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Optimization of oil extraction from high energetic potential plants performed through drying and solvent extraction methods

Reginaldo Ferreira Santos, Carlos Henrique Fornasari, Doglas Bassegio*, Samuel Nelson Melegari de Souza, Deonir Secco

UNIOESTE – Western Paraná State University – Post-graduation Program, Master Course of Energy in Agriculture.Rua Universitária, 2069, CEP: 85.819-130 Bairro Faculdade, Cascavel, Paraná, Brasil.

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The selection of species that accumulate oil with potential for biofuel production has favored advancements in the scientific and technological domains within the Brazilian biofuel program. The equipments and methods used for such selection have always prosecuted the objective of increasing oil extraction. The aim of this paper was to evaluate the yield of oil extracted from five vegetable species – castor oil plant (*Ricinus communis*), physic nut (*Jatropha curcas*), soybean (*Glycine max*), groundnut (*Arachis hypogaea L.*), and crambe (*Crambe abyssinica*) with two different moisture contents and using two different solvents, hexane and ethanol. The experimental design was factorial (5 × 2 × 2), in which grains of each of the five vegetable species in two different moisture contents were used for oil extraction. It can be concluded from this study that grain moisture content and solvent type had great influence in determining oil yield; and that hexane extraction was most efficient. *J. curcas* had the greatest increase of oil yield with 30.70% when performing extraction with grain moisture. The smallest differences between the solvents were found in the species *R. communis* with 12% of higher efficiency with hexane extraction.

Key words: Biodiesel, ethanol, hexane, oil extraction yield.

INTRODUCTION

The vegetable oil industry stands out within the agro-industry by the expressiveness of its economic stature. Vegetable oil is an important source of energy, essential fatty acids, vitamins and lipid-soluble antioxidants. The process for obtaining oleaginous grains and choosing the type of extraction process which they will go through depends on the initial oil content in the material. The methods must be simple and adaptable to various types of oleaginous (Singh and Bargale, 2000). Nowadays, the availability of oleaginous grains for supplying the agribusiness in the biofuels market has been increasing due to the need for compliance with the federal law that establishes the conditions for blending biodiesel into diesel. For that reason, it is important to plan and pursue solutions that will offer answers to issues that determine and influence the factors of production (Sartori et al., 2009). Different types of solvents, isopropanol, n-hexane, isohexane, acetone, methylpentanes, have been suggested in the literature (Wan et al., 1995; Apelblat et al., 1996; Batista et al., 1999; Kuk et al., 2005; Mohsen-Nia et al., 2007; Manic et al., 2011). Nowadays, there is a considerable interest in replacing these solvents (ethanol) by other alternative solvents, due to a growing concern regarding the environment and the safety of the process

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*Corresponding author. E-mail: doglas14@hotmail.com.

of oil production (Johnson and Lusas, 1983; Hammond et al.,2005). Among them, short-chain alcohols such as ethanol show the most promising results (Saxena et al., 2011).

The method that is mostly used for extracting oil from oilseeds is a petroleum distillate that contains a mixture of isomers of hexane (boiling points between 65 to 71°) industrially known as n-hexane. N-hexane can contain from 45 to 70% n-hexanes, as well as methylcyclopentane, 3-methylpentane, 2-methylpentane and cyclonhexane (Hammond et al., 2005; Wakelyn and Wan, 2006). Saxena et al. (2011) reported in a study, when comparing the yields of cottonseeds solvent extraction using hexane and ethanol at different temperatures, that higher efficiency was obtained using the renewable source ethanol as a solvent at higher temperatures. Brossard-González et al. (2010), when performing extraction with two different solvents (ethanol and hexane) and by pressing of physic nut seeds, concluded that extraction with ethanol as a solvent enabled higher yield when compared to pressing and no difference was found in the composition of the oil when using ethanol and hexane as solvents.

The higher moisture content in cold pressing reduces friction and results in low-yield and very low values of moisture effect the operation of the press (Singh and Bargale, 1990). Singh et al. (2002) showed that a decrease in moisture content and an increase in temperature improve oil extraction yield, thus reporting the importance of defining an optimum rage of moisture content. Solvent extraction is widely the most used method for oil extraction, which enables higher yield. However, there is little information about grain moisture content during the extraction process.

In the light of this consideration, this paper focuses on the energetic potential of oil extraction from energy crops. The aim of this study is to evaluate the extraction yield of oil from five species of plant using different solvents and different moisture contents.

MATERIALS AND METHODS

The experiment took place in a private laboratory in Cascavel-PR. The seeds used in the study were provided by Faculdade Assis Gurgacz (Assis Gurcacz College). The seeds were randomly chosen from different samples. Seeds of physic nut and castor oil plant were then shelled; all seeds were crushed in order to increase the surface area contacting the solvent. Seeds without moisture used in the tests were submitted to a drying process; moisture withdrawal was performed in an oven at 105°C to constant weight. Seeds with around 17% of moisture content were only crushed, weighted and then put into a soxhlet extractor. In this study, direct extraction process with hexane and ethanol solvents was performed in order to determine the oil content in the albumen. The soxhlet extraction method was used, based on procedures adapted from the analytical standards of the *Instituto Adolfo Lutz* (Adolfo Lutz Institute) (Pregnolato and Pregnolato, 1985), in order to determine the oil content of the seeds. Seeds were crushed in a portable mixer and then 5 g of the sample were weighted in filtering paper and transferred to the thimble of the soxhlet extractor. The flat bottom flask containing 200 ml of solvent was attached to the extractor. Heating was started to constant temperature and the extraction was carried out continuously for 8 h (four to five drops per second). The thimble was then removed. Solvents were distilled to a flask and the extracted residue remaining in the flask was dried in an oven at 105°C for 1 h and cooled in a desiccator to room temperature. The amount of extracted oil was then evaluated by the difference of the weights of the flat bottom flask with the oil and while empty.

The percentual (m/m) lipid or ethereal extract, E, was calculated according to the formula:

$$E = 100 \times N/P$$

Where N is the weight of lipids (g), and P is the weight of sample (g).

The experimental design was completely randomized factorial (5 × 2 × 2), with five vegetable species – castor oil plant (*Ricinus communis*), physic nut (*Jatropha curcas*), soybean (*Glycine max*), groundnut (*Arachis hypogaea L.*) and Crambe (*Crambe abyssinica*). Samples with two moisture contents were extracted with two solvents, hexane and ethanol, and four repetitions were done. The results were submitted to analysis of variance. The interaction between the factors, as well as their means were compared by Tukey's test at 1 to 5% error probability with the use of the statistics package Assistat® version 7.5 beta (Silva and Azevedo, 2002). Unfolding was performed when F was significant in the interaction.

RESULTS AND DISCUSSION

Table 1 shows the behavior of the analysis of variance, the significance of the treatments as well as the interacttion specie/moisture, specie/solvents and specie/moisture/ solvent. The interaction between specie and solvent did not provide significant response for the oil yield of the studied species. It is possible to observe a significant effect on oil yield for the different vegetables ($P<0.01$) (Table 1). The species *J*. *acurcas* and *R*. *communis* excelled in oil income when compared to the others. Oil content of *G*. *max* was below the average established for the species studied in this paper. The seeds used in the experiment showed characteristics of oil content similar to the ones reported by Drummond et al. (2006), Kandpal and Madan (1995), Melhorança et al. (2010) and Rosseto et al. (2012). Table 2 shows the unfolding of the interaction of the studied factor (specie/moisture) for oil yield. It is possible to verify that the moisture content caused different responses for the studied genotypes. Extraction without moisture showed a significant increase in oil yield for all the analyzed species, emphasizing *R*. *communis*, which had an increase in oil content of 119%, compared to extraction with moisture. *J*. *acurcas* had the greatest increase of oil yield with 30.70% when performing extraction with moisture. No study similar to this one was found in the literatures.

Mpagalile et al. (2006) and Pighinelli et al. (2008) evaluated the effect of moisture content of *A*. *hypogaea* L. and *Helianthus annus* L., respectively, in oil extraction by mechanical pressing through which the second author found the range of 8 to 8.5% that would be the maximum

Table 1. Yield oil (%) of the species under different conditions.

Treatment	Oil content (%)
Specie	
G. max	8.96^{d}
A. hypogaea	31.82^{b}
J. curcas	37.07^{a}
R. communis	37.32^{a}
C. abyssinica	23.25^{c}
Moisture content	
With 17% moisture	21.18^{b}
Without moisture	34.19^{a}
Solvent	
Hexane	34.36^{a}
Ethanol	21.00^{b}
CV (%)	10.86
Species (E)	**
Moisture (U)	**
Solvent (S)	**
E × U	**
E × S	**
U × S	n.s.
E × U × S	**

Coefficient of variation (CV %). Means with different small letters in the columns are statistically different at 1% (**) and 5% (*) probability; n.s, not significant. Tukey test.

Table 2. Unfolding of the interaction, for oil yield averages (%), according to specie/moisture and specie/solvent.

Specie	Moisture	
	With moisture	Without moisture
G. max	6.02^{dB}	11.90^{eA}
A. hypogaea	26.40^{bB}	37.23^{cA}
J. curcas	30.70^{aB}	43.45^{bA}
R. communis	23.41^{bcB}	51.23^{aA}
C. abyssinica	19.36^{cB}	27.14^{dA}

Specie	Solvent	
	Hexane	Ethanol
G. max	10.36^{dA}	7.56^{eA}
A. hypogaea	43.07^{bA}	20.56^{cB}
J. curcas	48.57^{aA}	25.57^{bB}
R. communis	39.39^{bA}	35.25^{aB}
C. abyssinica	30.43^{cA}	16.07^{dB}

oil yield. It is possible to conclude through the differences found in the unfolding of the interaction specie/solvent (Table 2) that the hexane solvent provided better oil yield. It is also notable the superiority of *J. curcas* in the extraction performed with hexane solvent, obtaining 48.57% of oil over ethanol extraction with 25.57%. The smallest differences between the solvents were found in *R. communis* with 12% of higher efficiency with hexane extraction. Melhorança et al. (2010) reported, when analyzing two solvents (hexane and methanol) for *J. curcas*, the

Table 3. Unfolding of interaction specie/moisture/solvent for oil yield (%).

Specie	Moisture/solvent			
	With moisture + hexane	**With moisture + ethanol**	**Without moisture + hexane**	**Without moisture + ethanol**
G. max	7.13^{cB}	4.91^{cB}	13.60^{dA}	10.20^{dAB}
A. hypogaea	40.75^{aA}	12.06^{bC}	45.40^{bA}	29.07^{bB}
J. curcas	43.70^{aB}	17.70^{abD}	53.45^{aA}	33.45^{bC}
R. communis	24.75^{bB}	22.07^{aB}	54.02^{aA}	48.44^{aA}
C. abyssinica	26.12^{bB}	12.60^{bD}	34.74^{cA}	19.54^{cC}

efficiency of hexane in the extraction; however, they emphasize that the cost-benefit is unfeasible because of its higher price. Brossard-González et al. (2010) found different values for *J. curcas* (31.22%) of average oil yield with hexane extraction compared to 34.34% with ethanol extraction. In this study, the authors reported the superiority of ethanol when compared to hexane solvent extraction and to pressing method extraction. Drumond et al. (2006), using ethanol as a solvent for extraction of seeds of *R. communis* obtained yields of 46.9% with ethanol, 51.1% with methanol and 41.1% with hexane. Kandpal and Madan (1995) obtained 37.4% inextraction of whole seeds and 46.0 to 48.6% with the albumen alone using petroleum ether solvent in the extraction of *J. cucas* in a soxhlet extractor. Oil yield was influenced by interaction specie/moisture/solvent (Table 3). Higher oil content was derived from combinations with no moisture and hexane solvent.

In this study, moisture content was a limiting factor. It is possible to observe that oil yield for *J. curcas*, even when extracted with ethanol that was the least efficient solvent in this study, was lower because of the moisture content in the extraction with hexane. *G. max*, when submitted to drying and hexane extraction, showed oil yield in conformity with the ones found in the literature. Ramesh et al. (1995) emphasize that drying or toasting processes optimize the extraction of oil from oilseeds and may affect the physical-chemical properties of the oil. Saxena et al. (2011) reported that the color of the oil extracted with ethanol solvent is a little bit darker than the color of oil extracted with hexane. Works that compare the extraction methods using biorenewable solvent and traditional fossil solvent (hexane) or pressing methods can be found in the literature by Brossard-González et al. (2010), Ribeiro et al. (2010), Ferreira-Dias et al. (2003) and Drumond et al. (2006). These authors emphasize that despite the better results of oil yield obtained by hexane extraction in some cases, its cost is high, and this can be a significant factor when compared to the low cost and the ease of use of ethanol; what adds to the much higher toxicity that hexane presents.

Conclusion

The grain moisture content and the solvent type used for oil extraction are two key factors that influence oil yield. The extraction with hexane solvent was significantly more efficient than the extraction with ethanol solvent, regardless of the moisture content. The species *J. curcas* and *R. communis* excelled in oil income when compared to the others.

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