Valorisation of process residues by biomass crops: the case of Torwash wastewater application on Giant reed (*Arundo donax* L.)

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Substantial challenges for the development of biomass supply chains include the distributed and bulky nature of biomass, as well as its potential for degradation during transport and storage. For these reasons, the densification of biomass prior to transport is a key requirement, in order to produce an energy carrier that is more easily handled and stored. Thermal pre-treatments (i.e. torrefaction) are a way to obtain such carriers, in wet or in dry processes.

The evaluation of pretreatment systems based on wet torrefaction was a key objective of LogistEC, aiming to enhance the logistics of energy crops, with a focus on perennial energy grasses. In particular, the wet torrefaction is a two-stage pre-treatment which consists of a washing phase (prewash, 50°C for 15 minutes) followed by a high temperature treatment ('Torwash', 200°C for 30 min) which allows for a solid biofuel, characterised by a higher heating value and a lower ash content compared with the original biomass, to be obtained. The use of biomass from perennial grasses for combustion involves some difficulties, owing to transport and storage, but also to its chemical characteristics, such as high ash, alkalis and chlorine contents, causing corrosion, fouling, and slagging problems. These issues are particularly critical for some crop species, such as giant reed (*Arundo donax* L.), whose ash and alkali content are usually high.

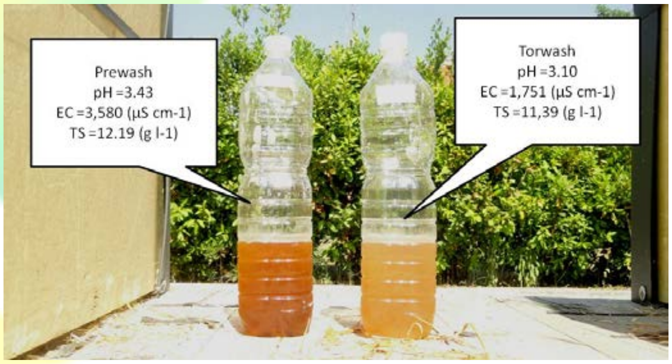

Figura 1: samples and main characteristics of Prewash (PW) and Torwash (TW) wastewaters.

Two kinds of wastewaters are originated from the two treatments: one from prewash and one from Torwash. Recycling the wastewaters obtained from wet torrefaction would allow to recover the nutrients, mostly potassium (K) removed from the biomass and to return them to the soil. Therefore, not only the characteristics of the solid biofuels are improved, but also the overall sustainability of the process can be increased through improved nutrient management, involving a proper handling of the wastewaters.

In order to assess the direct reuse of wastewaters on energy crops, a pot experiment was carried out on micro propagated plantlets of giant reed. A particular focus was put on this crop, since this species is very promising for bioenergy purposes, given its remarkable yield potential under low input management and rainfed conditions. In particular, the distribution of Prewash (PW) and Torwash (TW) wastewaters was investigated, in terms of effects on plant growth and on soil and leachate properties. This was compared with unfertilised plants and with plants that received K as mineral fertiliser (potassium sulphate) at the fertilisation rate usually adopted for crop establishment in field conditions (15 g plant-1). It is important to note that wastewaters were obtained from thermal pretreatment in a batch test of giant reed biomass, thus closely reflecting the composition of such wastewaters when obtained from biomass

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harvested and processed at scale in the giant reed-based supply chain. PW and TW were mixed with tap water (30%) to provide 7.4 and 2 g K plant-1 respectively.

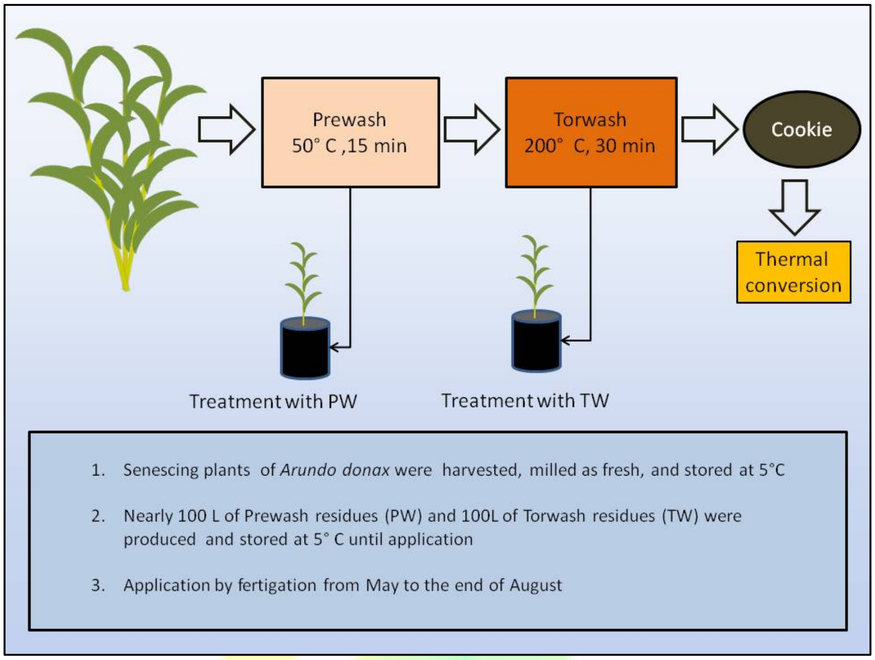

Figure 2: re-use of Torwash residues, conceptual approach

EFFECTS OF PREWASH AND TORWASH WASTEWATERS ON GIANT REED GROWTH

On average, the above ground biomass (AGB) of giant reed in the untreated pots (C) was about 150 g, while the below ground organs (BGB) reached 125 g (Fig. 3). Comparing the control with the treatments, a significant effect of PW and TW on AGB was observed ($p<0.001$). AGB was reduced by about 20% when giant reed was treated with PW, while TW led to a higher yield decline (-50%); conversely, no significant effects were observed on BGB. Some differences were also observed on above ground biomass partitioning, since the leaf mass ration in TW-treated plants was significantly higher than in C and in the other treatments (+14%) ($p<0.001$). However, no remarkable effects were noticed on partitioning of the below ground fractions (rhizomes and roots).

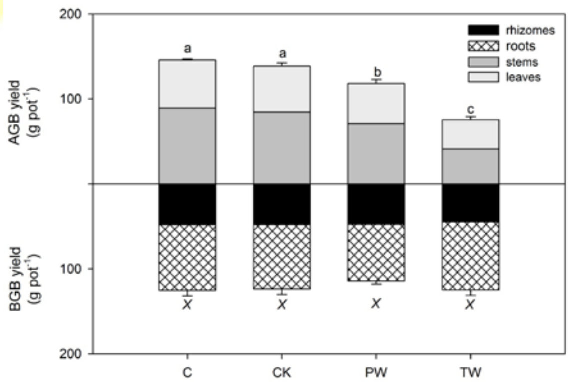

Figure 3: Aboveground (AGB) and belowground (BGB) biomass partitioning, according to different treatments (CK, PW, TW) and compared with the control (C). Lower case letters are for mean separation of aboveground yields, while upper case italic letters are for belowground biomass.

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MACRONUTRIENT UPTAKES

The highest aboveground nitrogen uptake was observed in C (1.4 g pot-1), while significant reduction was recorded in all the other treatments (-10% in CK; -20% in PW and -30% in TW). Moreover, slight differences were found for nitrogen uptakes related to the belowground biomass (-10% in PW) (Fig. 4a). Only a slight reduction in aboveground P uptakes was observed in TW-treated plants, while the other treatments were not significantly different (Fig. 4b). Moreover, regarding phosphorus, no significant differences were observed in belowground uptakes. On the contrary, K uptakes showed a different behaviour with significant higher values of the aboveground K uptake in CK and PW compared with the control, while a reduction of about -50% was observed in TW. A similar trend was observed in the belowground K uptakes, with the exception of PW, which showed similar values as C (Fig. 4c).

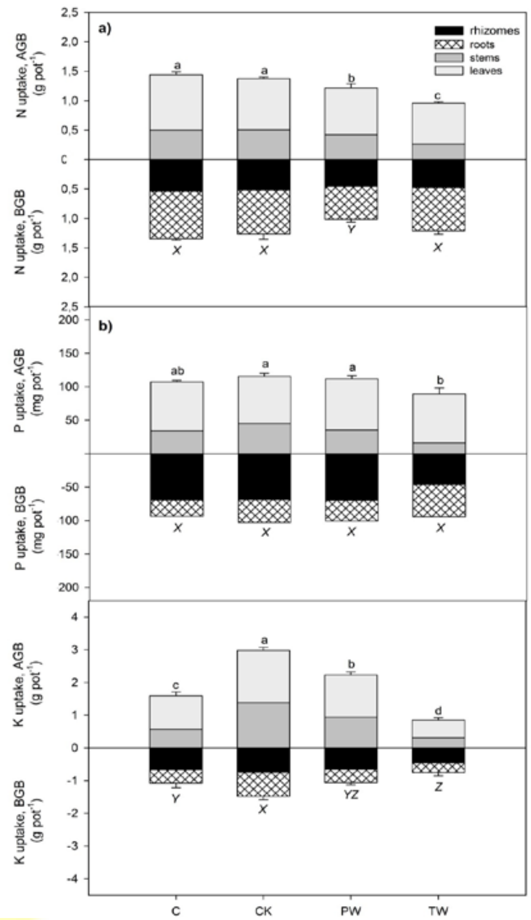

Figure 4: Nitrogen (a), phosphorus (b) and potassium (c) uptakes or each aboveground (AGB) and belowground (BGB) biomass component, among the different treatments (CK, PW, TW) and compared with the control treatment (C) set to 100%. Lower case letters are for AGB yields, upper case italic letters for BGB yields.

LEACHATE PROPERTIES

Leachate volumes (i.e. drainage) also played a role, as they differed according to the treatments and they determine the overall amounts of leached nutrients along with nutrient concentrations. Higher drainage volumes were observed in PW-TW treatments, which approached 6 L pot-1, while C and CK averaged 4.5 L pot-1 (-22%). Lower drainage volumes observed in control treatments may be explained by a higher water demand, i.e. higher evapotranspiration, owing to the higher aboveground biomass recorded.

Regarding nitrogen compounds, nitrites and ammonium were never detected in leachates. Regarding nitrates, the leached amounts in PW and TW treatments were markedly lower than in C and CK (36 vs 6 mg pot-1). Since the treatments did not differ in nitrogen supply, it might be hypothesized that the differences in nitrate leaching originated from the mineralisation of organic matter and from nitrification. Plant removal should have played the opposite role, lowering the availability of nitrates for leaching in C-CK treatments, in which the N uptake was higher. Therefore, plant uptake seemed not to be the most relevant factor in determining the observed difference in nitrate leaching. On the other hand, PW and TW might have reduced the biological activity in the soil, thus affecting mineralization and nitrification.

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SOIL PROPERTIES

Regarding soil conductivity, this parameter varied according to the EC of the applied wastewaters and, in general, to the ionic content of the applied fertilisers (PW≅CK>TW>C). The untreated soil did not differ markedly from the control.

As it may be inferred from wastewater compositional data, PW is also an interesting source of phosphates, which seemed to have slightly enriched the soil compared with the other treatments. Exchangeable potassium levels were also in line with the potassium contents of the applied fertilizers. The only exception is the level observed in CK, which was relevantly higher than that of PW. This might be explained with a lower retention efficiency showed by the soil in PW treatment, likely due to wastewater pH and interfering mineral elements.

OUTLINE MAJOR POINTS

- Even if giant reed is proposed as a stress-tolerant crop, potentially suitable for the valorisation of wastewaters, a negative effect of Torwash residues on biomass yield was observed.
- The lower aboveground yield observed in TW was related to reduced evapotranspiration, as confirmed by the higher volume of leachates.
- The high conductivity cannot explain the negative response to TW treatment, while it was probably the most relevant factor reducing productivity in PW treatment.
- A scarce effect of K fertilisation on plant growth was also shown, the aboveground dry yield being similar in C and CK. A high K availability may have led to potassium luxury uptake by this crop.
- Both the wastewaters turned out to be poorly suitable for fertigation at crop establishment, however PW could be used to restore the K content of the soil, in mature crops, in the perspective of soil nutrient restoration.
- It must be stated that the effects on giant reed growth in a pot experiment, carried out on micropropagated plantlets grown on a sandy soil, may have been exacerbated.
- Based on these results ECN will pursue the digestion of the pre-wash and torwash effluent streams, which have demonstrated increased conversion yields to biogas in order to sustain the torwash process.

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