ASSESSMENT OF COMMINUTED BIOMASS BEHAVIOUR DURING ARUNDO DONAX STORAGE

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ABSTRACT: Dedicated energy crops can play a key role in providing substantial amounts of lignocellulosic feedstocks equired for the second-generation biofuel production chain as well as heat and electricity production (JRC EC, 2011). Giant reed (*Arundo donax* L.) has already been recognized as a high yielding, stress tolerant crop suited to marginal lands and low-input cultivation, which could be encompassed in land-saving and environmentally sound bioenergy supply chains. For instance, giant reed has been proposed for bioethanol, biogas, and thermochemical conversion. Although considered for bioenergy throughout the world, this crop has received particular attention in the Mediterranean, where promising yields have been achieved in mid- and long-term field trials.
Keywords: *Arundo donax*, biomass, chip storage.

1 INTRODUCTION

Arundo donax L. belongs to Poaceae family and is a perennial grass. Usually, grows in damp soils, either fresh or moderately saline, and is native to the Greater Middle East. It has been widely planted and naturalised in the mild temperate, subtropical and tropical regions of both hemispheres [1], especially in the Mediterranean and California. Giant reed is one of the most promising crops for energy production in the Mediterranean climate of Europe and Africa, where it has shown advantages as an indigenous crop, with a durable yield and sufficient resistantance to long drought periods. In the last years *Arundo donax* L. has represented an important attractive as bioenergy source. Several studies have been carried out to improve the destructuration of the lignocellulosic fraction and facilitate the sugar release [2-3] with scope to bioethanol production. On the other hand, few experiences on storage of *A. donax* biomass have been carried out [4-5]. Little is known about the specific environmental factors that regulate A. donax growth, phenological changes and seasonality of storage that may affect its suitability as energetic source. However, Giant reed biomass calorific value can depend to period of storage and also affected by fertilisation and plant density. In order to improve knowledge on giant reed and to favour the diffusion of energy crops in cropping systems, the study based on different types of storage and assessment of biomass behaviour.

2 MATERIAL AND METHODS

The study was conducted between March and September 2019 at Research Centre for Engineering and Agro-Food Processing (CREA-IT) in Monterotondo, near Rome, Central Italy (42°10’19’’N latitude, 12°62’66’’E longitude). The biomass chips utilized derived from an Arundo plantation growing at CREA-IT experimental farm. 10 tonnes of comminuted biomass has been stored in 2 piles 4 m long, 3 m wide and 2 m tall. The material was stored for 7 months in a flat site close to the plantation (Figure 1).



Figure 1: Covered and uncovered pile of comminuted Arundo donax.

To isolate the chips from the soil and avoid contamination, a pvc sheet was layed on the ground working as storage floor. The shape and the orientation of the two piles were maintained as similar as possible, to ensure that climatic factors had the same influence on both treatments. One of the piles was covered using a Toptex textile tissue, i.e. a material capable to allow transpiration and avoid the penetration of precipitations. Each pile consisted of two sections (replicates), each one including 3 sampling points; in total 6 sampling points per pile were utilized (Figure 2); a similar scheme was already utilized in previous studies [6].

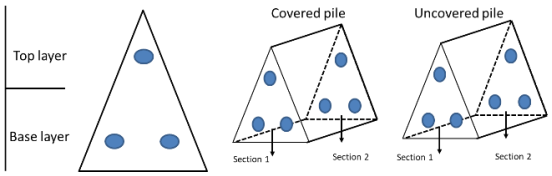


Figure 2: On the left side the single transversal section of the scheme utilized to set the experiment; on the right side the full scheme of the experiment with two sections (replicates) in both treatments.

Internal temperature during storage was monitored placing one pT-100 thermocouple in each sampling point. The probes were connected to a computerized data monitoring cab, connected itself to the web and remotely controlled. Chip storage was carried out outdoor with two different storage systems (covered *vs* uncovered); the material was exposed to the same weather conditions and the climatic parameters such as temperature, precipitation, wind speed and wind direction were recorded during the entire storage period (7 months). These parameters were

recorded using a weather cab "DAVIS VANTAGE PRO 2" placed in the proximity of the storage site and connected to wireless net. Near each thermocouple a plastic net filled with about 1 kg chips (pre-weighed) was placed in order to monitor dry matter losses. After storage the bags were removed from the piles and weighed before and after drying in a ventilated oven set at 105±2 °C. The calculation of the dry matter losses was performed using the following equation (Equation 1):

$$DML\ (\%) = \left[1 - \left(\frac{DW_2}{DW_1}\right)\right] * 100 \qquad [1]$$

DML: Dry matter losses (%)

DW_1: Dry weight prior storage (kg)

DW_2: Dry weight after storage (kg)

Moisture content of the chips was determined according to standard ISO 18134-1:2015 *"Solid biofuels - Determination of moisture content -- Oven dry method Total moisture -- Reference method"* [6] at the beginning of storage taking 10 random samples (500 g each) from the fresh material; at the end of the experiments the operation was repeated using 10 random samples (500 g each) taken during pile opening. For calculation of moisture content has been used the following equation (Equation 2):

$$MC\ (\%) = \frac{W_{fb} - W_{db}}{W_{db}} * 100 \qquad [2]$$

Wfb = Weight of the sample on fresh basis (g)

Wdb = Weight of the sample on dry basis (g)

In addition, the bulk density was assessed in-situ, according to the technical standard ISO 17828:2015 [7]. Briefly, a 0.05 m^3 metal basket was filled with chips, then jolted three times vertically and filled again. The extra chips were removed by swinging a small scantling over the container, then the basket was weighted. The measurement was repeated 5 times per treatment. The net weight of the basket was previously recorded.

3 RESULTS AND DISCUSSION

Comparison of two different storage methods of giant reed was tested. Bulk density is one of the important technical properties. It is very easy to determine and can be correlate to many other physical parameters. The experiment showed an initial bulk density (Table I) of 130 Kg m^{-3}, after the storage period covered and uncovered pile showed a reduction of about 50 %. the reduction of the bulk density was even higher in the uncovered pile.

Figure 3 showed the trend of principal climatic parameters referred to the whole period of storage of the biomass. The cumulated precipitations were higher in the months of May and September, while higher temperatures were concentrated in Summer, from June to August 2019.

Table I: Value of bulk density of *Arundo donax L.* stored in two different way (covered and uncovered)

Type of storage	Bulk density (Kg m^{-3})
Pre-storage	130.6
Post-storage (covered)	62.6
Post-storage (uncovered)	60.1

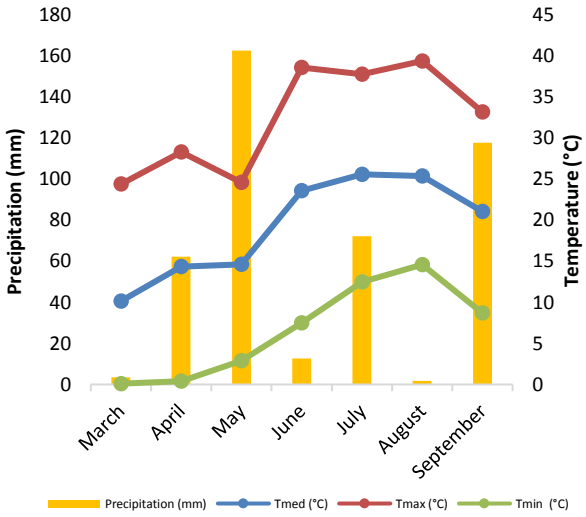


Figure 3: Trend of main climatic parameters, temperature (°C) and precipitation (mm) recorded during the storage of *Arundo donax*.

Comparison between monthly heat development in covered and uncovered (Figure 4) pile of *A. donax* biomass was evaluated. Generally, the inner temperature of the biomass is a reliable indicator of storage performance, since degradation reaction are exothermic and generate a marked temperature rise [6]. After one month from the initial experiment, the temperature in the covered pile (Figure 2) was irregular. Even if the trend was not regular for all the parts of the pile, the temperature recorded at the end of the storage was under 50 °C with a lowest value of 32 °C.

The uncovered pile (Figure 5) showed the temperature stabilized at around 60 °C. The temperature rise in stored biomass could be symptom of microbial activity or sufficient condition to start and favourite the development of microorganisms grow. At the end of the storage test the temperature was around 50 °C in all parts of the pile. However, could be necessary to extend the research activity to the whole energy chain in order to identify the most sustainable conversion technologies, in combination with the better storage way of *A. donax* biomass.

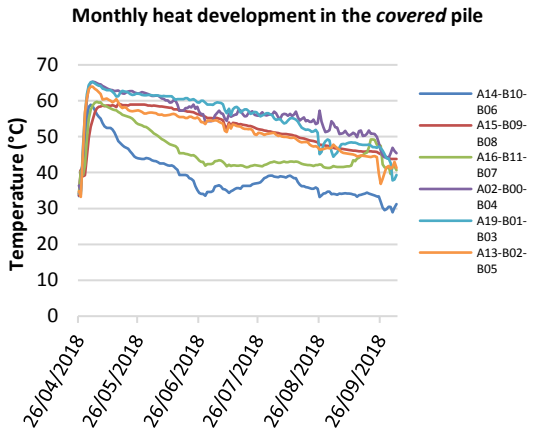


Figure 4: Monthly heat development in *covered* pile, where the numbered letters (e.g. A14, B10, etc.) indicate the thermocouple

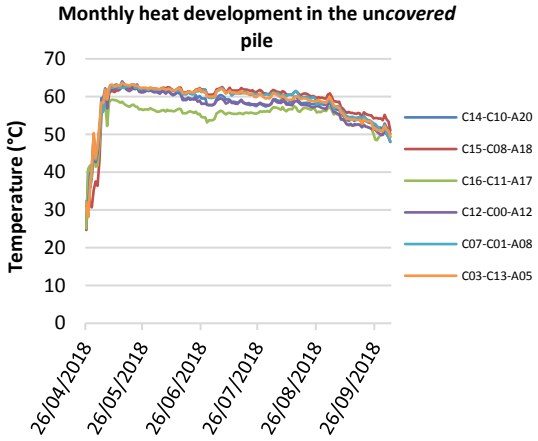


Figure 5: Monthly heat development in *uncovered* pile, where the numbered letters (e.g. C14, C10, etc.) indicate the thermocouple

Comparison of moisture content reduction during the storage test was also evaluated. the results are depicted in table II.

Table II: Moisture content (MC) of Arundo donax covered and uncovered piles, expressed in percentage (%), where: MC_i, initial moisture content, MCft is the final content in the Top layer, MFfb is the final content in the Base layer, and MC_f, final average moisture content, that is at the end the storage.

	Covered	Uncovered
MCi (%)	49.7±0.93	
MCft (%)	9.7±0.004	19.4±0.05
MCfb (%)	9.2±0.01	15.0±0.03
MCf (%)	9.4±0.003	17.2±0.03

Results highlighted that the reduction of moisture content was higher in the covered pile, as expected, respect to the uncovered pile. Inside each pile, the final moisture content was lower in the base layer respect to the top layer.

Starting from the evaluation of the moisture content reduction during the storage test, the dry matter losses were calculated. Results are shown in table III.

Table III: Dry Matter losses (DM) of Arundo donax covered and uncovered piles, expressed in percentage (%).

Dry Matter losses (%)	Covered	Uncovered
Top layer	7.3±0.03	15.6±0.11
Base layer	0.4±0.01	13.9±0.06
Total losses	3.8±0.04	14.7±0.06

Results of dry matter losses follow the trend of the moisture content reduction. The covered pile shown lower losses respect to the uncovered pile. Regarding each pile the losses were higher in the top layer respect to the base layer.

4 CONCLUSIONS

At the present, the harvesting period and the system adopted for giant reed are still under debate. The feasibility of the storage of giant reed as chipped biomass for energy purposes is unknown and represents a lack in the scientific literature. It strongly depends on the season, on the geographical area and on the system utilised. This study clarifies on the potentiality of different storage systems, highlighting the advantages and disadvantages by using the Toptex textile as storage material. The results showed how the storage of the biomass caused a reduction of almost 50 % of the bulk density. Furthermore, at the end of the storage the moisture content, the inner temperature and the dry matter losses were higher in the uncovered pile respect to the covered one. The storage test highlighted as it was possible to reach a moisture content suitable for energy production processes in 7 months using a covering textile and to sharply reduce the bulk density. The covered treatment allows to reduce the dry matter losses that usually affects the storage of comminuted biomass.

This study represents a critical data, useful for further investigation focused on the effect of the storage on the main energy parameters, such as fuel quality, heating value and principal elementary compounds.

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