bean seeds. Already the tapered portion of the sample axis was constituted by the substrate seed and vegetable oil. Even being able to generate a homogeneous mass, the pressure drag of the prototype seed still is unable to perform both the transport of mass flow as to achieve a separation between oil and substrate thereby producing the vegetable oil.

## 6. CONCLUSIONS

The prototype was built and the data obtained show the feasibility of constructing such equipment. It requires new research and testing to consolidate and develop design methods for new prototypes, as well as research of the flow and amount of oil produced. The experimental results show that there is need to work an improvement in extraction equipment, since the operating principle of the press has been reached, but not well, since there was no extraction efficiency due to the homogenization of the powdered seeds, which generated a kind of substrate that can not be used as pie, because of the presence of oil in it.

In future research, it is necessary to perform analysis of the value of pressure obtained within the compression chamber by means of measuring instrument to determine whether the pressure is to calculate the actual pressure of work. It is also recommended to perform more tests with different axle configurations to improve the design of the auger and increase efficiency. As an alternative to reducing manufacturing costs related to the development phase of the project is recommended to use software.

Finally, procedures for preparation and content of the seeds will be examined along with the integrity of the extracted oil, the latter being an important parameter for improvement for future projects, as well as developing the manufacturing processes used and the search for new production alternatives.

## 7. REFERENCES

- ADEMOLA, Oyinlola A. O.; ADEKOYA, L.O;. "Development of a laboratory model screw press for peanut oil expression" *Journal of Food Engineering* 64 (2004) 221-227.
- BEERENS, Peter. "Screw-pressing of *Jatropha* seeds for fuelling purposes in less developed countries" thesis to graduate for the Master Sustainable Energy Technology at Eindhoven University of Technology. 2007.
- COSTA, Dalmo Inácio Galdez. "Project development of a mechanical system for oil extraction plant". Monograph graduate in Industrial Engineering Mechanics Federal Center of Technological Education of Maranhão, 2008 – São Luiz, Brazil.
- EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Cotton Embrapa. Products: Castor. Available at:< <http://www.cnpa.embrapa.br/produtos/mamona/index.htm>>. Accessed: April 7, 2010.
- FERRARI, R. A. OLIVEIRA, V. S.; Scabies, A. Biodiesel soy - the rate of conversion into ethyl esters, physicochemical characterization and consumption in power generation. *Química Nova*, V. 28, 2005.
- KÖRBITZ, W. Biodiesel production in Europe and North America, an encouraging prospect. *Renewable Energy*, v.16, p.1078-1083, 1999.
- MARTINS, Keyll Carlos Ribeiro; VIANA, Luciano G.; SILVA, Lorenni Evren Matias Da; MAFRA, Ana Patrícia Da Silva. "Study of Extraction of vegetable oil seed castor". 2nd International Congress on Biodiesel, 2009.
- MELO, James C.; BRANDER JR, Walter, "Preliminary Assessment of the Potential of *Jatropha* for Biodiesel Production "I Congress of the Brazilian Biodiesel Technology".
- OLIVEIRA, L. B. "Biodiesel: an experiment in sustainable development". International Virtual Institute of global changes. Rio de Janeiro. Available in [www.ivig.coppe.ufrj.br](http://www.ivig.coppe.ufrj.br). Accessed: 10 mar. 2010.
- PIGHINELLI, Anna Leticia Montenegro Turtelli. "Optimization of cold pressing of seeds of peanut type continuous press expeller", *Campinas*, 28(Supl.): 66-71, dez. 2008.
- PIGHINELLI, Anna Leticia Montenegro Turtelli. "Optimization of pressing of sunflower seed and its characterization" *R. Bras. Eng. Agríc. Ambiental*, v.13, n.1, p.63-67, 2009.
- SINGH, P.C.; BARGALE. "Development of a small capacity double stage compression screw press for oil expression" *Journal of Food Engineering* 43 (2000) 75-82.
- VADKE, V.S.; SOSULSKI, F.W.; SHOOK, C.A. "Mathematical Simulation of an Oilseed Press". *Journal of American Oil Chemists*, 1988.
- WARD, J.A. "Processing high oil content seeds in continous screw presses" *Journal of American Oil Chemists*, 1976.

## 8. RESPONSIBILITY NOTICE

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