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1 **Processing of undervalued dates biomass from common cultivar (*Phoenix dactylifera L.*) for**  
2 **sequential production of soluble sugars syrup and biogas**

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29 **Abstract**

30 Date production is usually associated to a considerable loss either in common cultivars or in fruit  
31 picking and storage stages. This discarded biomass is not very well valued up to now especially in  
32 bioenergy production. The Tunisian second-grade cultivar ‘Kenta’ was biochemically  
33 characterized in the present study. ‘Kenta’ discarded flesh is rich in soluble sugars ( $79.5\% \text{VS} \pm$   
34  $0.8\% \text{VS}$ ) and fibers ( $7.4\% \pm 0.5\% \text{VS}$ ). The crude fibers were recovered after soluble sugars  
35 extraction. The biochemical composition analysis showed that this by-product contains mainly  
36 carbohydrates ( $33.2\% \text{VS} \pm 0.7\% \text{VS}$ ) and proteins ( $8.8\% \text{VS} \pm 0.1\% \text{VS}$ ) making it a suitable  
37 feedstock for biogas production. A biorefinery concept was therefore developed based on soluble  
38 sugars (date-syrup) aqueous extraction and biogas production via anaerobic digestion of the  
39 residual fibers. The proposed concept showed interesting results since it permitted the co-  
40 production of date syrup, as high-added value product, with  $0.6 \text{ g sugars/gVS}$  and biogas with  
41 maximum methane yield of  $225 \text{ mL CH}_4/\text{gVS}$  fibers. This study presents a proof of a sustainable  
42 processing approach allowing an almost bioconversion of undervalued secondary date variety and  
43 integrates the concept of circular bio-economy.

44 **Keywords:** Common date, biorefinery, crude fibers extract, biogas, date-syrup

45

46 **Statements and Declarations**

47 **Conflict of interest:** The authors declare no competing interests.

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52 **1. Introduction**

53

54 Dates are among the oldest fruits in the Middle East and the North Africa. In fact, date palms

55 (*Phoenix dactylifera L.*) have been cultivated since old-time and represent an important agriculture

56 crop in the arid and semi-arid regions (Lajnef et al., 2021, Awad et al., 2021). The world production

57 of dates has increased from 7 428 939 tons in 2014 to 9 075 446 tons in 2019 (FAOSTAT, 2019).

58 About 2000 date cultivars are known however less of them are valued for their performance and

59 their fruit quality. In Tunisia, the average annual production of dates has also improved

60 significantly from 199 000 tons in 2014 to 288 700 tons in 2019 (FAOSTAT, 2019).

61 Unfortunately, this progress in production is associated with a considerable loss either in secondary

62 (common) variety dates (about 30% of Tunisian dates) or in fruit picking and storage stages.

63 Indeed, approximately 30 000 tons and 2 000 000 tons of dates are often discarded in Tunisia and

64 worldwide, respectively, due to their unsuitable texture and deteriorated organoleptic qualities

65 (Mrabet et al., 2015). The few studies reported on the valorization of Tunisia low-quality dates,

66 permit to classify these fruits in two classes: dates from the coastal oasis (5 000 tons) which are

67 rich in reducing sugars and the continental oasis cv. Deglet Nour (30 000 tons), which are rich in

68 sucrose (Chaira et al., 2009). ‘Deglet Nour’ the most produced and appreciated date cultivar was

69 also the most investigated one even in the bioenergy production such as biogas and biohydrogen

70 production (Ben Yahmed et al., 2020).

71 Although Tunisian secondary varieties such as Garen Ghzel, Alig and Kenta cultivars have similar

72 fiber content and composition, they are less appreciated and not very used for human consumption.

73 They are used for limited purposes such as animal feed and fertilizers (Smaali et al., 2012). This

74 selective orientation results in a progressive disappearance of these common cultivars and

75 therefore a date genetic variability reduction. Annually, large amounts of secondary date waste are

76 produced and discarded in Tunisia without any treatment or proper valorization methods which

77 can be considered as a real economic loss. Previous studies focused mainly on the chemical  
78 characterization (Chaira et al., 2009) and technological applications of these dates by-products  
79 especially dietary fibers DF (Mrabet et al., 2012, Mrabet et al., 2015, Elleuch et al., 2008, Smaali  
80 et al., 2011, Kareche et al., 2020) however its energetic valorization has received a little attention  
81 of the scientific community up to now (Lattieff, 2016, Jaafar, 2010, Souli et al., 2018).

82 Bioconversion is a technology used to transform biomass into bioenergy and high added-value  
83 products (Smaali et al., 2009, Djaafri et al., 2020, Ben Yahmed et al., 2018). This technology offers  
84 several advantages: it is simple, mature, environment friendly, cheap, renewable, helping to reduce  
85 the environmental impact of waste disposal (such as agricultural residues, organic animal,  
86 vegetable and industrial waste...) and represent a good alternative to fossil fuels (Djaafri et al.,  
87 2020).

88 Different bioconversion techniques are used to produce energy, among them the anaerobic  
89 digestion. In fact, anaerobic digestion of organic waste has gained increased attention by means of  
90 producing energy-rich biogas, mitigating greenhouse gas emissions, destructing pathogenic  
91 organisms and reducing problems associated with the disposal of solid organic waste (Souli et al.,  
92 2018). The anaerobic digestion occurs in four steps: hydrolysis, acidogenesis, acetogenesis and  
93 methanogenesis. Depending of the substrate composition and its structure, hydrolysis or  
94 methanogenesis can be considered as limiting steps (Brémond et al., 2018).

95 Thus, the objective of this study is to demonstrate the feasibility of valorizing 'Kenta', a Tunisian  
96 common dates cultivar, by the implementation of an integrated biorefinery process aimed at the  
97 co-production of date syrup and biogas. The crude fibers of 'Kenta' variety were recovered after  
98 soluble sugars extraction. Chemical composition of 'Kenta' discarded biomass as well as of the  
99 date syrup and the crude fibers extract (CFE) were analyzed. Biochemical methane potential

100 (BMP) tests were assessed to evaluate the energetic potential of this undervalued by-product. A  
101 basic economic study was also performed.

102

## 103 **2. Materials and methods**

### 104 ***2.1. Samples***

105 ‘Kenta’ variety collected at the ‘‘Tamr stage’’ (full ripeness) was procured from the oasis of Gabes  
106 region (south of Tunisia) during the harvest season (September-October 2019). After removing the  
107 seeds, the date fleshes were rinsed with water, dried for 24 h at 40 °C, milled and preserved at 20  
108 °C prior to fiber extraction and bioconversion.

### 109 ***2.2. Chemical composition***

110 Date fleshes and date fibers were analyzed for TS (Total Solids) and VS (Volatile Solids) in  
111 accordance with APHA standard methods (Apha, 1998). The carbohydrates and uronic acids in  
112 solid phase were measured in duplicate using the strong acid hydrolysis protocol adapted from  
113 Effland (1977) (Effland, 1977) as described by Ben Yahmed et al (2020) (Ben Yahmed et al.,  
114 2020). Total fibers were determined according to the AOAC enzymatic-gravimetric method of  
115 Prosky et al. (Prosky et al., 1988) .

116 The cellulose and hemicelluloses content in Kenta fibers was determined on the basis of the  
117 monomeric sugar content as described by Monlau et al. following theses equations:

$$118 \text{Cellulose}(\% \text{TS}) = \text{Glucose}(\% \text{TS}) \cdot 1.11 \quad (1)$$

$$119 \text{Hemicelluloses}(\% \text{TS}) = [\text{Xylose}(\% \text{TS}) + \text{Arabinose}(\% \text{TS})] \cdot 1.13; \quad (2)$$

120 with 1.11 the conversion factor for glucose-based polymers (glucose) to monomers and 1.13 the  
121 conversion factor for xylose based polymers (arabinose and xylose) to monomers (Monlau et al.,  
122 2012).

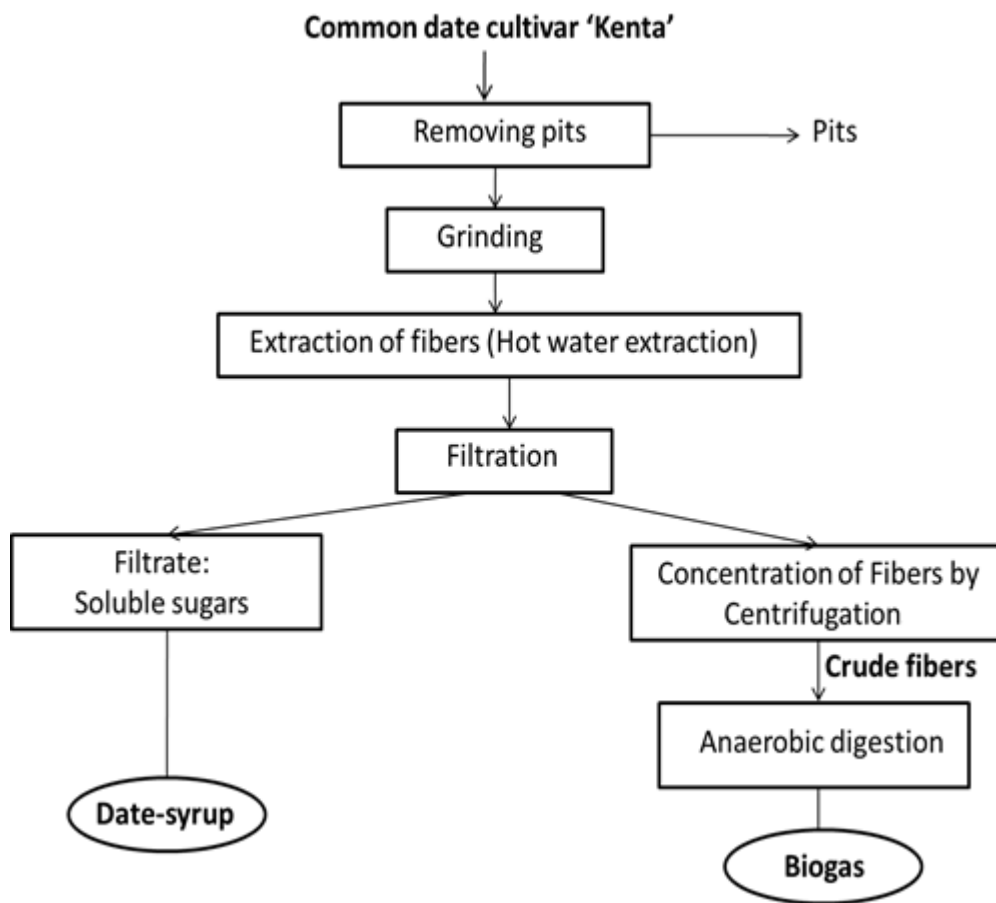
123 Kjeldahl nitrogen (TKN) was titrated using a Buchi 370-K after mineralization of the samples.

124 Proteins were determined by multiplying TKN by 6.25. The content of lipid was determined using  
125 the protocol described in the standard NF V 03-713 (AFNOR, 1984). The results of different

126 components of dates and dates fibers were expressed in percent of total solid and were presented  
127 as mean  $\pm$  SD (standard deviation of triplicates).

### 128 **2.3. Biorefinery concept based on the co-production of soluble sugars and biogas**

129 Figure 1 illustrates the overall methodology followed in this work. It consisted on a cascade  
130 bioconversion intended at the co-production of soluble sugars ‘dates-syrup’ and biogas via hot  
131 water extraction and anaerobic digestion of the residual fibers, respectively, from ‘Kenta’ common  
132 date cultivar (Fig.1).



133  
134 **Fig.1** Biorefinery concept aimed at the co-production of date syrup and biogas from common date  
135 cultivar

136  
137 The crude fiber extraction was carried out with hot water at 100 °C for 10 min. After solubilization  
138 of the sugars (sucrose, glucose and fructose), the fibers were recovered by filtration on gauze filter

139 and centrifugation (6500g, 10 min). Five successive rinsings with water at 40 °C and of five  
140 centrifugations was released to concentrate the fibers until the residue was free of sugars. The  
141 residues obtained were dried to give the fibers concentrates then stored for biogas production.

#### 142 ***2.4 Soluble sugars characterization***

143 Sucrose, fructose and glucose contents were analyzed using high-performance liquid  
144 chromatography HPLC equipped with Eurospher NH<sub>2</sub> column (100 Å pore size, 7 mm particle  
145 size, 250 mm 4.6 mm) and RI Detector K-2301 (Knauer, Germany). The samples were filtered  
146 over a 0.45 mm membrane filter and degassed for 15 min in an ultrasonic bath Cleaner Model SM  
147 25E-MT (Branson Ultrasonics Corporation, Danbury, CT). Acetonitrile and ultrapure water  
148 (80/20, v/v) were used as mobile phase with a flow rate of 1.0 mL/min. The integrator was  
149 calibrated with external standards consisting of glucose (2%), fructose (2%) and sucrose (1%)  
150 solutions.

#### 151 ***2.5 Biochemical methane potential (BMP test)***

152 To evaluate the methane production, batch BMP tests were performed in mesophilic conditions  
153 (35°C), as described by Jard et al. (Jard et al., 2013). Each bottle contained 4 gVS of inoculum  
154 (from an up flow anaerobic sludge blanket reactor of a sugar industry) and 2 gVS of ground dry  
155 dates fibers. They were filled to 400 mL with a bicarbonate buffer supplied with nutrients (Table  
156 S1 in Supplementary material). Two controls were used: sample containing ethanol to check the  
157 inoculum activity and a blank to measure endogenous methane production which was subtracted  
158 from the methane production. Bottles were rapidly sealed using butyl-rubber stoppers and held  
159 with clamped aluminum collars. Nitrogen gas was flushed into airspace in order maintain  
160 anaerobic conditions. Once prepared, bottles were shaken and incubated at 35 °C with continuous  
161 agitation.



162 During incubation, biogas production was regularly monitored by pressure measurement of the  
 163 headspace using a manometer (Keller, LEO 2). The concentration of CH<sub>4</sub> in biogas was determined  
 164 by gas chromatography (PerkinElmer, Clarus 480). BMP was carried out until biogas production  
 165 stopped. Methane yields were calculated by dividing the corrected methane volume (standard  
 166 pressure and temperature) by the weight of sample VS added to each bottle (Ben Yahmed et al.,  
 167 2020). The volume of methane produced  $\Delta V_{CH_4}$  (mL) between the dates j and j-1 was calculated  
 168 following Eq (1):

$$169 \quad \Delta V_{CH_4} = \left( \left[ y(j)P1(j) \frac{V}{RT} \right] - \left[ y(j-1)P2(j-1) \frac{V}{RT} \right] \right) \frac{RT^\circ}{P^\circ} \quad (1)$$

170 Where y(j-1) et y(j) are CH<sub>4</sub> contents in biogas at dates j-1 and j, respectively

171 P1(j) (Pa) is the bottle head space pressure before sampling at the date j,

172 P2(j-1) (Pa) is the bottle head space pressure after gas release at the date j-1,

173 V (mL) is the bottle head space volume

174 R is the ideal gas constant (8.314 J.(mol.K)<sup>-1</sup>),

175 T is the bottle temperature (K),

176 T° et P° are normal condition of temperature and pressure (273,15 K, 1013 hPa).

177 For the determination of the kinetic parameters of the methane production, a first-order exponential  
 178 model was used according this equation:

$$179 \quad M = M_{\max} \cdot (1 - \exp (-K.t))$$

180 where M (mL CH<sub>4</sub>/g VS) is the cumulative specific methane production, M<sub>max</sub> (mL CH<sub>4</sub>/g VS) is

181 the ultimate methane production, K (days<sup>-1</sup>) is the specific rate constant or apparent kinetic

182 constant and t (days) is the time. The adjustment by non-linear regression of the experimental data

183 (M, t) using the Sigmaplot software (version 14.0) permitted the calculation of the parameters K

184 and M<sub>max</sub>.

185

186 **3. Results and discussion**

187 **3.1 Chemical composition of dates fleshes**

188 The composition of the biomass feedstocks plays an important role in the energetic bioconversion.  
 189 Thus, the approximate chemical composition of dates fleshes (Table 1) as well as of the extracted  
 190 crude fibers (Table 2) of ‘Kenta’ cultivar was studied.

191 **Table 1.** Chemical composition of date fleshes of different Tunisian cultivars

Composition	Kenta	Deglet Nour	Garn ghzal	Alig	Smiti
TS (% wet weight)	93.1 ± 0.2	76.7 ± 0.1	ND	ND	ND
VS (% TS)	90.2 ± 0.2	98.6 ± 0.1	ND	ND	ND
Total carbohydrates (% TS) <sup>a</sup>	79.5 ± 0.8	79.8 ± 0.8	61.61 ± 4.92	62.7	35,57
Glucose (% TS)	27.4 ± 0.1	15.2 ± 0.1	ND	ND	17,74
Fructose (% TS)	28.1 ± 0.2	15.8 ± 0.1	ND	ND	17,83
Sucrose (% TS)	24 ± 0.4	48.8 ± 0.5	ND	ND	-
Total fibers (% TS)	7.4 ± 0.5	12.3 ± 0.4	ND	ND	ND
Proteins (% TS) <sup>b</sup>	2.8 ± 0.1	2.6 ± 0.1	1.70 ± 0.10	3.71	ND
Lipids (% TS)	0.41 ± 0.02	0.24 ± 0.02	0.52 ± 0.01	1.79	ND
Reference	Present study	(Ben Yahmed et al., 2020)	(Mrabet et al., 2015)	(Souli et al., 2018)	(Chaira et al., 2009)

192 ND: not determined.

193 <sup>a</sup> Total carbohydrate content was quantified as the sum of each individual sugar (glucose, fructose and  
 194 sucrose)

195 <sup>b</sup> The protein content was calculated by using a nitrogen conversion factor of 6.25

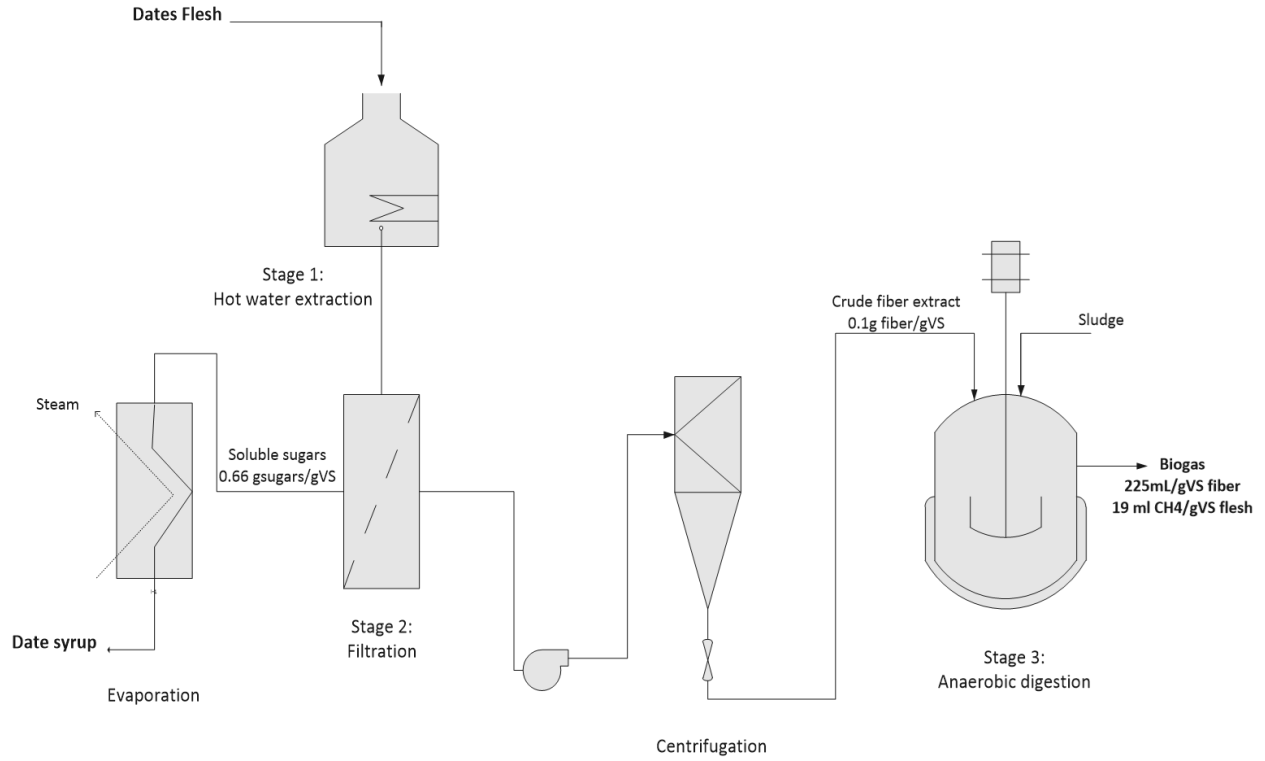
196  
 197 Table 1 shows that ‘Kenta’ flesh is rich in soluble sugars (79.5%) mainly fructose, glucose and  
 198 sucrose, fibers (7.4%) and small quantities of proteins and lipids based on total solids. These results  
 199 are in agreement with those reported by Chaira et al (2011) which demonstrated that ‘Kenta’  
 200 variety belonging to the coastal oasis cultivars is rich in reducing sugars unlike ‘Deglet Nour’  
 201 (continental oasis cultivar) which is rich in sucrose (Chaira et al., 2011, Ben Yahmed et al., 2020).  
 202 Indeed, as shown in table 1, the biochemical composition of dates varies significantly among  
 203 cultivars and it depends on the culture conditions such as the growth zone and the stage of maturity  
 204 (Chaira et al., 2009, Sahari et al., 2007). This variation in biochemical components resulted in a

205 significantly different biomethane production. In fact, Souli et al. study demonstrate that for date  
206 pulp, the carbohydrate is the most relevant parameter to evaluate the methane production kinetics  
207 of the wastes of dates (either methane potential or methane yield rate). Moreover, the results of  
208 this study showed a correlation between the lipid content and the methane production for both date  
209 pulp and seeds. An opposite observation was achieved reporting that lipids decreased the methane  
210 production (Souli et al., 2020).

### 211 **3.2 Development of an integrated biorefinery concept based on soluble sugars extraction and** 212 **biogas production**

213 An integrated processing approach based on the extraction of soluble sugars and the use of issued  
214 crude fibers for biogas production was developed. This process consisted of three main stages  
215 namely the hot water extraction of sugars, the filtration of the juice and the anaerobic digestion of  
216 the residual crude fiber with two intermediate units such as the centrifugation for the concentration  
217 of the crude fiber extract and the evaporation for the date syrup preparation. The detailed flow  
218 diagram of this process with main inputs and outputs is illustrated in Fig.2. The developed concept  
219 allows to recover 0.66 g sugars/gVS flesh and 0.1 g fibers/gVS flesh.

220



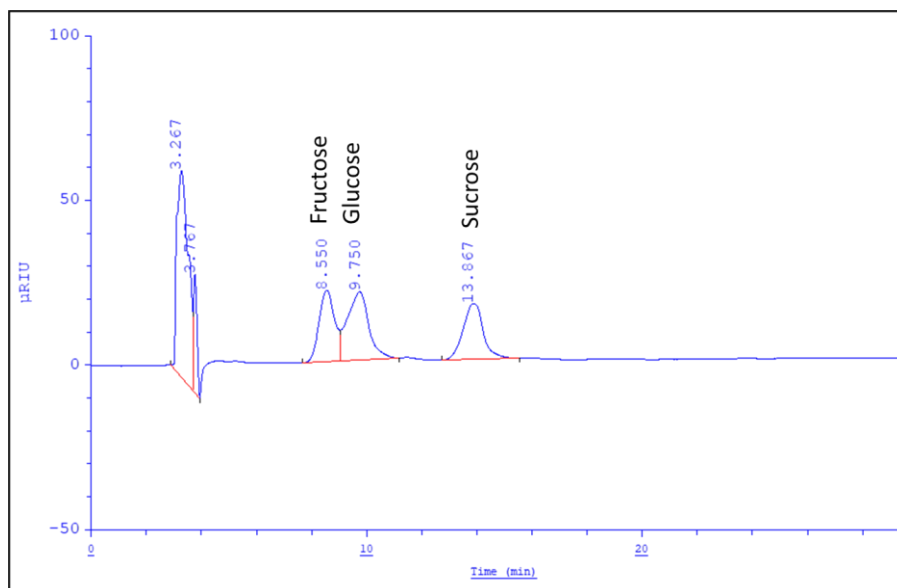
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223 **Fig.2** Diagram and main inputs/outputs of the units in the proposed biorefinery concept aimed at  
 224 the co-production of date syrup and biogas from ‘Kenta’ dates flesh.

225

226 The obtained date syrup was characterized. Sugar composition was assessed by HPLC  
 227 chromatography, which the chromatogram presented in Fig. 3 shows a typical composition of  
 228 fructose, glucose and sucrose (Fig.3).



229

230 **Fig.3** High performance liquid chromatography analysis (HPLC) of the ‘Kenta’ cultivar syrup

231

232 Their concentrations after calibration are given in table 2. This aqueous extract is rich in glucose  
 233 ( $22.6 \pm 0.1$  %TS) and fructose ( $23.2 \pm 0.2\%$  TS) which is characteristic of coastal oasis dates  
 234 cultivars. This sugar juice could be destined to the agro-alimentary industry such as bakery  
 235 products, ice cream and in confectionery (Lajnef et al., 2021, Abbès et al., 2015). Besides, this  
 236 high-added value product has recently an increased interest thanks to their potential health benefits  
 237 and great biological activities (Baliga et al., 2011).

238 Furthermore, the date crude fibers extract (CFE) was also characterized. As shown by Table 2 the  
 239 crude fiber fraction is rich in carbohydrates ( $33.2 \pm 0.7\%$  TS with  $10.2 \pm 0.5$  %TS of cellulose and  
 240  $19.4 \pm 0.6$  %TS of hemicellulose) and proteins ( $8.8 \pm 0.1\%$  TS) making it a suitable feedstock for  
 241 the biogas production. This production was carried out without any pretreatment step in order to  
 242 make the results of this study more applicable to the biogas plant operation and facilitate therefore  
 243 the scale up of the proposed concept.

244

245

246 **Table 2.** Chemical composition of ‘Kenta’ syrup and crude fibers

Composition	‘Kenta’ syrup	‘Kenta’ Fibers
TS (% wet weight)	93.1 ± 0.2	90 ± 0.2
VS (%TS)	90.2 ± 0.2	70 ± 0.1
Total carbohydrates (%TS) <sup>a</sup>	64 ± 0.8	33.2 ± 0.7
Glucose (%TS)	22.6 ± 0.1	11.2 ± 0.5
Fructose (%TS)	23.2 ± 0.2	ND
Sucrose (%TS)	18.2 ± 0.4	ND
Xylose (%TS)	ND	16.9 ± 0.2
Arabinose (%TS)	ND	5.1 ± 0.4
Total fibers (%TS)	7.4 ± 0.5	-
Uronic acids (%TS)	ND	16.8 ± 0.4
Proteins (%TS) <sup>b</sup>	2.8 ± 0.1	8.8 ± 0.1
Lipids (%TS)	0.41 ± 0.02	ND

247 ND: not determined.

248 <sup>a</sup> Total carbohydrate content was quantified as the sum of each individual sugar

249 <sup>b</sup> The protein content was calculated by using a nitrogen conversion factor of 6.25

250

251 After 45 days of anaerobic digestion of the residual fibers, a maximum biomethane yield of 225 ±

252 11 ml CH<sub>4</sub>/gVS<sub>fibers</sub> corresponding to 19 ml CH<sub>4</sub>/gVS<sub>flesh</sub> was obtained (Fig.4).

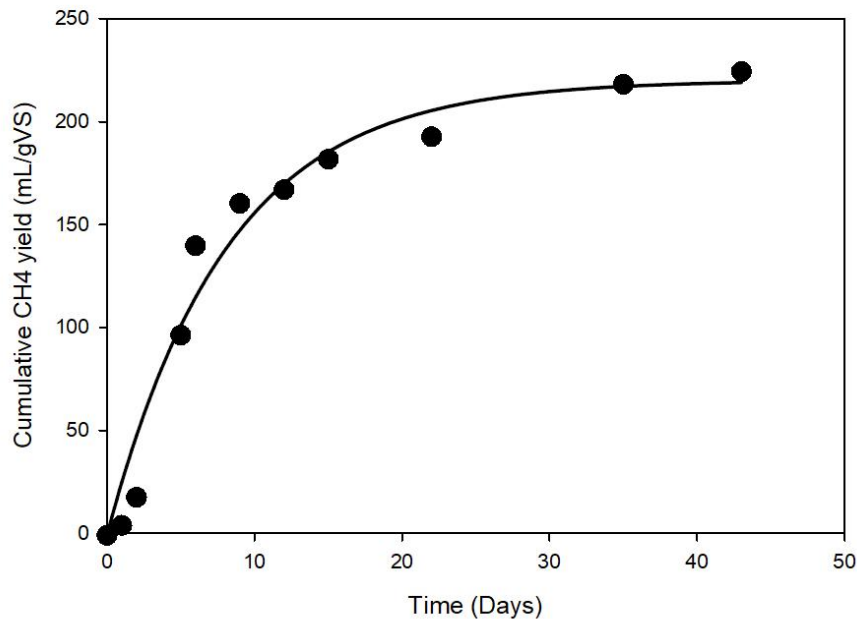
253 Besides, kinetic parameters were determined using a first order exponential model. The results of

254 the modelling given by the non-linear regression of the experimental data allowed the calculation

255 of the parameters K and Mmax for the methane production which were 0.12 ± 0.01 days<sup>-1</sup> and 217

256 ± 12 mL CH<sub>4</sub>/VS respectively.

257



258

259 **Fig. 4** Cumulative methane yield, expressed as mL CH<sub>4</sub>/gVS added, obtained during the BMP tests  
 260 performed with untreated ‘Kenta’ fibers extract. The standard deviation was lower than 10%.  
 261 Exponential model (solid line) fitting to experimental data (solid points)

262

263 The maximum methane yield obtained is higher than the predicted one. The variations of above  
 264 parameters could be attributed to factors such as the quantity and quality of the inoculums, batch  
 265 digestion test parameters (e.g. digestion temperatures, substrate to inoculum ratios) and substrate  
 266 characteristics (e.g. organic ingredients, volatile solid content) (Li et al., 2018).

267 In the same conditions (mesophilic conditions, without pretreatment), Souli et al (2018) found a  
 268 BMP of  $290.5 \pm 1.2$  mL CH<sub>4</sub>/VS by the anaerobic digestion of the entire ‘Kenta’ date pulp not  
 269 only the extracted fibers (Souli et al., 2018). However, the proposed biorefinery approach based  
 270 on crude fibers digestion after soluble sugars extraction allows both biogas production as source  
 271 of energy and date syrup recovery as high added value product. It permits therefore an almost  
 272 complete utilization of the dates byproducts and represents therefore a good alternative for the  
 273 management of this discarded biomass waste. The digestate is the only co-product of the entire

274 process remaining after methane production. It could be used as fertilizer since it represents the  
275 unconverted biomass without any chemical addition.

276 To better evaluate the proposed biorefinery concept, a preliminary economic study must be carried  
277 out. Typically, an economic approach of a biorefinery concept can be focused on two key cost  
278 contributors namely the raw material (including its transportation) and the operating costs (energy,  
279 enzymes, reagents...). For the glucose syrup production, the raw material cost is between 4% and  
280 8% approximately (Dávila et al., 2014). However, in our case, undervalued common cultivar  
281 which represent a discarded biomass is used as raw material. So, the proposed process will save  
282 about 4% of the biorefinery total cost if this later will be installed locally. Besides, it will allow  
283 financial benefits to farmers and meet the local fuel consumption of rural population.

284 The operating costs, especially the energy requirement, are the main factors that contribute to a  
285 high total production cost of 80% (Dávila et al., 2014). Generally, the pretreatment is among the  
286 costliest steps in the bioconversion of lignocellulosic biomass in particular dilute acid hydrolysis  
287 which is more expensive than other physicochemical pretreatments methods (Agbor et al., 2011).  
288 By using a hot water extraction, as simple and eco-friendly method, we can decrease the  
289 pretreatment cost step (no reagents or enzymes used). Besides, in order to reduce the energy cost,  
290 a heat integration strategy is suggested (Sánchez and Cardona, 2012).

291 An economic evaluation based on Tunisian market conditions permitted to estimate the cost and  
292 the revenue of the date syrup which are 0.45 USD/kg and 0.64 USD/kg, respectively (Lajnef et al.,  
293 2021). Nevertheless, the date syrup is not the only output of the proposed concept, the biogas  
294 issued from the anaerobic digestion of the residual crude fibers is also produced. This sequential  
295 production improves the energetic efficiency of the biobased process and represents an excellent  
296 example of circular bioeconomy.

297



298 **Conclusion**

299 This study presents a proof of an innovative concept demonstrating the feasibility of the co-  
300 production of both biogas and date syrup from the undervalued common cultivar ‘Kenta ‘using an  
301 eco-friendly process. Throughout the proposed integrated biorefinery approach, the date syrup was  
302 extracted with a 0.6 g/g yield and the residual crude fibers extract was submitted to anaerobic  
303 digestion. The methane potential reached 225 mL CH<sub>4</sub>/gVS fibers. Thus, it allows an efficient  
304 bioconversion of the discarded dates biomass. Furthermore, throughout the valorization of the  
305 date’s secondary varieties, the biodiversity of coastal oases could be conserved. This concept leads  
306 therefore not only to the bioenergy production but also to sustainable ecological effects. Some  
307 stages of this integrated process may be optimized to improve the production yields. A detailed  
308 techno-economic analysis is also necessary to envisage the scale-up of this biorefinery concept.

309 **Authors' contributions**

310 Ben Yahmed N. carried out the most of the experiments, participated to the interpretation of data  
311 and the redaction-correction of the manuscript. Carrere H. planned and supervised the BMP  
312 experiments at the LBE, participated to the interpretation of results and the correction of the  
313 manuscript. Chaira N. provided the dates cultivar and participated to the interpretation of results.  
314 Smaali I. conceptualized the work, supervised the soluble sugars extraction and characterization  
315 experiments at the LIP-MB Laboratory and participated to the redaction-correction of the  
316 manuscript.

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322

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## Supplementary material

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Macro nutriments		
NH <sub>4</sub> Cl	26.2	g/L
KH <sub>2</sub> PO <sub>4</sub>	10	g/L
MgCl <sub>2</sub> , 6H <sub>2</sub> O	6	g/L
CaCl <sub>2</sub> , 2H <sub>2</sub> O	3	g/L

Micro nutriments		
FeCl <sub>2</sub> , 4H <sub>2</sub> O	2	g/L
CoCl <sub>2</sub> , 6H <sub>2</sub> O	0.5	g/L
MnCl <sub>2</sub> , 4H <sub>2</sub> O	0.1	g/L
NiCl <sub>2</sub> , 6H <sub>2</sub> O	0.1	g/L
ZnCl <sub>2</sub>	0,05	g/L
H <sub>3</sub> BO <sub>3</sub>	0,05	g/L
Na <sub>2</sub> SeO <sub>3</sub>	0,05	g/L
CuCl <sub>2</sub> , 2H <sub>2</sub> O	0,04	g/L
Na <sub>2</sub> MoO <sub>4</sub> , 2H <sub>2</sub> O	0,01	g/L
Bicarbonate buffer		
NaHCO <sub>3</sub>	50	g/L

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**Table S1.** Composition of BMP nutriments

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