Storage stability of *Jatropha curcas* L. oil naturally rich in gamma-tocopherol

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29 **Abstract**

30 *Jatropha curcas* L. is an interesting tropical oil crop for biodiesel production.

31 However, seed conservation until oil extraction may be a problem under high

32 temperature and humidity. In this study, *Jatropha curcas* L. seeds grown in

33 Mozambique and presenting 160 mg/kg of gamma-tocopherol in their oil were

34 stored for 42 days, in dark, at 35°C and 75 % or 92 % Relative Humidity (RH).

35 Along storage, the oil was extracted and analysed in terms of fatty acid

36 composition, tocopherol content, acidity, initial and final oxidation products

37 (monitored by K232 and K270 values, respectively).

38 *Jatropha* seeds presented an initial water content of 8.4 % and an oil content of

39 45.7 % (dry basis). The oil was rich in oleic (41.2 %) and linoleic (38.8 %) acids.

40 Along 42 days of storage, the acidity increased from 0.8% to 7.4 % and 25.3 %
41 and K270 increased from 0.07 to 0.25 and 0.46 in oils from seeds stored at 75%
42 and 92% RH, respectively. Simultaneously, a decrease in gamma-tocopherol
43 content was observed, which was more pronounced at 92 % RH than at 75 %
44 RH (96 % decrease versus 57% decrease). Gamma-tocopherol showed to
45 protect the oil against oxidation principally during the second stage of oxidation.
46 During the storage at 35°C, the fatty acid composition of the oils from seeds
47 kept either at 75 % or 92 % of humidity, did not significantly vary throughout the
48 test.

49

50 **Keywords:** gamma-tocopherol; *Jatropha curcas* L.; oil; seeds, stability.

51 **1. Introduction**

52 Biofuels are an alternative to fossil fuels since they offer numerous advantages
53 for the environment namely reduced emissions of greenhouse gases and
54 particles, as well as for economy and development via energy security and
55 stimulation of rural development (Smeets et al., 2007; AETS Consortium, 2013).

56 As other developing countries, Mozambique has been exploring the potential for
57 renewable energy to fulfil its energy demands (FAO, 2008). A considerable
58 percentage of Mozambican GDP is spent on fuel and energy, which explains
59 the government's concern in investigating alternative energy sources, including
60 biofuels (World Bank, 2008; Schut et al., 2010). During the last decade, the
61 Mozambican government stimulated farmers to grow *Jatropha curcas* L. on
62 fallow and marginal soils with the aim that Mozambique could become an oil
63 exporting country (Schut et al., 2010). Ever since, investment in the agrofuel

64 sector increased and expanded, with several multinational companies
65 demonstrating interest in agro-industrial business centred on *Jatropha*.
66 *Jatropha curcas* L. is a drought-resistant shrub or tree belonging to the genus
67 *Euphorbiaceae*, which is cultivated in Central and South America, South-East
68 Asia, India and Africa (Giibitz et al., 1999). It grows in semi-arid marginal sites
69 and can be used for erosion control (Heller, 1996). The seed kernel of *Jatropha*
70 *curcas* L. contains 43-59 % oil which in the majority of genotypes cannot be
71 used for edible purposes without detoxification, making it attractive for biodiesel
72 production (Mtinch and Kiefer, 1986; Liberalino et al., 1988; Sharma et al.,
73 1997; Wink et al., 1997; Kumar and Sharma, 2008; Rodrigues et al., 2013). In
74 fact, some edible varieties of *J. curcas* have been cultivated for human food
75 from ancient times in the mountains of the Totonacapan (Mexico), but due to
76 the "biofuel program", these non-toxic genotypes are in serious risk of being lost
77 (King et al., 2009; Vera-Castillo et al., 2014).

78

79 The storage of large volumes of *Jatropha* seeds or oil under tropical climate
80 conditions without loss of quality is not an easy task. In order to maintain
81 stability of *Jatropha* oil, a good storage method needs to be developed. The
82 degradative reactions taking place in vegetable oils are mainly hydrolysis and
83 oxidation. Oil oxidation occurs in the presence of catalysts such as light, heat,
84 enzymes, metals and metalloproteins. Autoxidation is the most common
85 process promoting oxidative deterioration and is defined as the reaction of
86 atmospheric oxygen with lipids, which is faster at higher temperatures. It occurs
87 via a free radical chain reaction. Lipid hydroperoxides have been identified as

88 primary products of autoxidation (Shahidi and Zhong, 2005). In the presence of
89 metals or at high temperatures, these compounds are split in alkoxy radicals to
90 form aldehydes, ketones, acids, esters, alcohols, and short-chain hydrocarbons,
91 which originate unpleasant odours, characteristic of rancid fats (Choe and Min,
92 2006).

93 The presence of natural antioxidants in vegetable oils, such as tocopherols,
94 may delay the beginning or may slow the rate of lipid oxidation reaction, either
95 by quenching free radical reactions or by scavenging oxygen. Tocopherols are
96 primary or chain breaking antioxidants, which inhibit or slow down lipid oxidation
97 by interfering either with chain propagation or with initiation by donating
98 hydrogen atoms to lipid peroxy radicals. Tocopherols have two principal
99 oxidation mechanisms: (i) they may be oxidized in a one electron-transfer
100 reaction to a tocopheryl-radical or (ii) they may react with singlet oxygen to form
101 a hydroperoxide (Neely et al., 1988; Krieger-Liszkay and Trebst, 2006). These
102 reactions can be reversed, since both the tocopheryl-radical and the
103 hydroperoxide can be re-reduced to tocopherol by ascorbate. However, under
104 mild acidic conditions, the hydroperoxide is split to tocopherylquinone which is
105 an irreversible reaction (Krieger-Liszkay and Trebst, 2006). Tocopherols are
106 powerful antioxidants since they produce stable antioxidant radicals and have
107 the capacity to compete with the lipid substrate for oxygen (Van Aardt et al.,
108 2004).

109 Several experimental works have demonstrated that oil resistance towards
110 oxidation is a function of its tocopherol content (Emanuel and Lyaskovskaya,
111 1967; Reinton and Rogstad, 1981; Jung et al., 1990; Fuster et al., 1998; Kamal-
112 Eldin, 2006). In a previous study performed by our group (Rodrigues et al.,

2013), *Jatropha curcas* L. oil samples from 12 accessions and grown under the same edaphoclimatic conditions in Mozambique were analysed with respect to their oil content, fatty-acid composition and sterol and tocopherol composition. In all these samples, only gamma-tocopherol, which is a powerful natural antioxidant (Kamal-Eldin and Appelquist, 1996), was detected in contents ranging from 68.3 mg/kg to 181.8 mg/kg.

Storage stability tests were also performed with seeds from the accession present in most of the plantation area, with an average content of 89 mg of gamma-tocopherol per kg of oil. These studies were carried out under tropical climate conditions (28 °C and 35 °C, at relative humidities of 75 % and 92 %) for 45 days. The oxidation rate of the oil in the seeds increased with high relative humidity and temperature (Rodrigues et al., 2013). A higher resistance to oxidation would be expected in oils with higher gamma-tocopherol content.

The aim of this study was to investigate if *Jatropha* seed oil, from the accession containing the highest amounts of gamma-tocopherol, presents a higher oxidative resistance during storage, under tropical conditions, than the oil with lower content of gamma-tocopherol (89.1 mg/kg) used in the previous studies (Rodrigues *et al.*, 2013). Thus, along 42 day storage of seeds, the oil was extracted and analysed in terms of fatty acid composition, tocopherol composition, acidity and oxidation products.

2. Materials and methods

2.1 . Seed material

136 *Jatropha curcas* L. plants were planted in December 2010, in Búzi (19°56'S;
137 34°24'E), Sofala province, in central Mozambique, characterized by a "Tropical
138 rainy climate – Aw" (Köppen and Geiger, 1939). The seeds used in this study
139 were collected from plants included in an international breeding and cultivar
140 development program carried out by N.V. Quinvita (Ghent, Belgium). The seeds
141 were collected manually from healthy and ripened fruits that were harvested
142 from January to July 2013 (Rodrigues et al., 2013). After harvesting, the seeds
143 were manually dehulled, air dried until a seed water content below 10%, and
144 stored in perforated plastic bags, according to Quinvita's procedure guide.

145

146 **2.2. Seed storage stability tests**

147 Storage studies were carried out under the highest average temperature
148 observed at the plantation field in Búzi (Rodrigues et al., 2013). Thus, intact
149 seeds were stored at 35 °C, at 75 % or 92 % relative humidity (RH) values, in
150 the dark. These moisture values were achieved by contacting the seeds,
151 suspended in a plastic net, with the vapour phase of saturated salt solutions of
152 sodium chloride (NaCl; RH = 75.1 %, T = 35 °C) or potassium nitrate (KNO₃; RH
153 = 92.3 %, T = 35 °C) in closed glass vessels (Greenspan, 1977). One aliquot of
154 seeds (ca. 65 g) stored at each temperature and humidity was collected every 7
155 days, along 42 days and the oil was extracted and analysed (cf. Sections 2.3.
156 and 2.4.).

157

158 **2.3. Seed oil extraction**

159 The seed samples collected along the storage experiments were crushed with a
160 hammer. The oil contained in the fraction with particles lower than 2 mm was
161 extracted in a Soxtec apparatus for 4 hours, using petroleum ether p.a. (boiling
162 point 40-60 °C) as extraction solvent, as previously described (Rodrigues et al.,
163 2013).The extracted seed oil was stored in amber glass flasks, at -18 °C, for
164 subsequent analysis.

165

166 **2.4. Chemical analysis of seed oil**

167

168 **2.4.1. Acidity**

169 The acidity (% of free fatty acids, FFA) of seed oil was determined according to
170 ISO standard 660:2009. The FFA content was assayed by titration with a 0.1 N
171 sodium hydroxide aqueous solution using phenolphthalein as indicator. The
172 mass percentage was calculated on the basis of the molecular weight of oleic
173 acid (282.5). For each oil sample, the analysis was carried out at least in
174 triplicate.

175

176 **2.4.2. Oxidation compounds**

177 Oil thermoxidation was indirectly evaluated by UV absorbance at 232 nm
178 (K232) and at 270 nm (K270) of 1% (w/v) oil solution in isooctane.

179

180 **2.4.3 Fatty acid composition**

181 The analyses of fatty acid profile of Jatropha seed oil were performed according
182 to the official method of the European Community Regulation (1991), as fatty
183 acid methyl esters (FAME) using a Perkin Elmer Autosystem 9000 gas
184 chromatograph (GC), equipped with a FID and a fused silica capillary column
185 SPTM—2380 (60 m × 0.25 mm × 0.2 µm film thickness), as previously
186 described (Rodrigues et al., 2013). The results were expressed as area
187 percentage of each peak relative to the total area.

188

189 **2.4.4. Gamma-tocopherol oil content**

190 Tocopherol composition was performed according to ISO 9936:2006, using a
191 Perkin Elmer HPLC system equipped with a Perkin Elmer UV/VIS LC295
192 detector, a Perkin Elmer Series 200 Pump and a Peltier Column Oven Perkin
193 Elmer Series 200. The column used was a Li ChroCART® 250-4,
194 LiChrospher®, Si 60 (5 m), as previously described (Rodrigues et al., 2013).

195

196 **2.5. Statistical analysis**

197 For each data set, one-way analysis of variance (ANOVA) was performed using
198 the programme Statistica, version 6, Statsoft, Tulsa, OK, USA. Post-hoc
199 comparisons were carried out using Fisher LSD test at a p value of 0.05.

200

201 **3. Results and discussion**

202

203 **3.1. Oil acidity**

204 Jatropha seeds used in this study presented an initial water content of 8.4 %
205 and an oil content of 45.7 % (dry basis). The oil was rich in oleic (41.2 %) and
206 linoleic (38.8 %) acids (Tables 1 and 2), contained 160 mg/kg of gamma-
207 tocopherol, and had an acidity of 0.8 %, a K232 of 1.1 and a K270 of 0.07.

208 Along the experiments, the quality of Jatropha oils was evaluated in terms of
209 their acidity and content of oxidation products. When the oil is to be used for
210 biodiesel production, it is important that it does not have a high content of
211 oxidation products and free fatty acids, which inhibit the chemical alkaline
212 catalysts.

213 Figure 1 shows the evolution of acidity in oils extracted from seeds stored at 35
214 °C and 75 % or 92 % RH, along 42 days. A linear increase of acidity of the oils
215 (by 0.17 % FFA/day) extracted from seeds stored at 75 % RH was observed
216 along the storage. For the oils from seeds stored at 92 % RH, the acidity also
217 increased linearly during the first 28 days of storage, at a rate of 0.23 % FFA/
218 day and from 28 to 42 days of storage, about a six-fold increase in the
219 hydrolysis rate (1.32 % FFA/day) was observed. This may be due to the
220 presence of higher amounts of water available for the hydrolysis reaction at 92
221 % RH. In presence of high humidity, after 28 days of storage, growth of storage
222 fungi were observed that were microscopically identified as belonging to
223 *Penicillium* sp. and *Aspergillus* sp. (Rodrigues et al., 2013). These fungi
224 produce enzymes, such as lipases (EC 3.1.1.3., triacylglycerol acylhydrolases)
225 that catalyse oil hydrolysis.

226 At the end of the experiment, the oil from seeds kept under 92 % RH reached
227 about 25 % FFA while the oil from seeds stored at 75 % humidity presented a
228 much lower acidity of about 8 %. However, in our previous work performed with
229 *J. curcas* seeds containing lower amounts of gamma-tocopherol, lower final
230 acidity values were found: 17 % FFA and 1.2 % after 45 days of seed storage at
231 35 °C, at 92 % or 75 % RH, respectively (Rodrigues et al., 2013). The higher
232 acidity in the oil with higher gamma-tocopherol content may be explained by
233 higher levels of lipases in seeds, either from internal or external origin.

234 (Fig. 1)

235 An increase in FFA content of *Jatropha* seed oil during storage is also reported
236 by other authors. Tadakittisarn et al. (2011) observed an increase in FFA in oil
237 from three *Jatropha* accessions from different regions of Thailand, along seed
238 storage. A linear increase in acidity from 7.8 to 32.1 % was also observed in the
239 oil extracted from *Jatropha* seeds stored for 3 months, at 35 °C and under a RH
240 varying from 71 to 75% (Akowuah et al., 2012). An increase of FFA content of
241 *Jatropha* oil, along 72 days storage of seeds, was also reported (Gupta and
242 Rao, 2008).

243 In a study by Worang et al. (2008), FFA content increased with the storage
244 duration of *Jatropha* seeds packed in plastic material. The increase in oil acidity
245 was also reported by Sushma (2014) when *Jatropha* seeds were collected and
246 stored at room temperature (open air condition) for 15 months.

247

248 **3.2. Oxidation products and gamma-tocopherol content in oil**

249 The evolution of oil oxidation in seeds along the 42 days experiments at 35 °C,
250 under different relative humidity values, is presented in Figure 2.

251 (Fig. 2)

252 A linear increase in K232, related with the presence of initial products of
253 oxidation, i.e. conjugated hydroperoxides, was observed along the experiment,
254 for the oil in seeds stored at 75 % RH (increase of 0.029 absorbance units/day).
255 The K232 value increased faster in the oil extracted from seeds kept at 92 % of
256 humidity than in the oil from seeds stored at lower RH (75%), during the first two
257 weeks of storage (increase of 0.059 absorbance units/day). After 14 days
258 storage and until the end of experiments, a slower increase in K232 was
259 observed for the oil from seeds at 92 % RH. This is probably due to the
260 decomposition of the hydroperoxides in smaller molecules (final oxidation
261 products). At the end of the experiments, K232 values were similar for both oils.

262 The K270 values, related with the presence of final oxidation products (i.e. FFA,
263 aldehydes and ketones), increased from 0.07 to 0.22 in oils from seeds stored
264 at both RH, during the first 21 days of storage. For the oil in seeds stored at 75
265 % R.H., K270 remained approximately constant thereafter. However, in seeds
266 stored at 92 % RH, a linear increase in K270 was observed subsequently,
267 reaching an absorbance value of around 0.46 after 42 days of storage.

268 Similar K232 and K270 values were obtained for the oil from seeds stored at 75
269 % humidity when compared with those previously obtained for *Jatropha* oil with
270 lower amounts of gamma-tocopherol (89 mg/kg) (Rodrigues *et al.*, 2013).

271 With respect to the oils from seeds stored at 92 % RH, K232 and K270 values
272 of the oil with higher content of gamma-tocopherol were 1.5 or 2.8 times lower

273 than the values observed for the oil extracted from seeds of the previous study,
274 respectively (Rodrigues *et al.*, 2013). It seems that gamma-tocopherol protects
275 the oil against oxidation principally during the second stage of oxidation where
276 hydroperoxides are broken down into secondary products. Also, this protective
277 effect seems to be particularly important if the seeds are stored under high
278 humidity environments.

279 The evolution of the average gamma-tocopherol content in the oil extracted
280 from the seeds along the storage experiments is shown in Figure 3. A
281 significant decrease in gamma-tocopherol content ($p < 0.05$) was observed
282 during the course of the experiment for both relative humidities. This decrease
283 may explain the increase in oxidation products (related with K232 and K270
284 values) in the oils, observed along *Jatropha* seed storage. However, the
285 decrease in gamma-tocopherol content was more pronounced at 92 % RH than
286 at 75 % RH (96 % decrease versus 57% decrease on gamma-tocopherol
287 content, after 42 days of storage). Probably, this may be ascribed to the
288 presence of higher amounts of water which will promote the growth of fungi that
289 will produce oxidative enzymes responsible for lipid oxidation.

290 (Fig. 3)

291 The antioxidant activity of tocopherols is not only due to their ability to donate
292 their phenolic hydrogens to lipid free-radicals, but can also be explained by their
293 participation in certain side-reactions (Kulås *et al.*, 2002).

294 The following order for relative antioxidant activity of the tocopherols *in vivo* is
295 generally accepted: $\alpha > \beta > \gamma > \sigma$. However, when relative
296 antioxidant activities were compared *in vitro*, in fats, oils, and lipoproteins, a

297 reversed order was obtained ($\sigma > \gamma \sim \beta > \alpha$) (Kamal-Eldin and
298 Appelqvist, 1996). The reasons behind this reversed order are not yet clearly
299 understood but the "absolute" and "relative" *in vitro* activities of the tocopherols
300 depend on their absolute chemical reactivities toward hydroperoxy and other
301 free radicals, and also on many other possible side reactions. These side
302 reactions may be highly propagative and their extent greatly depends on
303 tocopherol concentrations, temperature and light, type of substrate and solvent,
304 and on other chemical species acting as prooxidants and synergists in the
305 system (Kamal-Eldin and Appelqvist, 1996).

306 In our study, the effect of gamma-tocopherol occurs inside the seed, along
307 storage, and not in the extracted oil. Thus, a similar behaviour to that observed
308 *in vivo* systems is to be expected. The effect of tocopherols on the oxidative
309 stability of vegetable oils during storage has been extensively evaluated.
310 However, according to our knowledge, few works have reported the effect of
311 tocopherols on the oxidative stability of *Jatropha* oil during seed storage
312 (Rodrigues et al., 2013).

313 Diwani et al. (2009) observed that the addition of natural antioxidants obtained
314 from Egyptian *Jatropha* crude root extracts, on *Jatropha* oil and its biodiesel
315 promoted higher oxidation stability than that observed with the addition of alpha-
316 tocopherol.

317 Antioxidants may have different effects on the formation and decomposition of
318 hydroperoxides. In a study on fish oil stability along storage, the tocopherol type
319 and concentration showed to affect not only the overall formation of volatile
320 secondary oxidation products, but also the composition of this group of

oxidation products (Kulås et al., 2002). The effects of individual tocopherols and tocopherol mixtures on the oxidative stability of corn oil were evaluated by Huang et al. (1995). In this study, gamma-tocopherol showed to promote the formation of hydroperoxides but, when in very high concentrations (5g/kg oil), it strongly inhibited hydroperoxide decomposition. Conversely, in the presence of tocopherols, the rate of hydroperoxides breakdown and induction of further oxidation was markedly inhibited in rapeseed oil stored at 40 °C in the dark. A concentration as low as 11 mg of gamma-tocopherol per kg of rapeseed oil was enough to markedly inhibit hydroperoxide and secondary product formation (Lampi et al., 1997). The antioxidant properties of alpha- and gamma-tocopherols in the oxidation of rapeseed oil at 40 °C, in the dark, for 16 days was also evaluated (Lampi et al., 1999). In vitro, at concentrations higher than 100 mg/kg, gamma-tocopherol is better antioxidant than alpha-tocopherol.

334

3.3. Fatty acid composition of oils

The fatty acid composition of Jatropha oil extracted from the seeds stored at 35 °C under 75 % or 92 % humidity, was evaluated along the 42 days storage experiments (Tables 1 and 2). As previously reported (Rodrigues et al., 2013), this is a highly unsaturated oil, rich in oleic (c.a. 41 %) and linoleic (c.a. 38.8 %) acids and it also contains 11.6 % of palmitic acid and 6.6 % of stearic acid. During the storage at 35°C, the fatty acid composition of the oil from seeds kept either at 75 % or 92 % of humidity, did not significantly vary throughout the test (Tables 1 and 2). Fatty acid composition and the proportions of different fatty acids of oilseeds during storage are dependent on the degradation rate of

345 different fatty acids (Khan and Shahidi, 2000). In a study by Balešević-Tubić et
346 al. (2007), sunflower seeds were stored under uncontrolled conditions for 12
347 months. During that period of time, the autooxidation of lipids occurred and led
348 to modifications in fatty acid composition of the seeds. Although oleic acid
349 content did not significantly vary, linoleic acid content was drastically reduced
350 from 23%, in fresh sunflower seeds, to 5.49 % at the end of the experiment.
351 (Tables 1 and 2)

352

353 **4. Conclusions**

354 The storage of *Jatropha curcas* L. seeds under tropical climate conditions of
355 high temperature and humidity is difficult without affecting oil quality. However,
356 the high content of gamma-tocopherol (160 mg/kg of oil) in *Jatropha* oil showed
357 to promote a high resistance to oxidation during seed storage.

358 Along storage, a decrease in gamma-tocopherol content in the oil was
359 observed, which may explain the increase in oxidation products. High humidity
360 conditions promoted the growth of storage fungi such as *Penicillium* sp. and
361 *Aspergillus* sp., which were also responsible for oil degradation, via hydrolysis
362 and enzymatic oxidation.

363 If *J. curcas* oil extraction from the seeds is not possible immediately after
364 harvest, *J. curcas* genotypes rich in gamma-tocopherol must be chosen, in
365 order to avoid a high extent of oil oxidation.

366 The control of storage conditions of the seeds (temperature and humidity) is
367 extremely important in order to preserve the quality and the yield of Jatropha oil,
368 with economic benefits.

369

370

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510 Figure 1. Variation of free fatty acid content (%) of *Jatropha curcas* L. oil from seeds
511 stored at 35 °C under different relative humidity (RH = 92% and RH = 75%) during 42
512 days.

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515 Figure 3. Average gamma-tocopherol content of the oil extracted from *Jatropha* seeds stored
516 at 35 °C and 75% RH along 42 days. Different letters indicate significant differences based on
517 Fisher LSD test ($p < 0.05$).

Jatropha seeds: 45.7% oil
rich in gamma-tocopherol
(160 mg/kg)

Storage under controlled humidity
with saturated salt solutions:
Relative Humidity = 75% or 92 %

Initial (K232) & Final (K270)
Oxidation products

Table 1

Table 1. Variation in fatty acid composition (%) of the oil extracted from the seeds of *Jatropha* stored at 35 °C and 75% RH over 42 days. C14: 0 (myristic acid), C16: 0 (palmitic acid), C16: 1 (palmitoleic acid), C17: 0 (margaric acid), C17: 1 (heptadecanoic acid), C18: 0 (stearic acid), C18: 1 (oleic acid), C18: 2 (linoleic acid), C20: 0 (arachidic acid), C18: 3 (linolenic acid), C20: 1 (gadoleic acid), C22: 0 (behenic) and C24: 0 (lignoceric acid). Standard deviations lower than 0.01 are not presented.

[illegible]

Table 2

Table 2. Variation in fatty acid composition (%) of the oil extracted from the seeds of *Jatropha* stored at 35 °C and 92% RH over 42 days. C14: 0 (myristic acid), C16: 0 (palmitic acid), C16: 1 (palmitoleic acid), C17: 0 (margaric acid), C17: 1 (heptadecanoic acid), C18: 0 (stearic acid), C18: 1 (oleic acid), C18: 2 (linoleic acid), C20: 0 (arachidic acid), C18: 3 (linolenic acid), C20: 1 (gadoleic acid), C22: 0 (behenic) and C24: 0 (lignoceric acid). Standard deviations lower than 0.01 are not presented.

[illegible]

Figure 1

Figure 1. Variation of free fatty acid content (%) of *Jatropha curcas* L. oil from seeds stored at 35 °C under different relative humidity (RH = 92% and RH = 75%) during 42 days.

Figure 2-corrected

Figure 3

Figure 3. Average gamma-tocopherol content of the oil extracted from Jatropha seeds stored at 35 °C and 75% RH along 42 days. Different letters indicate significant differences based on Fisher LSD test ($p < 0.05$).

Figure 2. Absorbances at 232 nm (K232) and at 270 nm (K270) in the oil extracted from *Jatropha curcas* L. seeds stored for 42 days at 35 °C under different relative humidity values (RH = 92 %, RH = 75 %).