Physicochemical, Microbial, and Microbiome Dynamics in Winery Waste Composting

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INTRODUCTION

Annually, the winemaking industry generates 0.3–0.5 kg of wine by-products/L, including winter pruning wastes that can be toxic if disposed of without pretreatment, due to high content of organic load and phytotoxic compounds along with high acidity. Composting is the natural process of transforming organic matter to fertilizers, rich in essential nutrients for plant growth by microorganisms under controlled conditions. The organic substrate used in the composting process affects microbial populations, reflecting thus the dynamics of enzymatic activity, decomposition of organic matter, and nitrogen transformations. However, the microbiome associations during the whole process are still unexplored.

OBJECTIVE

The aim of the present study was to investigate the physicochemical, microbial, and microbiome dynamics during the microbial composting of winery waste and assess the suitability of the resulting compost as a biofertilizer for grapevine growth.

MATERIALS AND METHODS

A pilot-scale composting system was utilized and samples were collected over a 60-day period to study the physicochemical parameters, enzymatic activity, microbial counts, and microbiome composition as described previously [1]. Additionally, the potential phytotoxicity of the compost was evaluated using a germination index test with barley seeds and its effectiveness as a substrate for grapevine growth was assessed in a proof-of-concept study [2].

RESULTS

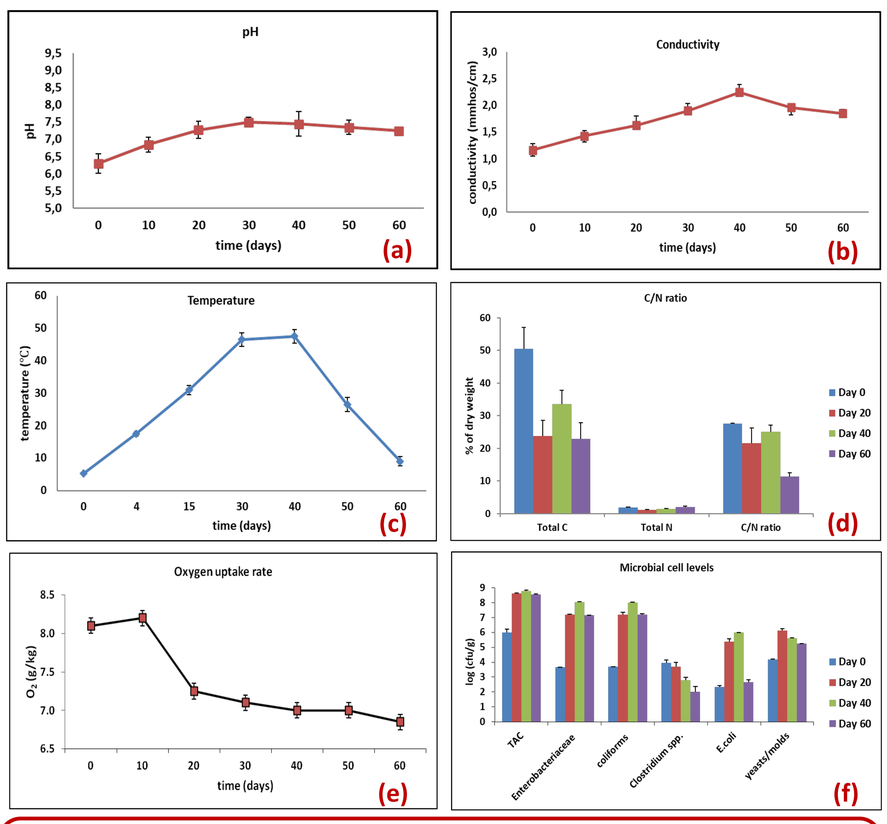

Figure 1: Changes in (a) pH, (b) conductivity, (c) temperature, (d) C/N ratio, (e) Oxygen uptake rate, and (f) microbial population levels during microbial composting of winery wastes.

Table 2: Dehydrogenase activity during microbial composting of winery wastes.

Dehydrogenase activity	Day 0	Day 60
(μg TPF/g dm/24h)	96.48±18.29	30.94±4.84

- Germination Index (GI) equal to 133.99 was estimated. Of note, GI values > 80 indicate no phytotoxicity.
- Effectiveness of the final product was verified by estimating the percentage yield of grapevine leaf dry matter compared to the control samples, leading to values 110 ± 1.3 and 90 ± 1.8 for 25:75 and 50:50 (product: commercial substrate), respectively.

Table 1: Concentration of important trace elements and metals during microbial composting of winery wastess

Trace elements/ metals	Day 0	Day 60
Total Ca (% dry weight)	0.10±0.06	1.50±0.50
Active Ca (% dry weight)	1.40±0.32	0.13±0.02
CaCO3 (% dry weight)	1.40±0.21	1.60±0.5
P (ppm)	0.32±0.04	0.25±0.02
K (ppm)	0.45±0.001	0.40±0.16
Mg (ppm)	3.92±0.09	2.00±0.64
Zn (ppm)	580.00±14.10	83.50±23.30
Mn (ppm)	331.50±2.12	237.50±24.75
Fe (ppm)	16.50±2.12	12.00±2.83
Cu (ppm)	32.00±1.41	33.50±2.12

Table 3: Changes in bacteria phylum abundances (%) during microbial composting of winery wastes.

Bacterial phyla	Day 0	Day 60
Acidobacteria	0.13±0.05	1.98±0.92
Armatimonadetes	0.03±0.001	0.28±0.12
Bacteroidetes	0.37±0.16	16.62±1.36
Candidatus saccharibacteria	0.01±0.001	0.04±0.001
Chloroflexi	0.01±0.001	0.06±0.02
Cyanobacteria	0.02±0.001	0.02±0.001
Planctomycetes	0.03±0.001	0.03±0.001
Proteobacteria	99.37±0.26	80.97±0.32

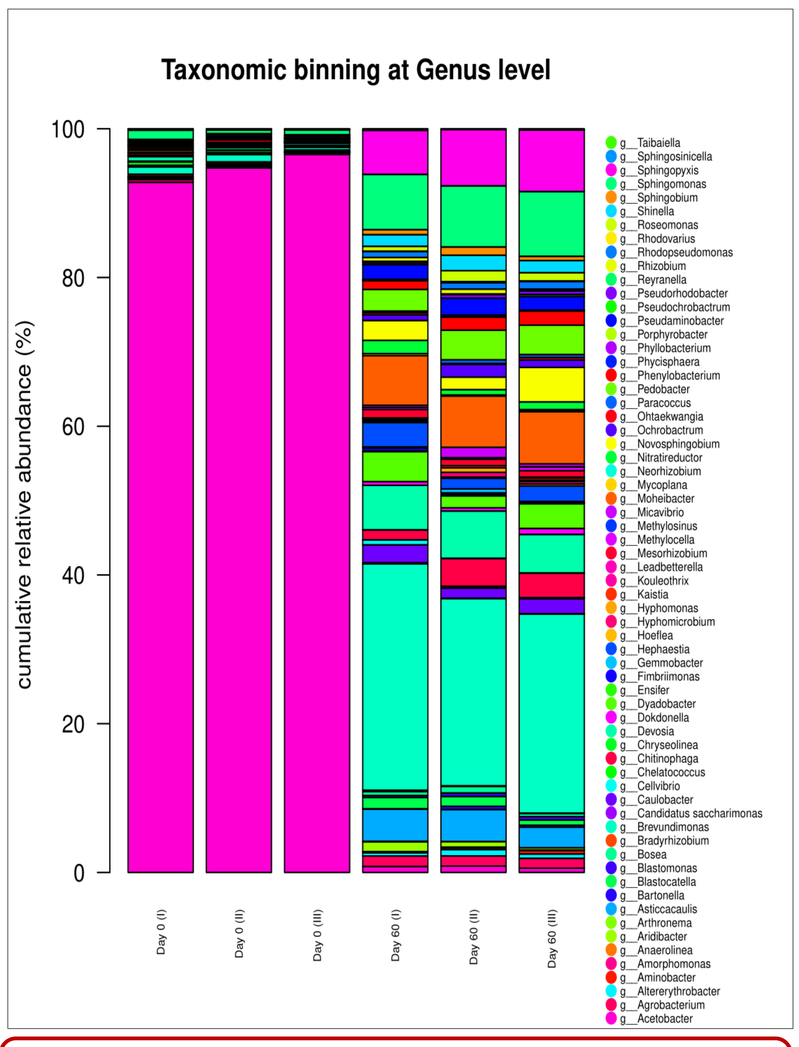

Figure 2: Taxonomic binning at Genus level of bacteria during microbial composting of winery wastes.

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Table 4: Changes in fungal phylum abundances (%) during microbial composting of winery wastes.

Fungal phyla	Day 0	Day 60
Ascomycota	97.43±0.64	90.28±3.05
Basidiomycota	2.35±0.64	8.16±2.57
Chytridiomycota	0.01±0.00	0.01±0.00
Entomophthoromycota	0.01±0.00	0.01±0.00
Glomeromycota	0.03±0.01	0.86±0.40
Mucoromycota	0.18±0.01	0.68±0.09

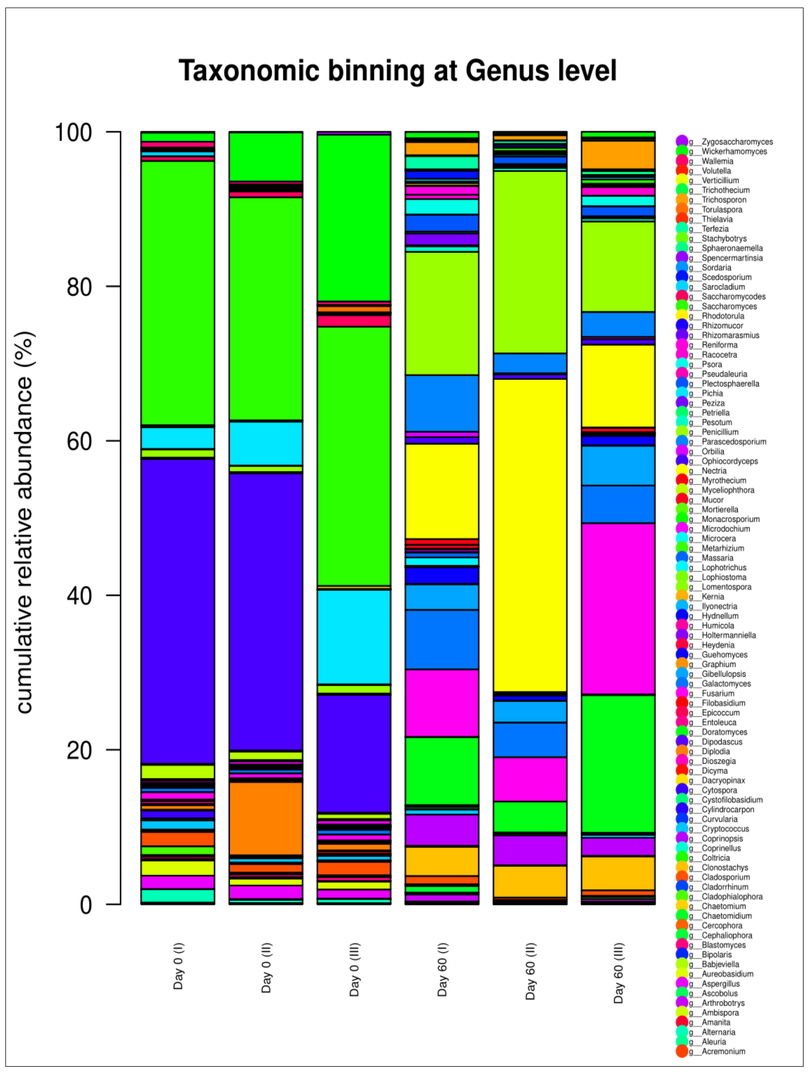

Figure 3: Taxonomic binning at Genus level of fungi during microbial composting of winery wastes.

CONCLUSION

- ✓ Analyzing the microbiome diversity at the beginning and at the end of the composting process of winery waste provided valuable insights about the bioprocess.
- ✓ Excess enzymatic activities, physicochemical analysis results (low C/N, total N increased, and neutral pH), along with lack of phytotoxicity indicated the suitability of the final product and its effectiveness as a substrate for vine growth was confirmed
- ✓ More research is still required to fully understand the underlying mechanisms of winery waste biotransformation into efficient biofertilizer and verify its efficiency in real plant culture conditions.

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