ANALYSIS OF A PROTOTYPE OF CONTINUOUS PRESS DEVELOPED FOR OBTAINING OIL FROM SEEDS OF CASTOR

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Abstract. *This present work the analysis of a continuous mechanical pressing system, developed for the extraction of vegetable oils from seeds of castor and jatropha. The press consists of a continuous auger mounted on an axle suspended by conical bearings. The axis of the extruder has the same rotation center of the cylinder in which he is confined. In the process of extracting oil from seeds, some conditions are required to maintain the quality of oil, one of them is the need to control the temperature in the cylinder during the extraction process and the understanding of the physical variables that must be applied so as to enable the design of the project, as 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 the pressure subjected to seed along the cylindrical chamber. The analysis of the physical variables of the project allowed to discuss their structural dimension to enable their CAD model and subsequent construction, assembly and testing. During the tests measurements were performed to compare the data with the experimental design.*

Keywords: *Continuous Press, Oilseeds, Vegetable Oil.*

1. INTRODUCTION

The use of vegetable oils in internal combustion engines dates from 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, since in 1896, Diesel designed his first engine with efficiency around 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 petroleum products, the use of vegetable oils as a source of fuel was completely abandoned for a time. However, the increase in oil prices, which started in 1973, created a new awareness about the global production and consumption of energy, especially when originating from non-renewable, such as fossil fuels (KÖRBITZ, 1999).

Thereafter, the extraction plant for producing biodiesel are promising because, when compared to the use of fossil fuels, their use reduces the emission of CO_2, SOx and hydrocarbons released to the environment and therefore there is the qualitative and quantitative reduction levels of environmental pollution. Thus, as a rapidly growing market (FERRARI et al., 2005).

In Brazil, the National Program of Biodiesel Production and Use (PNPB), has been articulated by the Federal Government since 2003, whose priority is to encourage the expansion of production and consumption on a commercial scale biodiesel as an additive to diesel oil. Law 11,097 of January 13, 2005, legally instituted early implementation of PNPB introducing biodiesel to the Brazilian energy matrix to establish the obligatory addition of biofuels to 2% of fossil diesel from January 2008 , a mixture known as B2. B2's arrival meant a saving of approximately $ 410 million in foreign trade balance, reducing foreign dependence on diesel by 7% to 5% (ANP, 2008). On 1st July 2008, the compulsory blending of biodiesel into diesel fuel from 2% to 3% (B3) on July 1, 2009, from 3% to 4% (B4), and in 2010 this mix binding to 5% (B5) (SUERDIECK, 2006). The small rural communities are currently supplying oil seed, constituting only a small part of the government, because with the policy of encouraging the Federal Government to add biodiesel to conventional diesel opens up great possibilities for concrete income generation for the family farmers of the semi-arid areas from the cultivation of these grains. To increase participation of such communities in the biofuels production chain, one option would be to enable farmers to vegetable oil extraction on their properties, using continuous mechanical presses (PIGHINELLI, 2008).

The main methods used for extraction of oil are: batch hydraulic pressing, pressing continuum mechanics (extruders) and solvent extraction, there may be variations or even combinations of these processes. In the mechanical extraction, the continuous pressing process is seen as the most efficient oil extraction and has been replacing the hydraulic presses (Weiss, 1983). As for process efficiency, 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 temperature, and constructive aspects of the press, such as scaling its axis and the chamber compression, in addition to heating conditions that may occur within this chamber.

Thus this study aimed at exploring the development of a prototype system for continuous screw pressing for oil extraction plant. The operating principles and parameters of the extraction process dealing with this type of equipment have been studied to understand the physical and dimensional variables involved in this process, which have direct or indirect influence on efficiency and / or income of such extraction. For testing, samples were initially used to seed castor, for being a kind of seed fresh in local culture.

2. SEMENTED OIL

2.1 Castor

The culture of castor bean (*Ricinus communis L.*) is one of the most traditional in the semi-arid areas and is relevant to economic and social importance, with many industrial applications. Despite being native to Asia, is found in semi-wild state in various regions of Brazil, from Amazonas to Rio Grande do Sul (Costa et al., 2004).

In the 1970s the castor oil was of great importance to agriculture and economy of the semi-arid region, a time that was very common planting them (Fig.1, 2) and at a time when the market for castor was safe. That is, what is planted is sold. After the market fell into decay and families were abandoning the planting of castor beans in much of the Northeast.

Figure 1. Castor in nature

Figure 2. Seeds of castor

In recent years, with the incentive policy of the Federal Government to add biodiesel to conventional diesel, have opened up large concrete possibilities of generating income for the family farmers of the semi-arid areas from the cultivation of castor beans to sell berries, but also to the participation of these families in the chain of manufacturing biodiesel.

Thus the culture of the castor bean has become of great importance to the economy of semi-arid Northeast to be resistant to drought, to be fixating manpower as well as generating employment and raw materials. Thus, currently the Northeast Region has more than 85% of cropland in the country. The production of the Northeast accounts for 78% of domestic production of berries, and most are from the State of Bahia.

3. ANALYSIS OF MECHANISM FOR CONTINUOUS PRESSING

In this machine, the pressing process is through the entry of material in the cylindrical chamber through a director in the power system and are driven by the propeller toward the compression zone which disintegrates the seeds preparing them for the area closures the end of the shaft, where the opening for the passage of the mass is minimal. The oil flows along the cylinder through the cracks of existing and is transferred to a suitable container for storage.

According to Ademola (2003) "the press extruder consists of an auger mounted on a tapered shaft suspended by bearings. " The axis of the extruder has the same rotation center of the cylinder to which it is confined. 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.

The press extruder works according to the difference in pressure between the feed zone and area closures and compression ratio promoted by the mass displacement caused by the helix is a key parameter for improving their efficiency. This ratio can be defined by:

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

Where:

R_c = compression ratio
D_{cil} = Diameter of cylinder
D_{min} = Minimum diameter of shaft
D_{max} = maximum diameter of the shaft

So, a model widely used for the extraction process is a model of continuous compression zones, see Fig 3. 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 4. 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).

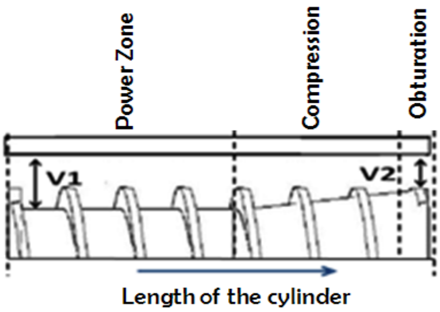

Figure 3. Representation of process model based on the mechanical pressing areas of compression.

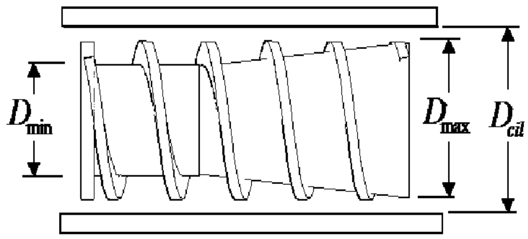

Figure 4. Representation of the compression ratio

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.

Thus, the model is based on the pressing fact that there is an increase in pressure at the end of the feed zone so there is the drag of the seed and a consequent separation of oil occurs from the compression zone. Thus, there must be enough pressure to shift to the area of seed compression, and a relatively high compression ratio for oil extraction.

3.1 Structural description

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.

In this type of engine oil in the form of vegetable 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 (5) you can see a representation of the micro-cell section of a canola seed.

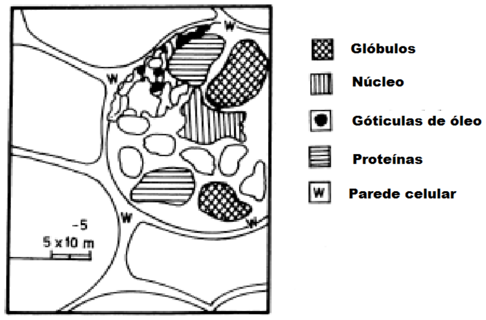

Figura 5. Micro-cellular Section.
Fonte: Singh and Bargale, (2000).

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 down cell walls and releases the oil globules. In Fig (6) the arrows indicate the stresses acting on the mass flow of between two screw pitch and direction of movement restrictions caused by the movement of the auger. The force that causes pressure in the chamber is the component that is in the forward direction of the material which can be seen in fig. (7)

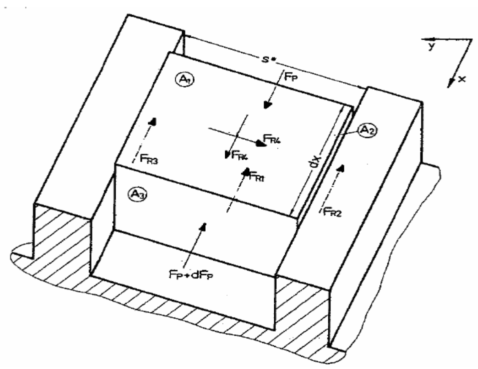

Figura 6. Tensions mass flow.
Fonte: Beerens, (2007).

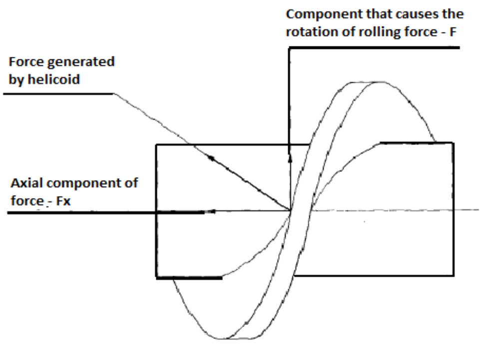

Figura 7. Forces generated by rotation of the auger.

Therefore, the 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 operates in the same direction of flow of mass within the compression chamber, divided by the length of the contact area by generating shaft end, the pressure of work.

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 prototype of 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
α	Angle of the cone axis	T	Torque
β	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

The equations used for calculations for sizing of the project are described in Table 2.

Table 2. Equations used for sizing the prototype of press extruder.

Equations						
Angle of the screw thread (β)	Compression [R]	Cross sectional area (m^2)	Force (N)	F_x (N)	Pressure (Mpa)	Torque (N.m)
$tg\beta = \frac{1}{2}\frac{d_{max}-d_{min}}{l_{con}}$	$R_C = \frac{D_{cil}^2 - D_{min}^2}{D_{cil}^2 - D_{max}^2}$	$A_{sec} = \frac{\pi(d_{max}^2 - d_{min}^2)}{4}$	$F = \frac{T}{\frac{d_{min}}{2}}$	$F_x = PA_{sec}.\cos(\alpha)$	$P = \frac{F}{A_{sec}}$	$T = F \times \frac{d_{min}}{2}$

3.2 Drive Shaft

An axis is a rotating member that very often has a circular cross section, and is used to transmit power or motion. He is the instantaneous center of rotation of elements such as gears, pulleys, wheels, cranks, sprockets, etc.

To operate the machine used was a three-phase electric motor with a speed of 1,710 rpm. Previously, the rotation was reduced to using a system of pulleys and belts, but due to its inefficiency was decided to change this mechanism, and thereafter, we established a transmission system that consists of using a worm screw and a crown , Where the threads of the bolt slides in contact with the gear teeth. The Fig (8) demonstrate this process.

Figure 8. Transmission system worm and crown.
Source: Handout Machine Components – IFSC.

The crown and screw-worm compose a system widely used in mechanical transmission, especially in cases where it is necessary speed reduction or an increase in strength, as in speed bumps, which brings us to the adequacy of this mechanism since it was proposed by VADKE (1988), which produce low speed of rotations greater efficiency in the extraction process.

So the system works so that the number of entries screw has influence on the transmission system. In the specific case of the extruder screw-worm has only one entrance, turning 1710 rpm and is coupled to a sprocket of 49 teeth, where in each round given the crown in the screw will rotate only one tooth. We calculate the RPM of the crown by means of Equation 2:

$$N_C = \frac{Np \times Ne}{Zc} \tag{2}$$

Where:

Nc: RPM crown
Np: RPM of screw-worm
Ne: Number of entries screw
Zc: Number of sprocket teeth

Thus, when we replace the values that the end of the rotation axis, which is the same crown, will be at 34.9 RPM.

4. MATERIALS AND METHODS

4.1 Description of the prototype

The prototype used in this study was developed at the Federal Institute of Maranhao - IFMA in an undergraduate research project of the Scholarship Program for Undergraduate Research - PIBIC the term 2009-2010. The same has been scaled by the relevant structural calculations, and idealized by means of technical drawings, with the aid of Auto CAD 2008, shown in figures (10) and (11).

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.(9).

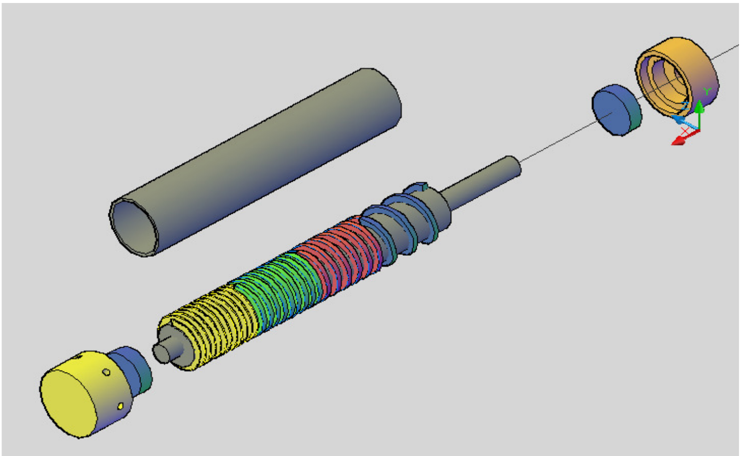

Figure 9. CAD modeling of the cylindrical chamber compression of the prototype of the screw press.

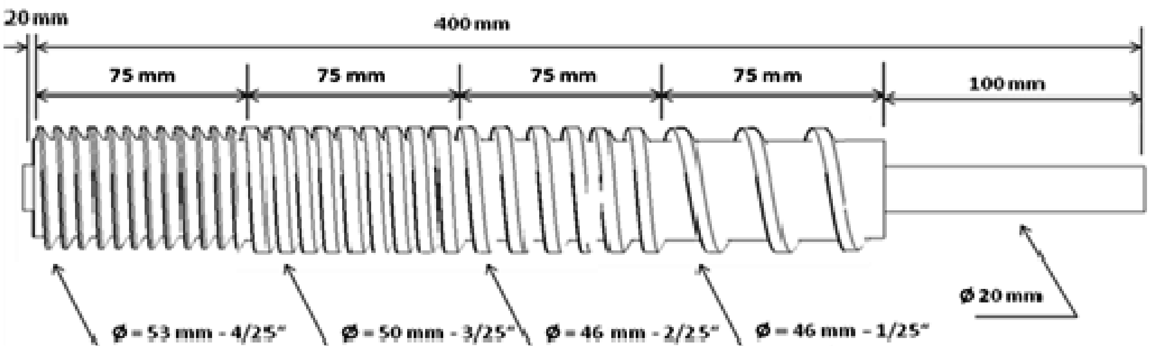

Figure 10. Sizing shaft extruder

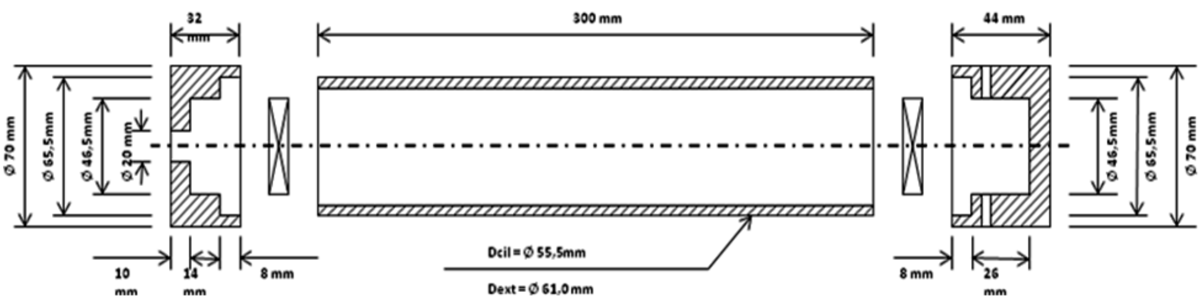

Figure 11. Drawing of cylinder support brackets and bearings

The shaft was machined steel SAE 1045 with a screw in four different types of inputs, working around industrial and, soon after the construction of it, the cylinder compression chamber was machined into a tube made of galvanized steel and small holes on its bottom. Were then machined in the SAE 1045 steel brackets that support for the bearings supporting the shaft

Table 3. Properties of 1045 steel

Properties	1045 Steel
Resistance limit (minimum)	58 kgf/mm²
Yield Strength (minimum)	30 kgf/mm²


Figure 12 and 13. Photo of the prototype of the screw press.

The design of this prototype was performed using as a basis the comparison with the dimensions of prototypes developed in other papers related to the design and construction of extrusion presses. Using the dimensions of the prototype developed by Singh and Bargale in 2000, theoretical data were obtained for pressure and compression ratio of 19.75 and 9.48 MPa, 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. (4).

Table 4. Comparison of dimensional data from other related to projects work continuous press.

Pot_{Nec} (Kw)	Ne(rpm)	T(N.m)	Fcosq (N)	A_{sec} (m²)	Dmin (m)	Dmax (m)	Dcil int (m)	[Rc]	P(Mpa)	DATA
5.600	96,00	557, 042	25.246, 550	0, 001278	0, 042	0, 058	0, 060	9, 480	19, 754	Singh and 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
2205	34,9	603,329	26231,717	0,0007139	0,046	0,055	0,0555	17,452	35,137	Prototype

Having both prototypes, achieved its objective in carrying out the extraction of oil from oilseeds has been assumed that the design methodology developed can be used to perform the design of a prototype press extruder similar principle, and operation.

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	34,9 rpm
Compression ratio	
1st stage compression	1,66 : 1
2nd stage compression	2,14 : 1
Total Compression Ratio	3,60 : 1

4.2 Testing and Analysis

For the test, were acquired the seeds of castor to pressing. The castor bean seeds were dried, shelled and weighed, with the selected sample approximately 200 grams.

The seeds were placed in the press, enter through the food system and deposited all the seeds were completely driven by the propeller toward the compression zone, which is responsible for disintegrating the seeds in preparation for the filling area at the end of the shaft , where the opening for the passage of the mass is minimal. During this shift due to the restriction of passing the seeds are subjected to axial and radial pressures created created that disrupt the cell walls of seeds and consequently it generates to plant mass composed of oil and cake.

Figure 14. Castor in the drying process

Figure 15. Peel of seeds of castor

Figure 16. Seeds of the castor

It was hoped the prototype tests to verify whether it would be able to meet four specific goals related to this initial stage of research: Ability to perform the maceration of the seed evenly generating pie; capacity to perform transport flow mass, consisting of oil and substrate along the compression chamber; ability to perform the separation between oil and the substrate; and finally, the ability to produce vegetable oil, since this would make it fit for use both in research related to production of biodiesel for the production of lubricating oils.

After twelve minutes 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. The transmission system was effective for facilitating the transport of material along the conical axis, since no locking, but due to friction between a metal heating occurred at the crown, even with the use of lubricants.

The oil does not come to be vented out through the compression chamber, due to limited amount of material and the need to disable the prototype seen in the heat transmission. However, to disassemble the shaft was observed that there was a quantity of oil present in the area of filling the same, which proves the feasibility of the prototype.

In this mode, the camera was mounted again to verify the capacity of the shaft end to the crushing and removal of samples. After 5 minutes of the restart of the test is again the expulsion of oil and composite substrate that goes on for 20 minutes. After the end of the expulsion of material the equipment is turned off and disassembled again and found that approximately 90% of the samples included were transported along the entire length of the compression chamber and expels the press in the form of substrate.

Figure 17. Substrate expelled by pressing the shutter area

5. CONCLUSIONS

During the development of this prototype, the physical concepts of mechanical engineering have been applied and has been the design of mechanical components. As a way to visualize what it was designed the system modeled is obtained in CAD, with an effective tool with regard to the assessment of form and arrangement of components resulting in a great ally in project development.

The relevant information obtained by the calculations have been grouped in order to facilitate a possible project design and development of system modeling pressing.

According to the literature it was observed that the press can present extruder productivity superior to that obtained with a hydraulic press or axial. Due to continuous pressure or of its operation, but has disadvantages with regard to the high consumption of energy for starting and operating the press. Another disadvantage is the temperature rise that occurs during operation of the extrusion press, which occurs because of the way the press, specifically because of the shear that occurs in plant mass and its friction against the cylinder wall of the press.

In its own literature notes that this type of equipment had its development largely by trial and error which leads to high costs and does not yet possible to predict at least in part as a function press without the need to build it.

From the testing of the extraction process in continuous pressing equipment, there was a need to work with the definition of effective parameters for efficiency of equipment to perform the separation of vegetable oil pie, since the Most often the yield is affected largely by the construction parameters of the press (and cylinder axis) and, by previous preparation of the raw material to be processed, so that to obtain the integrity of the extracted oil.

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.

The experimental results also point to a need for an improvement in the design of mining equipment, since the operating principle of the press extruder was hit, but not well, since there was an effective extraction of vegetable oil.

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