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Oil production and energy input from extraction of Jatropha curcas L. : Effect of seeds form, preheating temperature and applied pressure

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---***ABSTRACT***---

The effect of preheating temperature (25, 50, 75 and 100°C) and applied pressures (8400, 15000, 19500) on oil production characteristics (oil yield, oil quality and energy input) of whole, kernels and crushed Jatropha seeds was assessed between December 2017 and April 2018 at the Renewable Energy Laboratory of the University of Dschang-Cameroon. For this purpose, 100 g of each type of seeds preheated for 5 minutes at the above mentioned temperature, was introduced in the hydraulic press and subjected to the three levels of extraction pressures also mentioned above. The main results were as follows. The non-preheated kernels (25°C) at the applied pressure of 19500 had the highest oil yield (39.03±0.85%) significantly. the lowest oil yield was observed with the crushed seed preheated at 50°C at the lowest pressure (6,10±0,08%). The lowest energy input was obtained with crushed seeds preheated at 100°C with pressure of 8400 (2108.44±0.00 Joules). The highest energy input significantly was obtained at non preheated whole seeds associated to extraction pressure of 19500 (8157,67± 0,00). The lowest acidity (0,52±0,13 %) was obtained with the kernels preheated at 75°C at the extraction pressure of 8400. the highest acid value ($p < 0.05$) was obtained with the crushed seeds at the temperature of 100°C associated with the pressure of 8400. The lowest iodine number (56,61±0,97) is obtained with the kernels preheated at 50°C at the pressure of 8400. It was the highest (71,00±0,30) also with kernels at the temperature of 50°C associated with the pressure of 19500. The highest peroxide (40,98 ±5,75 meqO2/kg) is obtained with the whole seeds preheated to 100°C associated at extraction pressure of 19500. It is the lowest (3,49 ± 0,08 meqO2/kg) with non-preheated kernels (25°C) also at the highest extraction pressure. The oil acidity, iodine and peroxide index were also significantly affected by the seed form, preheating temperature and applied pressure levels.

KEYWORDS: Jatropha curcas, Oil yield, acidity, peroxide, iodine, energy input

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I. INTRODUCTION

In rural areas of developing countries, wood biomass are the most « green energy » ressources Used. Almost 99% of the rural households use wet fuel wood for energy supply (SNV, 2013) using crude and inefficient technology for heating, cooking and lighting (Tangka et al., 2016). The consequences of using these crude technologies are sometimes disastrous to health conditions (suffocation and eyes illnesses) and caused serious pressure on ecological resources like deforestation and climate change. This situation is further aggravated by rapid increasing population. It is of great importance to choose another biomass as an alternative to the conventional wood. Seeds oils in general and Jatropha curcas in particular seem to be one of the most promising renewable and independent energy sources in rural areas (Francis et al., 2005 ; Kumar and Sharma, 2008).

Jatropha is multipurpose small tree belonging to the family of Euphorbiaceae which is found in the tropics and subtropics (Petru et al., 2012 ; Herak et al., 2013). Energy production using Jatropha is considered more suitable than any other food based crop such as palm, rapeseed, soybean and sunflower (Pinzi et al., 2009 ; Achten, 2007). Jatropha curcas is more usable for its oil as a production of biofuels and for the residual cake after extraction which can be valorized by thermochemically and biologically processes (Navarropineda et al., 2016). There are different methods of oil extraction from Jatropha curcas seeds, solvent extraction (Sayyar et al., 2009), enzyme assisted extraction (Winkler et al., 1997) and supercritical fluid extraction (Chen et al., 2012). Those methods provide a lot of energy input associated to high cost. The most notable and preferred method for rural areas of developping countries is the mechanical pressing (Achten et al., 2007). It is then important to produce knowledges for efficient protocol of jatropha energetic valorisation specifically on oil quality and energy input for simple oil production.

Scientific littérature has been published on the various factors to improve the oil quantity. Notably, applied pressure, pressing time, adjustment of moisture content, temperature were considered (Mpagalile and clarke, 2005 ; Wilems et al., 2008 ; Tambunan et al., 2012). All these studies showed that kernels have higher oil yield than whole seeds. Conflicted results have reported the effect of particle size on oil recovery between Tambunan et al., (2012) and Subroto et al., (2015). Concerning the oil quality, Acid, peroxyde and Iodine values are the main indicators used to determine the quality of expressed oil. Oil production needs a lot of energy input. In rural areas of developing countries, women who are involved at the level 75% in the extraction process are concerned (Makkar, 2016). At this effect, studies are limited on the evaluation of oil quality and energy input for the treatments mentioned above. For Kabutey et al., (2012), heat treatments could have positive effect on deformation energy and compressive force. Subroto et al., (2015) shows that the acid value rises with an increase in preheating temperature from 25 to 60°c. Whatever the case, optimum level of preheating temperature coupled with optimum level of applied pressure are still to be determined. This research therefore is aimed to study the effect of the seeds form, preheating temperature and applied pressure on oil yield, energy input and oil quality (acid, iodine and peroxide values).

II. MATERIALS AND METHODS

Production of seeds materials

The study was carried out between December 2017 and May 2018 at the Renewable Energy Laboratory, Department of Rural Engineering at the University of Dschang-Cameroon (LN 5°20, LE 10°50). A total of 30 kg of jatropha seed was obtained from the SODEPA ranch at Jakiri, Guinean Sudano Guinean Zone (North West Region). The seeds were sun-dried to 1% water content (AOAC, 1990), then stored in an oven.

Effect of seeds form on the oil yield, extraction energy and oil quality

For each type of seed (Figure 1) namely whole, Kernels and crushed seeds, 6 kg of seeds previously stored in the oven were used. The whole seed was used as such. To obtain the kernel, 6 kg of whole seeds were dehulled using a manual rotary disk machine consisting of a sieve receiving residues from 1 to 2 mm, a 5 kg roll steel used as a counterweight for hulling. With a dehulling rate of 60%, the procedure was repeated until 5 kg of kernels were obtained. With regard to obtain crushed seeds, The crushing of 5 kg of whole seeds was carried out using a 2 kWh electric motor grinding machine. An adjustment of the spacing between the vis-sans-fin and the crusher wall was operated to obtain the seeds of 3 and 3.7 mm size. Calibration was performed using a sieve for this purpose. This operation was repeated until 5 kg of crushed seeds were obtained.

a : whole seeds ; b ; kernels ; c : coarse or crushed seeds

Figure 1 : Jatropha seeds forms

Effect of preheating temperature the oil yield, extraction energy and oil quality

Preheating was done at four temperature levels respectively, no preheating (25°C), 50, 75 and 100°C. For this purpose, 100 grams of each type of seed (weighed using a seedburo balance of 0.001 g accuracy) was introduced into an adjustable oven for five minutes (Subroto et al., 2015). The temperature in the oven was measured using a thermocouple probe. At the end the preheating process, the sample was removed and subjected to the hydraulic press.

Effect of level Applied pressure on the oil yield, energy input and oil quality

Extraction was carried out using the method proposed by Kabutey et al., (2012). A hydraulic press with a maximum pressure of 30000 or 500 bars (Figure 2) was used. It is composed of two independent units. The hydraulic press consists of a pressing chamber made of iron bar with 10 cm diameter and a height of 12 cm. A circular plunger of 10 cm diameter was used to apply the required applied pressure. The oil collector was composed of a 50 ml volume bottle associated with a perforated plate of 1 cm high which separates the oil and the residues.

1 : Plunger ; 2 : pressing chamber ; 3 : hydraulic piston ; 4 : pressure gauge ; 5 : hand pressure

Figure 2 : Representation of the hydraulic press

100 g of each of the preheated seeds (see above) randomly subjected to each of the pressures of 8400, 15000 and 19500 corresponding respectively to 181.81; 324.66 and 422.06 bars. Subroto et al., (2015) recommend an optimal pressure of 200 MPa. The oil extraction was carried out using a crank handle. The pressure process was stopped when the value of the desired experimental pressure was obtained and measured with a pressure gauge. In order to measure the plunger displacement in pressing chamber, a meter tape graduated in cm was used. Each procedures was in three replicates. At the end of the extraction, the oils were weighed, packaged in the plastic bottles (20 ml) and labeled to determine the acid, peroxide value and iodine number values.

- **Determination of oil production characteristics**

Oil production was evaluated by determining the oil yield, energy input and the oil quality (Acidity, peroxide and iodine values). The determination of oil yield was done by using the formula 1.1 (Adejumo et al., 2013).

$$\%\ oil\ yield = \frac{\text{Weigh of oil collected}}{\text{weigh of seed sample}}$$

The determination of energy input (E) was also evaluated by equation 1.2 (Kabutey et al., 2012)

$E = P * S * D$ where : E : extraction energy (joules) ; P : Applied pressure (N) ; S : pressing chamber surface (m^2) ; D : displacement of plunger (m)

The determination of Acid, peroxyde and iodine values was according to AFNOR method (1981).

For the statistical analyses, the data obtained were analysed using the software package SPSS 23.0.

III. RESULTS AND DISCUSSION

Effect of seeds form, preheating temperature and applied pressure on oil yield

Independently of the seed form, the applied pressure and the preheating temperature, the significantly highest oil yield (Table 1) was obtained with kernels at the temperature of 25°C and at the pressure of 19500 (422.06 bars) and the lowest yield with the crushed seed preheated at 50°C to the lowest pressure (8400). Whatever the seed form and the preheating temperature level, the oil yield increases with increasing applied pressure. No significant difference (p> 0.05) was observed between the preheating temperature levels.

Table 1: Effect of seedforms, preheating time and applied pressure on oil yield

Seed forms	Applied pressure	Preheating temperature			
		25°C	50°C	75°C	100°C
Whole seeds	8400	11,10 ± 1,47bA***	13,70 ± 1,21bB***	10,00 ± 0,66bB***	9,76 ± 0,76bB***
	15000	20,30 ± 1,27bA**	19,03 ± 0,64bB**	16,50 ± 1,13bB**	17,66 ± 0,25bB**
	19500	23,06 ± 1,85bA*	22,63 ± 2,09bB*	20,63 ± 0,92bB*	19,50 ± 2,45bB*
Kernels	8400	26,63 ± 0,75aA***	24,00 ± 1,56aB***	25,26 ± 3,20aB***	30,30 ± 4,16aB***
	15000	35,53 ± 0,65aA**	29,06 ± 2,24aB**	33,76 ± 1,65aB**	34,06 ± 0,72aB**
	19500	39,03 ± 0,85aA*	33,66 ± 1,85aB*	35,16 ± 0,37aB*	36,40 ± 1,96aB*
Crushed seeds	8400	7,45 ± 0,15cA***	6,10 ± 1,08cB***	6,76 ± 1,89cB***	6,31 ± 0,17cB***
	15000	12,00 ± 1,45cA**	11,00 ± 0,70cB**	11,46 ± 0,32cB**	10,36 ± 2,04cB**
	19500	14,86 ± 0,35cA*	14,40 ± 0,45cB*	15,63 ± 0,80cB*	12,96 ± 1,15cB*

a,b,c : means with the same letter on the same column are not significantly differents (p>0,05)
A,B,C :means with the same letter on the same line are not significantly different (p>0,05)
* : means with the same number of star in the same column are not significantly different (p>0,05)
8400, 15000, 19500 : 181,81 ; 324,66 ; 422,06 bars

It appears that the preheating temperature had no effect on the oil yield regardless of the seed form and the applied pressure. The highest oil yield (39.03%) was obtained in non-preheated kernels at 25°C. This value is lower than those found (47.06%) by Sirisomboon and Kitchaiya (2008) in kernels preheated to 80°C or 36.83% with preheating of 40°C. Our results tend to demonstrate no effect of preheating. This is opposed to Tambunan et al., (2012) findings where preheating temperature increased with the oil yield. This difference between our results may due to either the preheating time or to seed quality due to postharvest storage condition. Indeed, a preheating time of 5 minutes was used in our work as opposed to one hour for Sirisomboon experiment.

The seeds form has a significant effect on the extraction characteristics of the oil, the crushed seeds registered the lowest oil yields.

The same results was obtained by Koreissi et al., (2005) But in the contrary the best oil yield was obtained in crushed seed by Tambunan et al. (2012). One may believe that crushed seed having specific surface, offer a better contact with the pressing chamber but the porosity between the particles are very low, limiting the oil flow compared to the whole seeds and kernels.

Effect of seeds form, preheating temperature and applied pressure on energy input

The lowest energy input (Table 2), regardless of preheating temperature, applied pressure and seed form, was obtained with crushed seeds preheated at 100°C with pressure of 8400. The highest energy input significantly was obtained at non preheated whole seeds (room temperature) associated to extraction pressure of 19500. Regardless of the seed form and preheating temperature, the energy input was increased with the applied pressure. No significant difference (p>0,05) was observed between the preheating temperature levels.

Table 2: Effect of seed forms, preheating temperature and applied pressure on energy input

Seed form	Extraction pressure	Preheating temperature 25°C	50°C	75°C	100°C
Whole seeds	8400	2752,69 ± 58,57aA***	2967,44 ± 135,25aA***	2655,07 ± 376,53aA***	2850,28 ± 178,92aA***
	15000	6275,13 ± 00,00aA**	5438,44 ± 209,17aA**	4880,65 ± 639,02aA**	5298,99 ± 639,02aA**
	19500	8157,67 ± 0,00aA*	7069,98 ± 271,92aA*	6707,41 ± 684,32aA*	6616,77 ± 313,99aA*
Kernels	8400	2928,39 ± 351,41bA***	2819,94 ± 536,78bA***	2850,30 ± 294,78bA***	2303,67 ± 135,25bA***
	15000	4288,00 ± 104,58bA**	4392,59 ± 209,17bA**	4253,14 ± 870,84bA**	4880,65 ± 319,51bA**
	19500	5846,33 ± 407,88bA*	6435,49 ± 684,32bA*	5801,01 ± 874,10bA*	6435,49 ± 954,95bA*
Crushed seeds	8400	2459,85 ± 00,00bA***	2967,43 ± 178,92bA***	2655,07 ± 135,26bA***	2108,44 ± 0,00bA***
	15000	4601,76 ± 209,17bA**	5089,82 ± 319,51bA**	4810,93 ± 553,41bA**	4601,76 ± 553,41bA**
	19500	5068,9 ± 574,491bA*	6707,41 ± 784,97bA*	6163,57 ± 156,99bA*	6254,21 ± 719,43bA*

a,b, : means with the same letter on the same column are not significantly differents (p>0,05)
A :means with the same letter on the same line are not significantly different (p>0,05)
* : means with the same number of star in the same column are not significantly different (p>0,05)
8400, 15000, 19500 : 181,81 ; 324,66 ; 422,06 bars

The energy input values between 2 and 5kJ are in the same range mentioned by Sirisomboon et al., (2007). In general the preheating temperature has no influence on the energy input. Our results are contrary to those of Kabutey et al., (2012) who observed an increased in the extraction energy with the increase of the preheating temperature. The difference observed may be due to either preheating time which was 6 times greater than that of our work or to the long storage duration of our jatropha seeds which may have inhibited the action of temperature on oleic cells. Kernels and crushed seeds obtained the lowest energy input. Till now very few authors have assess the effect of seed form on energy input (Kabutey et al., 2012, Beerens, 2007). It appears logically that the presence of hulks would have increased the energy required to grind whole seeds compared to kernels and crushed seeds, which are less robust and consist of small particles respectively.

Effect of seeds forms, preheating temperature and applied pressure on oil quality -Oil Acidity

The effect of preheating temperature, applied pressure and seed form on the oil acidity(figure 3) shows that the lowest acidity is obtained with the kernels preheated to 75°C and the highest (p <0.05) with the crushed seeds at the temperature of 100°C associated with the pressure of 8400. No significant difference was observed between the applied pressures.

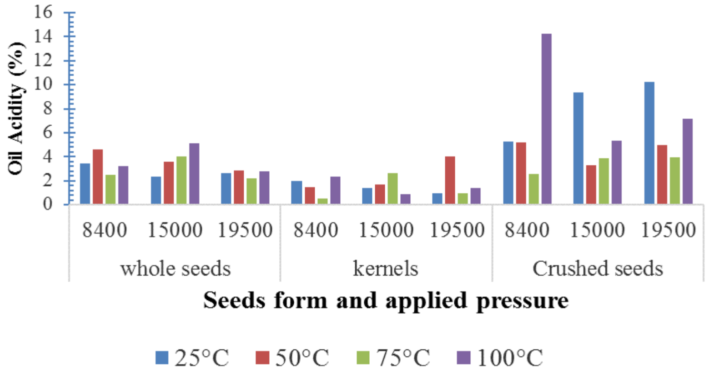

Figure 3: oil acidity with regards to seed forms, preheating temperature and applied Pressure

The crushed seeds produced the highest acidity values. Similar results was obtained by Adeeko and Ajibola (1990) in peanut seed extraction also with the smaller particle size. The formation of free fatty acids in the seeds is mainly due to the destruction of the cells. Crushing, resulting in massive destruction of cells, lead naturally to the production of acids. The difference between our results and those mentioned may be attributed to the type of seeds amongst others.

The acidity values of non-preheated whole seeds and kernels was between 0.2-3,0% slightly higher than compared to the findings (0.29-1.75%) of Domergue and Pirot (2008) for seeds which have not undergone any storage period after harvest. It may appears then that storage duration may not have significant effect on acidity.

- **Iodine index**

The lowest iodine number (figure4), irrespective of the preheating temperature, applied pressure and the seed form, is obtained with the kernels preheated at 50°C at the pressure of 8400. It was the highest ($p>0.05$) also with kernels at the temperature of 50°C associated with the pressure of 19500. The values of the iodine number are between 50-71% regardless of the treatment performed. These results are in the range of 50-100% established by Abulude (2007) indicating that our oil obtained is unsaturated.

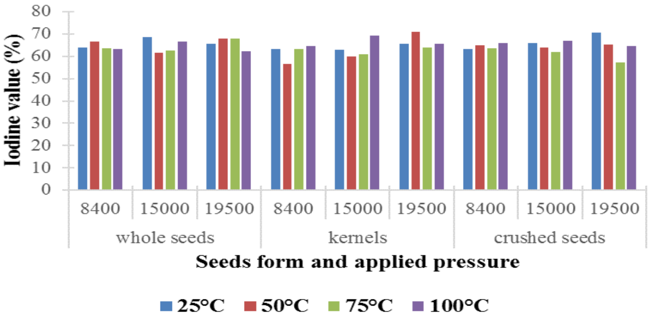

Figure 4: Effect of seeds forms, preheating temperature and applied pressure on Iodine value

The iodine number measures the saturation level of an oil, the higher this index, then the lower is the level of saturation. In terms of energy, a less unsaturated oil is a great advantage because the combustion of a highly unsaturated oil leads to the polymerization of glycerides and consequently to deposits and the deterioration of lubrication (Mittelbach et Remschmidt 2004; Belewu et al., 2010).

In general, no significant difference was observed between the seed forms. Also, regardless the seed form, the iodine value increases with the applied pressure and decrease as the preheating temperature increase. This observation is similar to Adejumo et al. (2013) findings. The rise in temperature may have induced evaporation of water in the lipidic bonds and further promoted the rigidity of the chemical bonds and thus reducing the level of unsaturation. Increased applied pressure may also have contribute to the increase to the level of saturation. The temperature in addition to vaporization of water, expansion of volatile matter combined with the compressive force and destruction of cell wall may have contribute to the unsaturated oil. This may justify globally that the highest iodine index was observed the whole and crushed seeds.

- **Peroxyde Index**

The highest peroxide (figure 5) value ($p < 0.05$), regardless of the preheating temperature, the applied pressure and the seed form, is obtained with the whole seeds preheated to 100°C associated at extraction pressure of 19500. It is the lowest with non-preheated kernels (25°C) also at the highest extraction pressure. Indeed, the peroxide index indicate the resistance of oil to deterioration or rancidity.

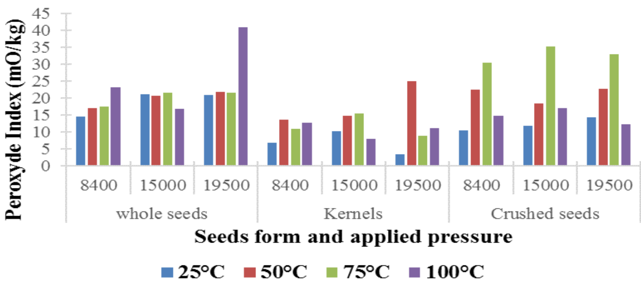

Figure 5 : Effect of seeds forms, preheating temperature and applied pressure on peroxide index

With an average value of 17.86 meqO2/kg, whatever the treatment, it is much lower than that found on the jatropha seeds of Nigeria and India 56 and 39 meqO2/kg respectively (Belewu et al., 2010). The difference between our value and those of the literature may be due to seed characteristics or experimental conditions.

Oil from kernels obtained the lowest peroxide value, maybe due to the absence of the hulks. In fact, the shells, being fibrous and difficult to degrade, increase the saturation level of the oil with the volatile material, thus increasing the oxidative stability. The peroxide index increase with preheating temperature whatever the seed form and applied pressure. This observation is contrary to the results obtained by Adéjumo et al. (2013). The differences between our results may be due to the type seed material and experimental condition. The increase in peroxide level with temperature can be explain by a rise in temperature favors the dilation of the cell walls which contain organic matter. This organic matter combined to compressive forces liberate the oil with a lot of material which promote longer oxidative stability as a consequence of high oxidation.

IV. CONCLUSION

At the end of this study, the main conclusions are as follows:

Oil yield was significantly affected by seed form and applied pressure level. On the other hand, the preheating temperature had no effect on the oil yield. Thus it was the highest with non-preheated kernels (25°C) and applied pressure of 19500. Energy input was significantly affected by seed form and applied pressure. Thus, the significantly lowest value was observed with the crushed seeds preheated at 100°C associated with the applied pressure of 8400. The oil acidity, iodine and peroxide index were also significantly affected by the seed form, preheating temperature and applied pressure levels. For these three characteristics, the lowest value was observed with kernels associated with the preheating temperature-extraction pressure pairs of 75°C-8400, 50°C-8400 and finally 25°C-19500 respectively for the acid, iodine and peroxide number.

REFERENCES

[1]. Abulude, F.O., Ogunkoya, M.O., Ogunleye, R.F., (2007) : Storage properties of soils of two Nigerians oil seeds Jatropha curcas (physic nut) and Hellanthus annuus (sunflower). American Journal of Food Technology, 2(3), 207-211

[2]. Achten, W.M.J., Mathijs, E., Verchot, L., Singh, V.P., Aerts, R., Muys, B., (2007) : Jatropha Biodiesel fueling sustainability ? Biofuels Bioprod. Biorefining 1, 283-291.

[3]. Adejumo, B.A., Alakowe, A.T., Obi, D.E., (2013) : Effect of Heat treatment on the characteristics and oil yield of Moringa oleifera seeds. Inter. J. Eng. Sci. 2(1), 232- 239.

[4]. Adeeko, K.,A., Ajibola, O.O., (1990) : Processing factors affecting yield and quality of mechanically expressed groundnut oil. J. Agric. Eng. Res. 45, 31-43.

[5]. AOAC. (1990): Official Methods of Analysis of the Association of Official Analytical Chemists, Association of Official Analytical Chemist. 14th Ed, Arlington, VA

[6]. Belewu, M.A, Adekola, F.A., Adebayo, G.B., Ameen, O.M., Muhammed, N.O., Olaniyan, A.M., Adekola, O.F. and Musa, A.K.. (2010) : Physico-chemical characteristics of oil and biodiesel from Nigerian and Indian Jatropha curcas seeds. International Journal of Biological and Chemical Sciences, 4(2): 524-529

[7]. Chen, C.R., Cheng, Y.J., Ching, Y.C., Hsiang, D., Chang, C.M.J., (2012) : Green production of energetic Jatropha oil from de-shelled jatropha curcas L. using supercritical carbone dioxide extraction. J. Supercrit. Fluids, 66, 137-143Domergue, M., Pirot, R., 2008. Jatropha curcas L. : Rapport de synthèse bibliographique. Edition Cirad, 118p

[8]. Eromosele, I. C., Eromosele, C. O., Akintoye, A. O. and Komolafe, T. O. (1994):Characterization of Oils and Chemical Analysis of the Seeds of Wild Plants. Plant Food For Human, Nutrition Journal. 5(2):30-50

[9]. Kabutey, A., Sedlacek, A., Divisova, M., Svatonova, T., (2012). Heat treatment of Jatropha curcas L. seeds under compression loading. Scientia Agriculturae Bohemica, 43(3) : 116-121.

[10]. Herak, D., Kabutey, A., Hrabe, P. (2013). Oil point determination of Jatropha Curcas L. bulk seeds under compression loading. Biosystems Engineering, 116(4) :470- 477.

[11]. Makkar, H.P.S., (2016). State of the art on detoxification of Jatropha curcas products aimed for use as animal and fish feed : a review. Anim. Feed Sci. Technol. 222, 87-99

[12]. Mittlebach M, Remschmidt C. 2004. Biodiesel: The comprehensive handbook. Boersedruck. Ges. M.B.H.: Vienna

[13]. Mpagalile, J.J., Clarke, B., (2005). Effect of processing parameters on coconut oil expression efficiencies. Int. J. Food Sci. Nutr. 56 : 125-132.

[14]. Navarro-pinda, F., Baz-Rodriguez, S., Handler, R., Sacramento-Rivero, C.,(2015): Advances on the processing of Jatropha curcas towards a whole biorefinery. Renewable and sustainable energy reviews, 54 : 247-269p

[15]. Petru, M., Novak, O., Herak, D., Simanjuntak, S., (2012). Finite element method model of the mechanical behaviour of Jatropha curcas under compression loading. Biosystems Engineering. 111 : 412-421.

[16]. Pinzi, S., Garcia, I.L., Lopez-Gimenez, F.J., Luque De Castro, M.D., Dorado, G., Dorado, M.P., (2009) : The ideal vegetable oil-based biodiesel composition : a review of social, economical and technical implications. Energy Fuels 23, 2325-2341

[17]. Sayyar, S., Abidin, Z.Z., Yunus, R., Azhari, M., (2009) : Extraction of oil from Jatropha seeds- optimization and kinetics. Am. J. of Appl. Sci. 6(7) : 1390-1395

[18]. Sirisomboon, P. and Kitchaiya, P. (2008): Physical Properties of Jatropha Curcus L. Kernels after Heat Treatments. Journal of Biosystem Engineering, 102 (2009):

a. 244-25

[19]. Subroto, E., Manurung, R., Heeres, H.J., Broekhuis, A.A., (2015). Mechanical extraction of oil from Jatropha curcas L kernel : Effect of processing parameters. Industrial and products. www.elsevier.com/locate/indcrop. Le 4 mai 2016

[20]. Tangka, J.K., Ketuma, C.T., Ajaga, N., Viyoi, C.T., (2016) : Modelling of the operation of a small generator set powered by scrubbed biogaz from cow dung. British Journal of Applied Science and Technology, 14 (1) : 1-8

[21]. Tambunan, A.H., Situmorang, J.P., Silip, J.J., Joelianingsih, A., Araki, T., (2012) Yield and physicochemical properties of mechanically extracted crude Jatropha curcas L oil. Biomass and Bioenergy, 43, 12-17.

[22]. Wilems, P., Kuipers, N.J.M., De haan, A.B., 2008. Hydraulic pressing of oilseeds : experimental determination and modelling of oil yield and pressing   rates. J. Food Eng. 89, 8-16.Winkler, E., Foidl, N., Gubitz, G.M., Staubmann, R., Steiner, W., (1997) : Enzyme supported oil extraction from Jatropha curcas seeds. Appl. Biochem. Biotechnol. 63- 65, 449-456.

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