ISSN 2359-6562 (ONLINE) 2359-6562 (CD-ROM)

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

PEDRO HENRIQUE WEIRICH NETO[1], HEVANDRO COLONHESE DELALIBERA[2], NÁTALI MAIDL DE SOUZA[3], JHONNY MARTINI[4], JAIME ALBERTI GOMES[5]

[1] Laboratório de Mecanização Agrícola, Universidade Estadual de Ponta Grossa, Av. Carlos Cavalcanti, 4748, Campus Uvaranas, CEP 84030-900, Ponta Grossa, Paraná, Brasil, lama1@uepg.br
[2] Instituto de Desenvolvimento Rural do Paraná (IDR - PR), Rodovia Celso Garcia Cid, km 375, CEP 86047-902, Londrina, Paraná, Brasil, hevandro@idr.pr.gov.br
[3] Laboratório de Mecanização Agrícola, Universidade Estadual de Ponta Grossa, Av. Carlos Cavalcanti, 4748, Campus Uvaranas, CEP 84030-900, Ponta Grossa, Paraná, Brasil, natalimaidl@uepg.br
[4] Laboratório de Mecanização Agrícola, Universidade Estadual de Ponta Grossa, Av. Carlos Cavalcanti, 4748, Campus Uvaranas, CEP 84030-900, Ponta Grossa, Paraná, Brasil, jhonny_martini@hotmail.com
[5] Laboratório de Mecanização Agrícola, Universidade Estadual de Ponta Grossa, Av. Carlos Cavalcanti, 4748, Campus Uvaranas, CEP 84030-900, Ponta Grossa, Paraná, Brasil, jagomes@uepg.br

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 (DEMIRBAS, 2009; CÉSAR; BATALHA, 2010).

Recebido em 06/04/2019 e aprovado para publicação em 18/05/2020
DOI: http://dx.doi.org/10.17224/EnergAgric.2020v35n2p225-235

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 (ZIMMERMAN 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).

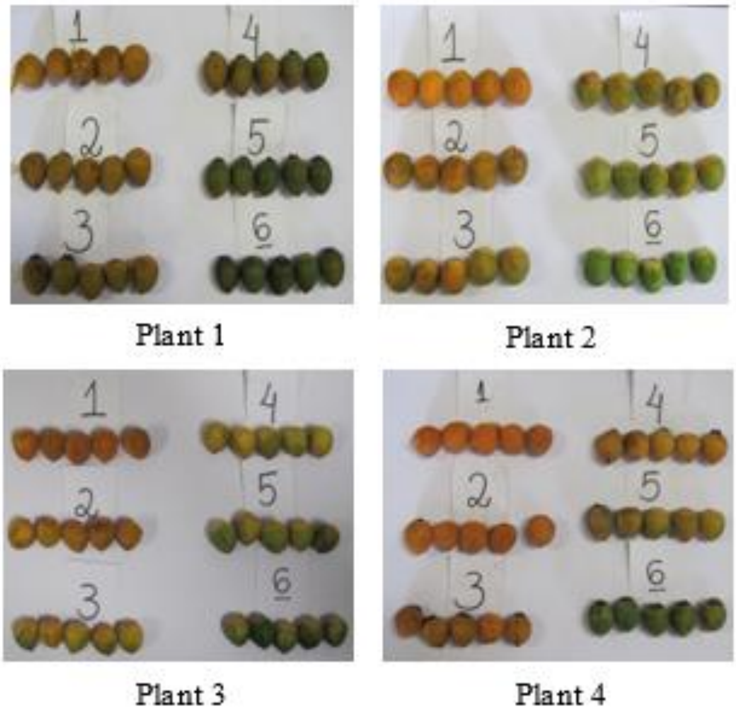
As the maturation of these plants was not uniform, the production of flowers and the maturation visual condition were observed weekly. The fruit clusters were harvested when presenting visually over 50% ripe fruits (yellow-orange).

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 Ipb32t (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 ºC 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 phmeter 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	kg plant^{-1} year^{-1}			
	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

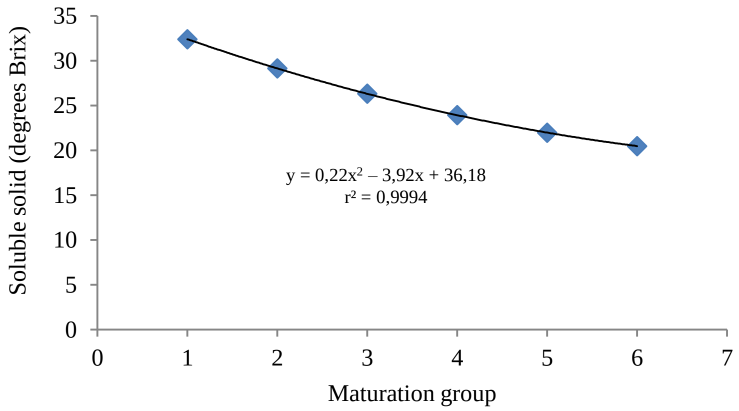


Table 4 shows the almond relative mass and the endocarp relative mass found in green fruit (between 57.2 $g\ kg^{-1}$ and 71.2 $g\ kg^{-1}$) and in ripe fruit (between 54.3 $g\ kg^{-1}$ and 69.8 $g\ kg^{-1}$) and in little coconuts originated from the green fruit (between 168.8g kg^{-1} and 195.5 $g\ kg^{-1}$) 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 (*Elaeais 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	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 açai 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
	------- g kg^{-1} -------			
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	Green	Ripe	Green	Ripe	Green	Ripe	Green
	-------------------------- g kg^{-1} --------------------------							
Oil obtained through cold physical extraction	459.0	447.8	466.5	438.6	437.2	427.1	459.7	474.9
Oil obtained through physical extraction and solvent	638.1	630.2	638.3	624.5	-	-	-	-

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}

	Plant 1	**Plant 2**	**Plant 3**	**Plant 4**	**Average yield**
Spacing (m)	--------------------------------- kg ha^{-1} --------------------------------				
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.

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