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Optimization of a High Capacity Industrial Bar Press for Jatropha Curcas Oil Extraction

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Abstract: This study allowed us to achieve the optimal yield for the extraction of Jatropha Curcas oil from the main operating variables of an industrial press. We used an industrial bar press with a large extraction capacity to carry out this work. Two interesting and indicative parameters on the influence of the efficiency of the press have been analyzed, namely the number of steps of screw and the no-load temperature on the efficiency, the temperatures of the screw, oil and cake, the flow rate of the press, the power, the specific mechanical energy of the press. The best result of 31.09%, which corresponds to the maximum recovery rate of 76.92%, was obtained with the highest number of steps of screw and the highest no-load temperature. The influence of the no-load temperature of the screw on the stability of the press has also been highlighted. The screw, the oil and the cake temperatures stabilize when the no-load temperature is greater than or equal to 100°C. The study of operating variables shows their role on the specific mechanical energy. Indeed, the increase in the number of steps of screw from 4 to 6 results in a decrease in seed flow and increase in power leading to an increase in the specific mechanical energy from 34.01 to 49.83 Wh/kg.

Keywords: Extraction, No-Load Temperature, Efficiency, Stability, Yield, Recovery Rate, Bar Press

1. Introduction

Extraction is an ancient operation used to remove food, pharmaceutical, or odoriferous products from plants and some animal organs [1]. Solvent extraction and pressing are the two methods conventionally used to extract oil from oil seeds [2, 3].

Solvent extraction: it has the advantage of producing an excellent recovery rate with a residual oil content in the cake below 5% [4, 5]. However, this technique suffers from the long duration of the operation and the high consumption of solvents, some of which have been re-examined because of their toxicity and explosiveness with respect to the environment and health [6].

Pressing is a simple and well known technique that requires practical skills to obtain quality oil [7, 8]. The extraction yield and the quality of the extracted oils are variable [9-11]. Both of these essential components must be optimized and largely depend on the type of press and the seed quality. All motorized presses are equipped with an auger, but depending on the press cage and the shape of the auger, a distinction is made [12]:

The screw press: The body of the press is pierced to allow the flow of oil as the pressing progresses. The screw has an increasing diameter to increase the pressure at the end of the seed. The cakes come out as granules and the flow rate is less than 50 kg/h.

The bar press: The oil passes through rings whose spacing can be adjusted according to the type of seeds to be pressed. The cakes come out in the form of chips or scales. The pressing speed is from 40 kg/h to more than 2,000 kg/h for large productions of crude vegetable oils.

In industrial oil mills, given the high extraction capacities, the choice is increasingly made for large capacity bar presses. Unfortunately, there is very little data on the influence of operating conditions for oilseed pressing in high-capacity ring presses on press stability, yield and recovery rate. As part of our research, we studied the influence of temperature and the number of steps of screw on the stability of the press on the one hand and on the other on the yield and recovery rate of Jatropha Curcas oil.

2. Materials and Methods

2.1. Biological Material

The Jatropha seeds used within the framework of this study consist of two samples especially G3 and G4 from Burkina Faso with respective storage times of two and one year. These seeds have respectively a free fatty acid content of 2.63 and 1.13% (NF T60-204), a water content of 5.68 and 4.84% (NF T 60-201) and an oil content of 33.42 and 40.42% (NF V03-908) in relation to the raw seed.

2.2. Bar Press

The pressing is carried out using an industrial press. It is an AISO type AE-V6 bar press, with a crushing capacity of 500-600kg/h, a frequency of 50Hz and a power of 17.6-19.36KVA. The press is equipped with an electric motor, a filter placed in parallel on the press and a vacuum pump in series. An acquisition system made up of one thermocouple probe and a three-phase electrical connection provides information on the main parameters such as the evolution of the temperature in different places (screw, oil and cake), the frequency, the electrical voltage, the current intensity and the power.

2.3. Operating Procedures

The pressing is done cold with seeds at room temperature of 28 to 30°C. The hopper is permanently filled with 400 kg of Jatropha seeds for each test. The press is started with the screw totally loosened. Tightening is carried out manually and the number of auger pitches is set at 4 for the first test of the day then progressively at 5 or 6 steps of screw for the other tests. Once the screw is set, the pressure has been adjusted constant the extraction can begin. Five minutes later, the crude oil begins to come out throughout the auger between bars or comes out as a jet and the cake comes out as a cooked "cake".

The crude oil is filtered directly from the press outlet using a plate filter press without passing through a decantation phase. The principle of this type of filtration is to send oil loaded with sediment under pressure between the filter plates. A succession of plates covered with filter cloths is tightened by a hydraulic jack. A pipe is installed at the end of the filter to pass and store the filtered oil in a tank. Finally, it is recommended to filter at a temperature of at least 20°C in order to avoid a too important viscosity of the oil which would decrease the efficiency and the performances of the filtration.

2.4. Calculated Parameters

The oil production efficiency and the rate of recovery are expressed in the following:

$$Rh\% = \left(\frac{Mh}{Mg}\right) x100 \quad (1)$$

$$Tr\% = \left[1 - \frac{Th-Rh}{Th}\right] x100 \quad (2)$$

Where Rh is the oil production efficiency,
Tr the rate of recovery,
Th the oil content,
Mh oil mass and Mg seeds mass.

3. Results and Discussion

3.1. Effect of the Number of Steps of Screw and No-Load Temperature on the Screw, the Oil and the Cake Temperature

Figures 1, 2, 3, 4 and 5 show the evolution of the temperature of the screw, the oil and the cake as a function of the no-load temperature and the number of the steps of the screw.

The above figure analysis shows the influence of the no-load temperature on the outlet temperatures of the oil, the cakes and the screw. We notice a much more significant increase for the lowest no-load temperatures. This increase is smaller for no-load temperatures greater than or equal to 100°C (Figure 3 and Figure 4). This can explained by the stability of the press for no-load temperatures above 100°C. This stability is reflected in the stability of the screw, oil and cake temperatures. The screw temperatures reach 100°C within 30 minutes for 5 and 6 steps of screw (Figure 2 and Figure 5) while we obtained 100°C for the screw temperature after 60 minutes from the beginning of the test (Figure 1). This shows that increasing the number of steps of screw allows to increase the screw temperatures faster and to reach the press stability.

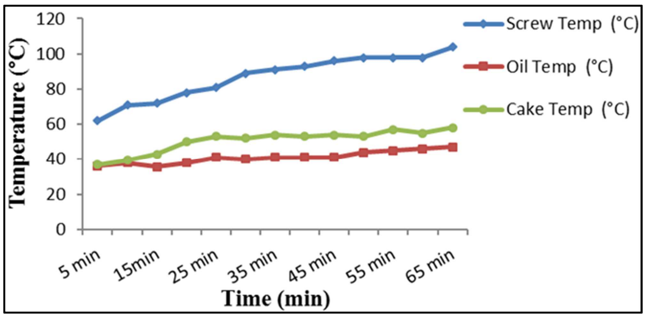

Figure 1. *Temperatures at 4 steps of the screw and the no-load temperature at 62°C.*

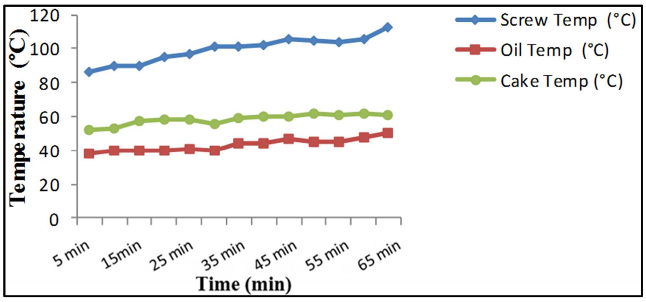

Figure 2. Temperatures at 5 steps of the screw and the no-load temperature at 86°C.

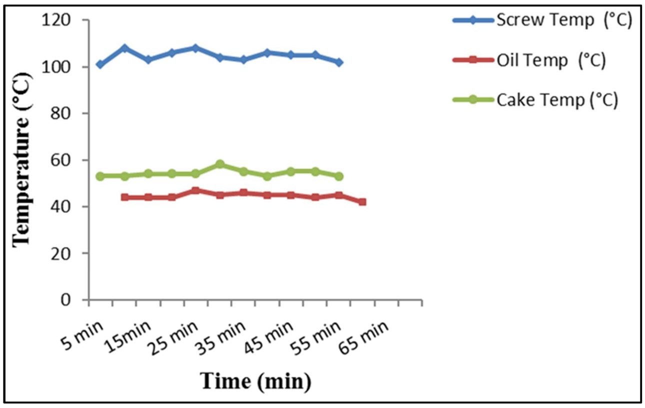

Figure 3. Temperatures at 5 steps of the screw and the no-load temperature at 101°C.

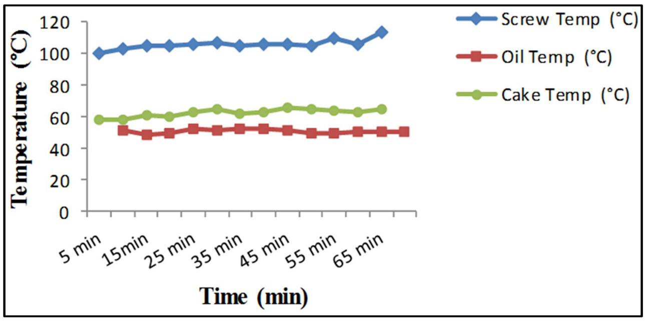

Figure 4. Temperatures at 6 steps of the screw and the no-load temperature at 100°C.

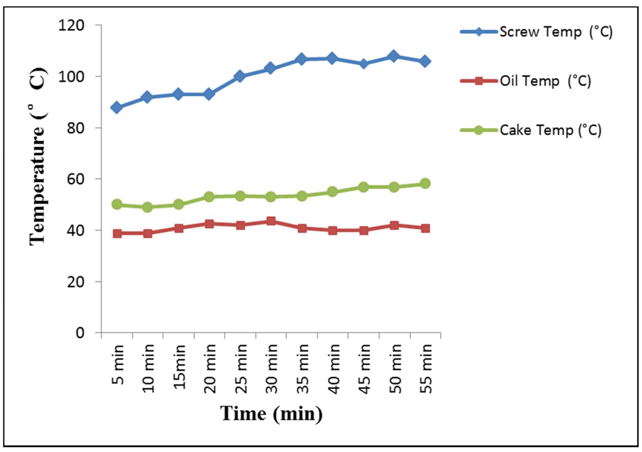

Figure 5. Temperatures at 6 steps of the screw and the no-load temperature at 88°C.

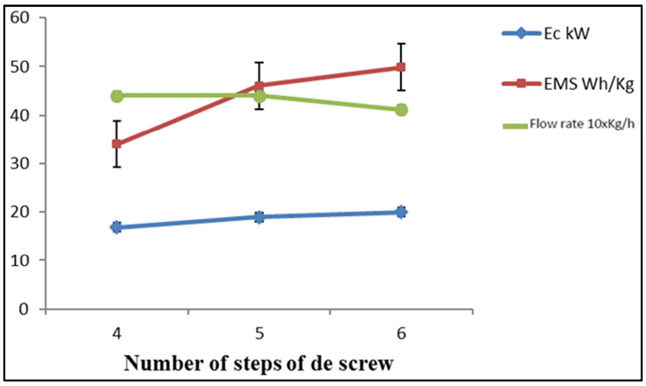

Figure 6. Flow rate, power and specific mechanical energy of the press as a function of the number of the steps of the screw.

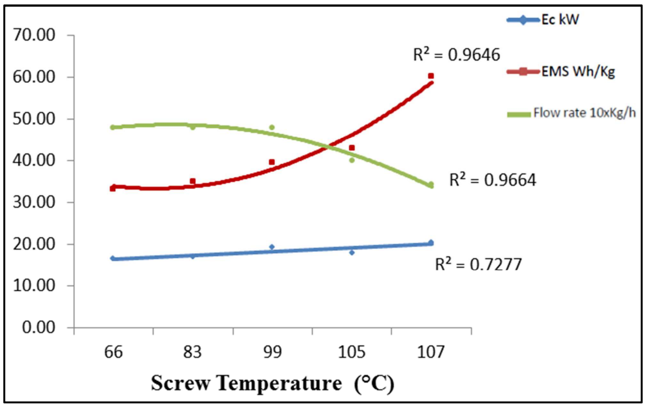

Figure 7. Flow rate, power and specific mechanical energy of the press as a function of the temperature.

3.2. Effect of the Number of Steps of Screw and No-Load Temperature on the Flow, the Power and the Specific Mechanical Energy of the Press

Figures 6 and 7 show the evolution of the flow rate, the power and the specific mechanical energy of the press as a function of the number of the steps of the screw and the no-load temperature.

3.2.1. The Flow of the Press

The analysis of these figures shows that the flow rate decreases respectively from 440 to 414.4 kg/h for an increase in the number of steps of screw from 4 to 6 and 480 to 342.86 kg/h for an increase in the screw temperature from 66 to 107°C. An increase in the number of steps of screw results in an increase in screw temperatures and a restriction of the air gap opening. This restriction has the effect of a constraint on the material and its flow becomes very difficult, and its residence time inside the press too long. It is this increase in the residence time of the material inside which results in this flow decrease.

3.2.2. The Power

The analysis of the evolution of the power shows that it increases according to the number of steps of screw and the screw temperature. This increase in the power of the press is due to the increase in the energy used. Indeed, the restriction of the opening of the air gap due to the increase in the number of steps of screw leads to the compression of the material, the solid/solid friction and the viscous dissipation corresponding to a transformation of the material. These factors explain the increase in energy used and the increase in power from 16.86 to 19.96 kW, when the number of steps of screw varies from 4 to 6 and in power from 16.55 to 20.52 W when the temperature varies from 66 to 107°C. Many authors agree that energy consumption has a dominant influence on power [13, 14].

3.2.3. The Specific Mechanical Energy

The specific mechanical energy increases from 34.01 to 49.83 Wh/kg while the number of steps of screw increases from 4 to 6 steps and 33.12 to 60.09 Wh/kg when the temperature varies from 66 to 107°C. This can be explained by the fact that the flow rate decreases slightly, while the power increases very slightly. And as, the specific mechanical energy is the ratio between the power and the flow rate of the press. It results with a small increase of the power and a decrease of the flow of the press, the increase of the specific mechanical energy. Here, the effect of the flow rate is preponderant over that of the power.

3.3. Effect of the Temperature on Oil Yield and Recovery Rate

The results obtained for an increase in temperature from 66 to 107°C, favor an increase in oil yield from 19.23 to 31.09. This increase is much more important for temperatures greater than or equal to 100°C. This shows the importance of the temperature factor on the oil yield, reflecting a good efficiency of pressing. This increase in yield can be explained through the pressure increase inside the press. Like the crude oil yield, the recovery rate (Table 1) increases from 57.55 to 76.92% while the screw temperature increases from 66 to 107°C. These obtained recovery rate results are slightly lower than the results obtained by the laboratory press [15] and other studies [16, 17]. This decrease in recovery rate can be explained by the difference in press capacity.

Table 1. *Oil yield and recovery rate as a function of the temperatures.*

Temperatures (°C)	Oil yield (%)	recovery rate	Cake (%)
66	19,23	57,55	80,77
83	23,08	69,07	76,92
96	22,49	67,30	77,51
99	23,32	69,79	76,68
107	31,09	76,92	68,91

4. Conclusion

The results obtained at the end of this work show that the increase in the number of steps of screw from 4 to 6 results in a decrease in the seed flow rate from 440 to 414.4 kg/h and an increase in power from 16.86 to 19.96 kW, leading to an increase in specific mechanical energy from 34.01 to 49.83 Wh/kg. The press rate remains constant for temperatures below 100°C and decreases with increasing screw temperature for temperatures above 100°C, while the overall power increases slightly with increasing screw temperature. This results in an increase of the specific mechanical energy. The study of the operating variables temperature and number of steps of screw highlights their role on the efficiency of the pressing. Indeed, the best oil yield calculated was obtained with the highest number of step of screw and the highest temperature.

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