# CARBON AND NITROGEN MINERALIZATION OF ORGANIC WASTES FROM SUGARCANE DISTILLERIES: VINASSE AND YEAST WASTE

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## 1 INTRODUCTION

In Madeira Island (Portugal) significant amounts of wastes are generated in sugarcane distilleries, namely vinasse (the remaining fermented must after distillation) and yeast waste (the yeast surplus produced during the alcoholic fermentation). These wastes have high organic loads and low pH, leading to serious environmental problems when released directly into natural watercourses or when poorly managed (Hati et al., 2007).

As a solution to avoid expensive treatments, both wastes have been used as soil amendment, since they contain important amounts of plant nutrients and organic matter (Resende et al., 2006; Parnaudeau et al., 2008). Indeed, application to soils of vinasse is a common practice in sugarcane cultivated areas and can fully substitute K and partially P on crops fertilization. Nevertheless, additional mineral nitrogen fertilization is needed when vinasse is spread in the soils (Junior et al., 2007; Oliveira et al., 2009). On the other hand, yeast waste has been considered as an excellent potential source of nitrogen for plant nutrition when applied to soils (Rezende et al., 2004). Thus, combined application of both wastes should ensure a more balanced supply of nutrients to plants. However, scarce information is available on the combine use of both wastes as fertilizer.

The main objective of this study is to assess the effect of the combined application to soil of both organic materials (vinasse and yeast waste), and to evaluate its subsequent effects on nitrogen mineralization/immobilization process to supply nitrogen to crops and to preserve/restore soil carbon.

## 2 MATERIALS AND METHODS

In this study an Haplic Arenosol with a pH ($H_2O$) of 5.9 containing 87.7% sand, 9.7% silt and 2.6% clay, and an organic matter content of 10.7 g $kg^{-1}$soil was used and amended with vinasse (V), yeast waste (Y) and 3 different combinations of both wastes.

Both wastes were collected in the sugarcane distillery “Engenho Novo da Madeira Lda”, located in the Madeira Island, Portugal. The vinasse used in this study resulted from the thermal concentration of dilute vinasse (Parnaudeau et al., 2008). Selected properties of the waste materials are shown in table 1.

TABLE 1 **Selected properties of the organic amendments in a dry matter basis**

| Waste | Organic C (g $kg^{-1}$) | Total N (g $kg^{-1}$) | $NH_4^+$-N (mg $kg^{-1}$) | $NO_3^-$-N (mg $kg^{-1}$) | Total P (g $kg^{-1}$) | Total K (g $kg^{-1}$) | C:N ratio | Moisture (g $kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Vinasse (V)** | 371.2 | 6.7 | 56.7 | 35.4 | 4.9 | 90.2 | 55 | 502 |
| **Yeast Waste (Y)** | 476.7 | 57.9 | 747.1 | 14.7 | 48.8 | 73.6 | 8 | 826 |

6 treatments, 4 times replicated, were established in order to supply an amount of total N equivalent to 200 kg $ha^{-1}$ (66.6 mg total N $kg^{-1}$ soil): control (only soil), 200V (soil + 200 kg N $ha^{-1}$ via V), 200Y (soil + 200 kg N $ha^{-1}$ via Y), 150V50Y (soil + 150 kg N $ha^{-1}$ via V + 50 kg N $ha^{-1}$ via Y), 100V100Y (soil + 100 kg N $ha^{-1}$ via V + 100 kg N $ha^{-1}$ via Y), and 50V150Y (soil + 50 kg N $ha^{-1}$ via V + 150 kg N $ha^{-1}$ via Y).

Two aerobic incubations (98 days) were performed under temperature and soil moisture controlled conditions (25ºC and 70% of the maximum soil water holding capacity), one to follow N mineralization and a second to measure $CO_2$ emissions. To evaluate $CO_2$-C emissions each mixture was incubated in a sealed “reactor” where the $CO_2$ evolved was trapped in a 1M NaOH solution. Periodically the reactors were aerated, the NaOH solution was replaced in the reactor and the $CO_2$ evolved was measured (Zibilske, 1994). The nitrogen mineralization incubation was performed using 1 kg of dry soil equivalent mixed with an amount of waste equivalent to 200 kg N $ha^{-1}$ and distilled water, as described above (Ribó et al., 2003). At different sampling dates, soil samples were collected and analyzed for nitrate; nitrite and ammonium content by using a colorimetric method on a segmented flow autoanalyzer (Skalar, The Netherlands).

# 3 RESULTS AND DISCUSSION

## 3.1 Carbon mineralization

During the first day of incubation $CO_2$-C emissions from 200V and 150V50Y treated soils were lower than those of control treatment (table 2). This reduction of soil microbial activity could be due to the low pH as well as to the presence of short-chain organic acids, melanoidins and phenolic compounds in the vinasse waste, which can inhibit or reduce the activity of soil microorganisms (Parnaudeau et al., 2008). However, in the following days, a strong increase in $CO_2$ emission was observed in all waste-amended treatments, compared with control treatment, showing that the initial reduction of the microbial activity was temporary (table 2).

TABLE 2 **Cumulative $CO_2$-C emissions in the first four sampling dates**

| | **Cumulative $CO_2$-C emissions** (mg $CO_2$-C $kg^{-1}$ dry soil) | | | |
|---|---|---|---|---|
| **Treatments** | Day 1 | Day 3 | Day 7 | Day 14 |
| **Control** | 29.3 d | 51.3 a | 70.0 a | 109.1 a |
| **200V** | 15.6 b | 563.2 d | 1014.8 e | 1382.5 e |
| **150V50Y** | 19.2 c | 513.6 e | 947.6 f | 1236.6 f |
| **100V100Y** | 32.6 d | 547.6 b | 799.0 b | 966.7 b |
| **50V150Y** | 68.9 c | 327.2 a | 487.7 c | 617.3 c |
| **200Y** | 55.5 a | 175.1 c | 263.4 d | 360.5 d |

In each column, values followed by the same letter are not statistically different at P=0.05, according to the least significant difference (LSD).

At the end of the incubation, the 200V treatment showed the highest $CO_2$ emissions -2726 mg $CO_2$-C $kg^{-1}$ soil during 98 days (figure 1A), while the lowest $CO_2$ emissions were observed in the 200Y (868 mg $CO_2$-C $kg^{-1}$) and control treatments (445 mg $CO_2$-C $kg^{-1}$).

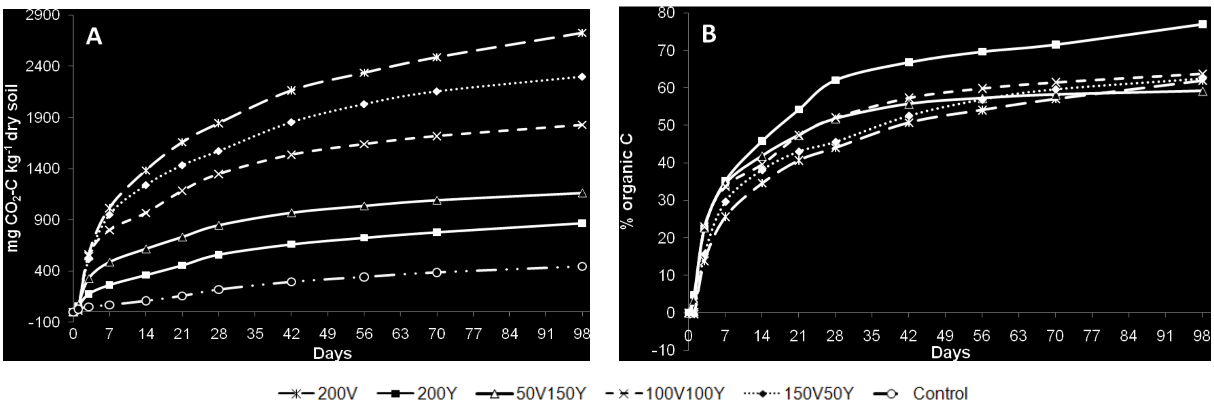


FIGURE 1 **Carbon mineralization. A – Cumulative $CO_2$-C emission (mg $CO_2$-C $kg^{-1}$ soil) during the experiment; B – percentage of the applied organic carbon mineralized**

However, since different amounts of C were incorporated into the soil in each treatment, the percentage of applied C that was mineralized was evaluated (figure 1B). At the end of the experiment, a significantly ($P<0.05$) higher amount of applied C was lost in the yeast waste treatment (200Y, 77% of C applied) when compared to vinasse (200V, 62% of C applied) or to the three combined treatments (59-64% of C applied), suggesting that yeast waste is an easy degradable substrate for soil microorganisms, and therefore has a lower contribution for soil organic matter. Similarly, Rezende et al. (2004) observed high $CO_2$ emission from two soils amended with yeast wastes, and attributed these high emissions to the $CO_2$ evolved from the mineralization of the organic carbon of yeasts.

### 3.2 Nitrogen mineralization

Figure 2A shows the evolution of mineral N along the incubation period in the waste treated soils and control treatment. During the first 28 days of incubation, the mineral N in the yeast amended soil (200Y) significantly increased whereas in the vinasse treated soil (200V) mineral N decreased and remained very low till day 56. At the end of incubation (98 days), mineral-N in 200V (28 mg N $kg^{-1}$ soil) and 150V50Y (48 mg N $kg^{-1}$ soil) treated soils remained lower than in the control treatment (62 mg N $kg^{-1}$ soil), suggesting that vinasse led to soil nitrogen immobilization. On the contrary, yeast waste led to net nitrogen mineralization, since mineral N in 200Y (92 mg N $kg^{-1}$ soil) and 50V150Y (84 mg N $kg^{-1}$ soil) was higher than in the control.

Rezende et al (2004) found a high increase in soil nitrate content, after the application of 0.5% and 1% (w/w) of yeast waste to different soils. According to these authors, the enhanced content of nitrate was a consequence of yeast mineralization resulting in a similar concentration of nitrate than that found with the application of NPK fertilizers.

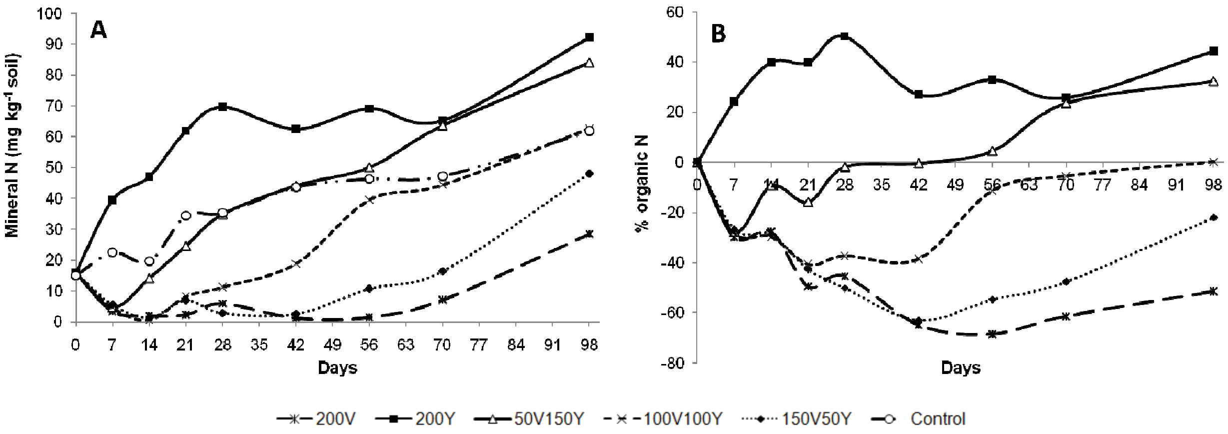


FIGURE 2 **Nitrogen mineralization. A – Evolution of the mineral N in the soil (control) and soil amended treatments (mg N $kg^{-1}$ soil); B – Percentage of the applied organic nitrogen mineralized.**

At the end of the incubation period, 44.3 and 32.3% of the organic N applied was mineralized in 200Y and 150Y50V treated soils, respectively (figure 2B). The N immobilization in 200V, 150V50Y and 100V100Y treated soils corresponds to -51.5%, -22.1 and -0.1 % of the organic N applied, respectively.

It is well known that N mineralization is mainly ruled by the C:N ratio of the organic materials added to soil (Chadwick et al., 2000; Fangueiro et al., 2008). Hence, the higher N mineralization of yeast waste (200Y) relatively to that of vinasse (200V) may be explained, at least in part, by the lower C:N ratio (8) of yeast waste compared with that of vinasse (55). However, the N mineralization pattern also depends on the carbon quality of the organic materials applied to soil (Ribeiro et al., 2010). In fact, figure 1B shows that the carbon present in yeast waste (200Y treatment) showed a lower stability, being easily degraded by soil microorganisms and, consequently, ensuring a faster release of nitrogen.

## 4 CONCLUSIONS

Spreading vinasse and yeast wastes into agricultural soils constitutes an adequate disposal for these organic materials, leading to benefit of the soils and potentially crop growth since they are important sources of organic matter and plant nutrients. Nevertheless, when only vinasse is used additional nitrogen fertilization is recommended, in order to counterbalance the initial soil N immobilization. Indeed, according to the results obtained, combining yeast waste with vinasse (50V150Y) appears as the most consistent and best option for the management of both wastes, resulting in a mixture that highly contributes for soil organic carbon sequestration while remaining a potential source of nitrogen to plants.

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