**Syagrus romanzoffiana** (Cham.) Glass. **PALM FRUIT ENERGY CAPACITY**

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**ABSTRACT:** The demand for energy and natural resources conservation results in disputes, concerns and studies. In an attempt to respond to both areas a study was developed aiming at characterizing the energy capacity of native palm tree jerivá [**Syagrus romanzoffiana** (Cham). Glass]. Four plants of this species were evaluated. The aspects investigated were fruit yield and potential for lipid and ethanol production. The fruit average yield potential was 41,829 kg ha⁻¹, 24,930 kg ha⁻¹ pulp (59.6% of the fruit) and 2,593 kg ha⁻¹ almond (6.2% of the fruit). These contents can provide 1,641 kg ha⁻¹ of lipid (62.2% of the almond) and 1,819 kg ha⁻¹ of ethanol (7.3% of the pulp). The species **Syagrus romanzoffiana** even without any selection or genetic improvement processes, correction of soil acidity or fertility, showed high potential to be used in lipid production (almond) and ethanol (pulp).

**Keywords:** vegetable oil, storage lipid, ethanol, alcohol, renewable energy.

**POTENCIAL ENERGÉTICO DO FRUTO DA PALMEIRA Syagrus romanzoffiana** (Cham.) Glass

**RESUMO:** a demanda por energia e a conservação dos recursos naturais estimulam disputas, preocupações e estudos. Tentando “transitar” nas duas áreas objetiva-se caracterizar o potencial energético da palmeira nativa jerivá [**Syagrus romanzoffiana** (Cham). Glass]. Foram avaliadas quatro plantas. Determinou-se produtividade, potencial para produção de lipídio e de etanol do fruto. O potencial produtivo médio de frutos é 41.829 kg ha⁻¹, 24.930 kg ha⁻¹ de polpa (59,6% do fruto) e 2.593 kg ha⁻¹ de amêndoa (6.2% do fruto). Esses conteúdos podem proporcionar 1.641 kg ha⁻¹ de lipídio (62,2% da amêndoa) e 1.819 kg ha⁻¹ de etanol (7,3% da polpa). A espécie potencial **Syagrus romanzoffiana** mesmo sem passar por processos de seleção e melhoramento genético, correção de acidez e fertilidade do solo apresenta elevado potencial de uso na produção de lipídio (amêndoa) e de etanol (polpa).

**Palavras-chave:** óleo vegetal, lipídio de reserva, etanol, álcool, energia renovável.

**1 INTRODUCTION**

Increasing demand for energy, originating from renewable energy or not, has been promoting disputes in the global geopolitical field, at the same time it has enhanced academic research on new sources. The humankind has been using animal and vegetable products in chemical-physical processes, which release energy, mainly thermal energy, for centuries. Therefore, the research with vegetable species which store starch, sugar and fatty acids might bring about positive results (DEMRBAS, 2009; CÉSAR; BATALHA, 2010).
In Brazil, the transportation sector is one of the main consumers of energy and the current law already provides for the increase in biofuel demand. Biodiesel, for example, can be obtained from several different species, commercial or not, however, in 2019 68% of the biofuel produced in Brazil was extracted from the soybean (ANP, 2020).

Regarding crops with energy purposes, species which are not used as food for human consumption such as Euphorbia lathyris, Sapium sebiferum, Jatropha curcas, Xanthium sibiricum, Acrocomia aculeata, Syagrus oleracea and Syagrus romanzoffiana, present potential and start to deserve academic interest (ASHWATH, 2010; COIMBRA; JORGE, 2012; GOUDEL et al., 2012; MOREIRA et al., 2013; CHAG at al., 2013; DUCCA; SOUZA, PRETE, 2015). In addition to tackling indirectly the polemic of food safety, they are usually low cost raw material (HASHEMINEJAD et al., 2011). Particular interest should be directed to the forecast of these native or acclimatized plants energy production potential (ASHWATH, 2010).

The Brazilian biodiversity energy potential is not fully known yet and its use is neglected, therefore, it is vital to search better use for this resource in the production of food, energy and medicine, which might result in economic value for these species. The potential of biodiversity species results from the proper combination among raw material availability, technology and market. In such context, the acclimatization of native plants should be considered (ZIMMERMANN et al., 2011).

Comprising around 40 species, the genus Syagrus (Arecaceae) is native in South America (BERNACCI; MARTINS; SANTOS, 2008), with high incidence in the South and Southeast of Brazil (GLASSMAN, 1987). It occurs naturally in the Mata Atlântica, Cerrado and Pampa biomes associated to several habitats such as ombrophilous forests, steppes and fields (CARVALHO, 2006). As it is decorative and easy to transplant, the adult plant is used ornamentally and in urban forestation (ASHWATH, 2010; ZIMMERMANN; BEGNINI; SILVA, 2011).

The Syagrus romanzoffiana palm or jerivá presents a single, cylindrical trunk, whose thickness is almost uniform and the aspect is smooth. It can reach up to 20 meters high. Its fruit is an ovoid drupe which, when ripe, is yellow-orange with a fleshy and smooth pulp, thin epicarp and fibrous mesocarp, mucilaginous, juicy and edible. It can measure up to 5 cm in length and 3 cm in diameter and presents only one seed. The trees produce fruit from flowers in clusters and can produce all year long (CARVALHO, 2006).

This species plays a relevant ecological role (BERNACCI; MARTINS; SANTOS, 2008; SILVA et al., 2011; BEGNINI; SILVA; CASTELLANI, 2013) representing important food source to the fauna (SILVA et al., 2009; ZIMMERMANN; BEGNINI; SILVA, 2011). In Argentina, its presence has been recognized as a positive factor in honey production and it has also deserved some study regarding its use in biodiesel production (FALASCA et al., 2012; MOREIRA et al., 2013).

This study aimed at characterizing the Syagrus romanzoffiana (Cham.) Glass fruit energy capacity.

2 MATERIAL AND METHODS

The fruit collection was carried out in the region of Campos Gerais of Paraná, with a mesothermal humid subtropical climate, classified as Cfb, with regular rainfall along the year, mild summers and occurrence of frost in winter. The region is located in the Mata Atlântica biome with the presence of grassy-woody vegetation (native fields) and elements of a mixed ombrophilous forest (Araucaria moist forest) containing sparsely treed areas and gallery forests (ROCHA, 2006).

Four Syagrus romanzoffiana (Cham.) Glass trees were selected, which are located in the State University of Ponta Grossa, campus Uvaranas, and labeled 1, 2, 3 and 4. These palm trees were incorporated to Campus landscape in the 1990s. The trees were observed for 36 months (plants 1, 2 and 3) and 27 months (plant 4).

As the maturation of these plants was not uniform, the production of flowers and the maturation visual condition were observed weekly. The fruit clusters were harvested when presenting visually over 50% ripe fruits (yellow-orange).
After harvested, the fruit was picked manually from the rachillae and separated according to their maturation stage (green and ripe). The fruit average annual yield per tree was evaluated as follows: mass of the fruit collected from the first inflorescence plus the amount produced in the subsequent 12 months; mass of the fruit produced excluding the first month and adding the subsequent month and so forth throughout the period of study.

To calculate the yields of plants 1, 2, 3 and 4, we carried out 14, 13, 11 and 8 harvests (clusters) of each tree, respectively. The fruit harvest varied from four to six harvests (clusters) for each 12-month period.

In order to evaluate maturation and the relation with the fruit soluble solid concentration, thirty fruits were collected from each tree, which were separated into six maturation groups with five fruits each, being 1 the highest degree of maturation and 6 the lower degree of maturation (Figure 1). After the separation, the pulp soluble solid content (degrees Brix) from each fruit group was measured in a portable refractometer Impac, model Ip3t (0~32% Brix).

**Figure 1.** Maturation groups originated from the same fruit collection of four *jerivá* plants

As to determine water content, five samples were separated containing ten ripe fruit (condition 1) and five containing green fruit (condition 6) (Figure 1). These fruits were dehydrated in forced air oven, at 60°C up to the mass stabilization.

A pulper was developed (Figure 2) to separate the pulp from the seed (endocarp + almond, commonly known as coquinho (little coconut)). The capacity of this pulper is 10 kg fruit and it is driven by a 0.55 kW electrical motor. To have some control of the working conditions, a set of pulleys was adapted to enable the pulper rod axle to perform three rotations.
Figure 2. Pulper developed for the *jerivá* pulp and seed initial separation process

Tests were carried out to adjust the mechanism and develop the pulp separation process. The determination of rotation speed was carried out aided by a contact digital tachometer. Through efficacy and quality tests, the rotation 1,429 min\(^{-1}\) was defined as the working rotation, and an average 5.09 min processing was necessary to extract the pulp. The rotation 2,830 min\(^{-1}\) was seen to damage the endocarp and the rotation 755 min\(^{-1}\) required around 14.39 min. to extract the pulp.

To extract the pulp of green fruit, water was added at the ratio 1:1 (mass:mass). To separate that pulp from the fiber and endocarp, a 2 mm mesh sieve was employed. The green fruit pulp was disposed and the fiber separated manually from the endocarp. These were dried protected from the sun for seven days. Fiber yield after dehydration was evaluated. Ripe fruits were processed with the addition of water at the ratio 2:1 (mass:mass), fruit and water, respectively.

The fermentation process to obtain ethanol was carried out with the ripe fruit pulp (ITO et al., 2005). Initially, the pulp pH was measured with a pH meter Quimis, model Q400BD. Next, for each liter of pulp, 50 g yeast (*Saccharomyces cerevisiae*) was added and it was fermented for 24 hours at 30ºC. The yeast used was obtained from the sugar-energy industry, selected by Cooperval (Agroindustrial Cooperative of Vale do Ivaí Ltda. in Jandaia do Sul, state of Paraná). The must obtained was distilled in a 20 liter stainless steel distiller.

The dry little coconuts (endocarp + almond) were separated into three 100 g samples originated from ripe fruit and three 100 g samples originated from green fruit. These samples had the endocarp broken weekly, and their components were separated determining the mass of endocarp and almonds (0.05 g accuracy scales). The samples were then submitted to a mechanical press with 200g bash processing capacity. These almonds remained under pressure for 8 hours for the physical extraction of oil and then the paste and oil contents were determined (0.05 g accuracy scales). With the paste originated in the press extraction, solvent extraction was carried out by employing the Soxhlet method, as recommended by the Instituto Adolfo Lutz.
(2008), with 8-hour reflux and n-hexane as solvent.

Regarding the statistical analysis, variance analysis was carried out followed by the Tukey mean comparison test or regression analysis and variance analysis through the Kruskal-Wallis method followed by the comparison test through the Student-Newman-Keuls method. The methods were applied according to the variable.

3 RESULTS AND DISCUSSION

The fruit mass per cluster reached 33.3 kg on average, ranging from 9.9 kg (plant 2) to 43.2 kg (plant 1). In the Australian subtropical condition Ashwath (2010) reported 10 kg average mass per cluster. Table 1 shows the average fruit yield per plant (kg plant\(^{-1}\) year\(^{-1}\)) in 12-month periods.

### Table 1. Fruit yield per plant (kg plant\(^{-1}\) year\(^{-1}\)) in 12-month periods

| 12-month periods | Plant 1 | Plant 2 | Plant 3 | Plant 4 |
|------------------|---------|---------|---------|---------|
| 1                | 156.13  | 78.56   | 82.51   | -       |
| 2                | 142.97  | 76.59   | 89.61   | -       |
| 3                | 196.43  | 89.55   | 75.71   | 59.8    |
| 4                | 183.37  | 79.56   | 59.91   | 66.2    |
| 5                | 179.10  | 85.23   | 77.74   | 73.3    |
| 6                | 172.22  | 68.11   | 74.82   | 63.9    |
| 7                | 171.44  | 98.25   | 78.24   | 78.4    |
| 8                | 158.61  | 104.16  | 77.01   | 73.9    |
| Average          | 170.03  | 85.01   | 76.93   | 69.3    |

In order to qualify fruit yield, the mass of 100 green fruit and 100 ripe fruit was determined for the four plants. Eleven replications were carried out for each plant, and plant 2 outstood in this characteristic (Table 2). This plant differentiated values might indicate genetic condition not specified for the species.

### Table 2. Jerivá plant 100 green fruit and 100 ripe fruit mass

| Plant | 100 green fruit average mass (g) | Variation coefficient (%) | 100 ripe fruit average mass (g) | Variation coefficient (%) |
|-------|---------------------------------|---------------------------|---------------------------------|---------------------------|
| 1     | 390 a                           | 3.64                       | 450 a                           | 8.99                      |
| 2     | 630 b                           | 4.01                       | 710 c                           | 4.58                      |
| 3     | 400 a                           | 8.59                       | 460 a                           | 9.55                      |
| 4     | 490 a                           | 10.29                      | 560 b                           | 10.26                     |

Averages followed by the same letter in the column did not differ one from the other. Green fruit results evaluated by the Student-Newman-Keuls test. Ripe fruit results evaluated by the 5% Tukey test.

For the little coconut mass (endocarp + almond) in relation to the fruit total mass, including green and ripe fruit, plant 2 presented significant differences again when compared to the remaining ones (Table 3). In this case, this plant, together with plant 1 (highest yield) (Table 1) should be recommended for studies of propagation and genetic improvement. This kind of monitoring can be carried out on family farming properties, that is, the farmer can observe the plants and determine which ones present best values of yield components in order to select seeds and generate seedlings.
Table 3. Relative mass and water content in 100 green and 100 ripe little coconuts (endocarp + almond), present in the *jerivá* fruit (pulp + endocarp + almond)

| Plants | Green fruit | Ripe fruit |
|--------|-------------|------------|
|        | Relative mass (endocarp + almond) (g kg⁻¹) | Water content (g kg⁻¹) | Relative mass (endocarp + almond) (g kg⁻¹) | Water content (g kg⁻¹) |
| 1      | 140 a       | 487        | 170 a       | 427        |
| 2      | 220 b       | 514        | 230 b       | 474        |
| 3      | 150 a       | 502        | 160 a       | 473        |
| 4      | 160 a       | 539        | 170 a       | 492        |

Averages followed by the same letter in the column did not differ one from the other in the Student-Newman-Keuls test at 5%.

Figure 3 presents the soluble solid average values (degrees Brix) for each maturation group as suggested (Figure 1). The soluble solid contents were strongly correlated to the degree of maturation suggested visually. For this study, there was no distinction among the plants.

Figure 3. Soluble solids regression analysis and *jerivá* fruit pulp maturation groups

Table 4 shows the almond relative mass and the endocarp relative mass found in green fruit (between 57.2 g kg⁻¹ and 71.2 g kg⁻¹) and in ripe fruit (between 54.3 g kg⁻¹ and 69.8 g kg⁻¹) and in little coconuts originated from the green fruit (between 168.8 g kg⁻¹ and 195.5 g kg⁻¹) and ripe fruit (between 170.6 g kg⁻¹ and 195.0 g kg⁻¹) of the four plants. Comparatively, regarding fruit, the African oil palm (*Elaeis guineenses*) in three physiographic regions was reported to yield 100 g kg⁻¹ almonds (SANTOS, 2010). The Babassu (*Orbignya phalerata*) almonds were reported to represent between 60 and 70 g kg⁻¹ of the fruit total weight (CARVALHO, 2007).

It is important to highlight that the endocarp mass is around four times larger than the almonds mass. One potential use of this byproduct could be its conversion into energy or as a co-generator.
Table 4. Almond (A) and endocarp (E) relative mass present in the little coconuts (endocarp + almond) and in the fruit (pulp + endocarp + almond) of the four *jerivá* plants, according to their maturation.

| Origin                  | Mass (g kg$^{-1}$) | Plant 1 | Plant 2 | Plant 3 | Plant 4 |
|-------------------------|--------------------|---------|---------|---------|---------|
|                         | A   | E   | A   | E   | A   | E   |
| Fruit                   | Green| 71.2| 292.9| 59.0| 285.3| 62.2| 306.1| 57.2| 272.0 |
|                         | Ripe| 69.8| 287.9| 54.3| 264.0| 60.9| 278.2| 56.5| 243.5 |
| Little coconuts         | Green fruit | 195.5| 804.5| 171.2| 827.8| 168.8| 831.2| 173.6| 826.4 |
|                         | Ripe fruit | 195.0| 805.0| 170.6| 829.4| 179.6| 821.4| 188.4| 811.6 |

The average of fiber relative mass present in the *jerivá* plant green and ripe fruits is presented in Table 5. The fiber masses reported for *açaí* palm (*Euterpe oleracea*) 327 g kg$^{-1}$, moriche palm (*Mauritia flexuosa*) 79 g kg$^{-1}$, American oil palm (*Elaeis oleifera*) 68 g kg$^{-1}$, peach palm (*Bactris gasipaes*) 38 g kg$^{-1}$ and tucum (*Astrocaryum tucuma*) 192 g kg$^{-1}$ demonstrate the great difference of this variable in palm plants (AGUIAR et al., 1980).

Table 5. Fiber relative mass present in the *jerivá* green and ripe fruits

| Plant 1 | Plant 2 | Plant 3 | Plant 4 |
|---------|---------|---------|---------|
| Ripe 62.5| 53.5 | 59.0 | 61.0 |
| Green 68.0 | 64.0 | 62.1 | 66.5 |

In order to evaluate the yield of total lipid present in the fruit almonds, cold mechanical extraction and extraction through solvent were carried out in the paste resulting from the final oil removal from plants 1 and 2 (Table 6).

No significant difference was found for the lipid extracted physically from the ripe fruit of the four plants under study (Kruskal-Wallis test for independent samples). No difference was observed for this variable when comparing green to ripe fruits. No significant difference was found in solvent extracted lipids when comparing green and ripe fruit of plants 1 and 2 (Table 6).

Table 6. Lipids through cold physical extraction and the sum of lipids obtained through cold extraction and solvent from the *jerivá* almonds

| Plant 1 | Plant 2 | Plant 3 | Plant 4 |
|---------|---------|---------|---------|
| Ripe 459.0| 447.8 | 466.5 | 438.6 |
| Green 437.2| 427.1 | 459.7 | 474.9 |

In a study carried out in Australia, values between 41.6 ± 3.8% oil were found (ASHWATH, 2010). Moreira et al. (2013) reported 52% oil for *jerivá* fruit collected in the same region of the relevant study. These data demonstrate the variability of the oil content in fruit, probably, due to edaphic, climatic and phenological factors inherent in this species.
The process to obtain ethanol was carried out with the pulp extracted from the ripe fruit. Distillations were carried out for the pulp originated from plants 1 and 2. Before being distilled, plant 1 pulp presented 13% soluble solid average content and plant 2 presented 11.5%. Plant 1 conversion efficacy was from 67.1 mL to 82.6 mL ethanol (97%) while plant 2 conversion efficacy was from 68.6 to 72.0 mL ethanol per mass kg.

Regarding studies on the optimization of alcohol extraction from the jerivá pulp, the maximum value obtained was 260 mL kg\(^{-1}\) (ARIELO et al., 2014). This data seems to be interesting when compared to more traditional plants used with this purpose: 70 mL kg\(^{-1}\) for sugar cane; 180 mL kg\(^{-1}\) for corn; 110 mL kg\(^{-1}\) for beetroot (FOOD AND AGRICULTURE ORGANIZATION, 2008).

The table 7 illustrates the productive potential, in a hypothetical monoculture system production, using the 6x4 m spacing as reference, totalizing 417 plants ha\(^{-1}\) (ASHWATH, 2010) considering the average value of the plants under study. The average hypothetical yield obtained was 41,829 kg ha\(^{-1}\), which can be considered relevant.

### Table 7. Hypothetical yield of fruits with 6 x 4 spacing or 417 plants ha\(^{-1}\)

| Spacing (m) | Plant 1 | Plant 2 | Plant 3 | Plant 4 | Average yield |
|-------------|--------|--------|--------|--------|--------------|
| 6 x 4       | 70,902.5 | 35,449.2 | 32,079.2 | 28,885.6 | 41,829.1 |

Based on the fruit average yield (Table 7) and the pulp and almond productivity (Table 4) the annual production can be estimated as 1,641 L ha\(^{-1}\) lipid (obtained from the almond through physical extraction and solvent) and 1,819 L ha\(^{-1}\) lipid (obtained from pulp fermentation) (Table 8).

### Table 8. Potential products of the jerivá culture in a hypothetical culture (417 plant ha\(^{-1}\))

| Product                          | kg ha\(^{-1}\) year\(^{-1}\) |
|----------------------------------|-------------------------------|
| Fruit                            | 41,829.1                      |
| Pulp (59.6% of the fruit) (no fiber) | 24,930.1                      |
| Endocarp (27.9% of the fruit)     | 11,670.3                      |
| Almond (6.2% of the fruit)        | 2,593.4                       |
| Pulp fiber (6.2% of the fruit)    | 2,593.4                       |
| Lipid (63.3% of the almond)       | 1,641.6                       |
| Ethanol (7.3% of the pulp)        | 1,819.9                       |
| Paste and or meal (36.7% of the almond) | 951.8                      |

It seems important to highlight that the plants under study did not receive any treatment for soil acidity correction or fertility, which might have been altered in intensive commercial plantation. Bearing in mind the potential extraction activity in legal reserve areas and lower farming aptitude soils or even family farming properties, these results become representative. Taking into consideration that the species under study is native and was not submitted to any selection or genetic improvement treatment, the variability of yield components tends to be high. Besides that, it can be used together with other domesticated species in agroforestry systems, for example Ashwath (2010).

Therefore, this study aims at helping in the current challenge to produce or increase biomass yield without clear cutting of natural biome, as well involving the family farming, which has historically faced difficulties, in the division of economic potential. The sum of these factors demands the use of concepts from different areas such as science, technology and society aiming at the rational use of natural resources (DELALIBERA et al., 2008). One solution could be the extractive rational exploitation of *Syagrus romanzoffiana* in legal
reserve areas, which are compulsory areas, except for the permanent preservation ones, which are needed for the sustainable use of natural resources (OKUYAMA et al., 2012).

4 CONCLUSION

The Syagrus romanzoffiana culture studied, even without being exposed to selection processes, genetic improvement and soil fertility or acidity correction treatments, presents a high potential for biomass (fruits) production. This is the specific case of plant 1 and 2.

Several energy products of commercial interest such as lipids, ethanol, substrate and others can be obtained through fruit processing. The experiments showed that the amounts obtained of such products are comparable to those reported in the scientific literature.

5 REFERENCES

AGUIAR, J. P. L.; MARINHO, H. A.; REBÊLO, Y. S.; SHRIMPTON, R. Aspectos nutritivos de alguns frutos da Amazônia. Acta Amazonica, Manaus, v. 10, n. 4, p. 755-758, 1980.

ANP. Agencia nacional de petróleo, gás natural e biocombustíveis. Anuário Estatístico Brasileiro do Petróleo, Gás Natural E Biocombustíveis, Rio de Janeiro, 2020. Disponível em: http://www.anp.gov.br/publicacoes/anuario-estatistico/anuario-estatistico-2020. Acesso em: 01 de julho de 2020.

ARIELO, G. R. M.; ANTUNES, S. R. M.; WEIRICH NETO, P. H.; BORBA, S.; COPPO, R. L.; BORSATO, D. Optimization of the alcoholic fermentation of aqueous jerivá pulp extract. Acta Scientiarum Technology, Maringá, v. 36, n. 4, p. 699-705, 2014.

ASHWATH, N. Evaluating biodiesel potential of Australian native and naturalized plant species. Kingston: Rural Industries Research and Development Corporation - RIRDC Publication No. 10/216. ISBN: 978-1-74254-181-5, 2010.

BEGNINI, R. M.; SILVA, F. R.; CASTELLANI, T. T. Fenologia reprodutiva de Syagrus romanzoffiana (Cham.) Glassman (Arecaceae) em Floresta Atlântica no sul do Brasil. Biotemas, Florianópolis, v. 26, n. 4, p. 53-60, 2013.

BERNACCI, L. C.; MARTINS, F. R.; SANTOS, F. A. M. Estrutura de estádios ontogenéticos em população nativa da palmeira Syagrus romanzoffiana (Cham.) Glassman (Arecaceae). Acta Botanica Brasileira, Belo Horizonte, v. 22, n. 1, p. 119-130, 2008.

CARVALHO, J. D. V. Cultivo de babaçu e extração do óleo. Brasília, DF: Centro de Apoio ao Desenvolvimento Tecnológico da Universidade de Brasília, 2007. Disponível em: http://sbrt.ibict.br/dossie-tecnico/downloadsDT/NaA=/. Acesso em: 14 maio 2012.

CARVALHO, P. E. R. Espécies arbóreas brasileiras. Brasília, DF: Embrapa Informação Tecnológica; Colombo: Embrapa Florestas, 2006. v. 2.

CÉSAR, A. S.; BATALHA, M. O. Biodiesel production from castor oil in Brazil: A difficult reality. Energy Policy, [s.l.], v. 38, n. 8, p. 4031-4039, 2010.

CHANG, F.; HANNA, M. A.; ZHANG, D. J.; LI, H.; ZHOU, Q.; SONG, B. A.; YANG, S. Production of biodiesel from non-edible herbaceous vegetable oil: Xanthium sibiricum Patr. Bioresource Technology, [s.l.], v. 140, p. 435-438, 2013.
COIMBRA, M. C.; JORG, N. Fatty acids and bioactive compounds of the pulps and kernels of Brazilian palm species, guaraná (Syagrus oleracea), jerivá (Syagrus romanzoffiana) and macaúba (Acrocomia aculeata). *Journal Science Food Agricultural*, [s.l.], v. 92, n. 3, p. 679-684, 2012.

DELALIBERA, H. C.; WEIRICH NETO, P. H.; LOPES, A. R. C.; ROCHA, C. H. Alocação de reserva legal em propriedades rurais: do cartesiano ao holístico. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v. 12, n. 3, p. 286-293, 2008.

DEMIRBAS, A. Progress and recent trends in biodiesel fuels energy conversion and management. *Energy Conversion and Management*, [s.l.], v. 50, n. 1, p. 14-34, 2009.

DUCCA, C. A. D.; SOUZA, N. M.; PRETE, C. E. Qualidade fisiológica e lipídios totais de sementes de pinhão-manso (*Jatropha curcas* L.) em função de épocas de colheita. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v. 19, n. 4, p. 364-368, 2015.

FALASCA, S. L.; MIRANDA DEL FRESNO, C.; ULBERICH, A. Possibilities for growing queen palm (*Syagrus romanzoffiana*) in Argentina as a biodiesel producer under semi-arid climate conditions. *International Journal of Hydrogen Energy*, [s.l.], v. 37, n. 19, p. 14843-14848, 2012.

FOOD AND AGRICULTURE ORGANIZATION. *Faostat*. Rome: FAO, 2008. Disponível em: http://faostat.fao.org. Acesso em: 27 set. 2013.

GLASSMAN, S. F. *Revision of the palm genus Syagrus Mart. and the other genera in the Cocos Alliance*. Illinois Biological Monographs 56: 1-231. 1987.

GOUDEL, F.; SHIBATA, M.; COELHO, C. M. M.; MILLER, P. R. M. Fruit biometry and seed germination of *Syagrus romanzoffiana* (Cham.) Glassm. *Acta Botanica Brasílica*, Belo Horizonte, v. 27, n. 1, p. 147-154, 2013.

HASHEMINEJAD, M.; TABATABAEE, M.; MANSOURPANAH, Y.; FAR, M. K.; JAVANI, A. Upstream and downstream strategies to economize biodiesel production. *Bioresourc Technology*, [s.l.], v. 102, n. 2, p. 461-468, 2011.

INSTITUTO ADOLFO LUTZ. *Métodos Físico-Químicos para análise de alimentos*. São Paulo: Instituto Adolfo Lutz, 2008.

ITO, T.; NAKASHIMADA, Y.; SENBA, K.; MATSUI, T.; NISHIO, N. Hydrogen and ethanol production from glycerol-containing wastes discharged after biodiesel manufacturing process. *Journal of Bioscience and Bioengineering*, [s.l.], v. 100, n. 3, p. 260-265, 2005.

MOREIRA, M. A. C.; PAYRET ARRÚA, M. E. P.; ANTUNES, A. C.; FIUZA, T. E. R.; COSTA, B. J.; WEIRICH NETO, P. H.; ANTUNES, S. R. M. Characterization of *Syagrus romanzoffiana* oil aiming at biodiesel production. *Industrial Crops and Products*, [s.l.], v. 48, n. 7, p. 57-60, 2013.

OKUYAMA, K. K.; WEIRICH NETO, P. H.; ROCHA, C. H.; ALMEIDA, D.; RIBEIRO, D. R. S. Adequação de propriedades rurais ao Código Florestal Brasileiro: estudo de caso no estado do Paraná. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v. 16, n. 9, p. 1015-1021, 2012.

ROCHA, C. H. Selection of Priority Areas for Conservation in Fragmented Landscapes: Case Study in Paraná State Campos Gerais. *Natureza & Conservação*, Curitiba, v. 4, n. 2, p. 189-211, 2006.
SANTOS, E. A. Caracterização de dendezeiros subespontâneos com base na produção de frutos e cachos. Dissertaçao (Mestrado em Produção Vegetal) – Universidade Estadual de Santa Cruz, Ilhéus, 2010.

SILVA, F. R.; BEGNINI, R. M.; KLIER, V. A.; SCHERER, K. Z.; LOPES, B. C.; CASTELLANI, T. T. Syagrus romanzoffiana (Arecaceae) seed utilization by ants in a secondary forest in South Brazil. Neo-tropical Entomology, Londrina, v. 38, n. 6, p. 873-875, 2009.

SILVA, F. R.; BEGNINI, R. M.; LOPES, B. C.; CASTELLANI, T. T. Seed dispersal and predation in the palm Syagrus romanzoffiana on two islands with different faunal richness, southern Brazil. Studies on Neotropical Fauna and Environment, [s.l.], v. 46, n. 3, p. 163-171, 2011.

ZIMMERMANN, T. G.; BEGNINI, R. M.; SILVA, F. R. Syagrus romanzoffiana (Jerivá). In: CORADIN, L.; SIMINSKI, A.; REIS, A. (org.). Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro – Região Sul. Brasília, DF: MMA, 2011. p. 812-819.