THE UNIVERSITY OF ARIZONA
Cooperative Extension

az1921 January 2022

Aerobic and Anaerobic Grape Pomace Composting: The Pros and Cons

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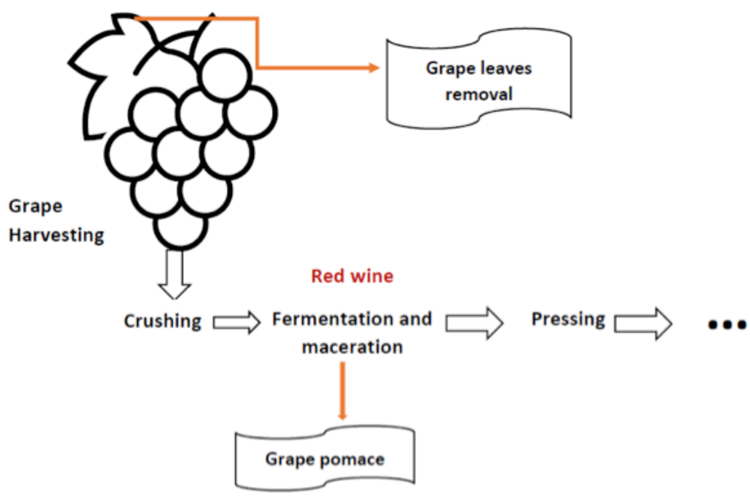

Figure 1: Diagramatic representation on how red grape pomace is obtained from wine making

Introduction

In Arizona, wine production increased from 65,413 gallons (2007) to 297,145 gallons 2017) (Murphree, 2018), with an estimated 354% increase in grape pomace production within the same period. The grape pomace is a by-product of the wineries, which is obtained after crashing the grape fruits, fermenting and pressing the juice. Note that the red grape for red wine are fermented and macerated while the white grape used for white wine is not fermented before pressing. In this study, the grape pomace from red wine making was used (Fig. 1). It has both macro-and micro-nutrients with acidic pH (Table 1) due to the organic acid content and it have several uses (García-Lomillo and Gonzalez-San, 2017). The low pH of GP limits microbial activities making decomposition very slow. Composting the GP is important to help kill the grape fruits seeds and potential pathogens that may be present and could contaminate crop fields after application as a soil amendment (organic fertilizer). The use of the GP as an organic fertilizer could be a sustainable waste management strategy to reduce the waste generated in the growing wine inductry in Arizona. The study assessed poultry manure and zeolite's effect on grape pomace (GP) pH and the impact of aerobic and anaerobic composting on the compost mineral concentrations.

Materials and Methods

Study area and materials: The experiment was conducted in the field at the University of Arizona Cracchiolo DK Experiment Station in Cornville, Arizona. The set up established on September 16th, 2020 and was left to run for 15 weeks.

Compost materials: Grape pomace was obtained after red wine making process with red grapes from Alcantara Vineyards, Camp Verde, Arizona, the poultry manure (PM) from Hickman's Farms, Arizona, and the zeolite from KMI zeolite (Pahrump, NV, USA), with varied mineral compositions and pH (Table 1).

Mineral analysis: All minerals analysis were done at the Texas A&M AgriLife Extension Service Soil, Water and Forage Testing Laboratory (http://soiltesting.tamu.edu/) using their standard protocols.

Table 1: Chemical properties of grape pomace, zeolite, and poultry manure

	Grape Pomace (GP)	Zeolite	Poultry Manure (PM)
pH (1:1_water)	3.9	9.3	7.1
EC (1:1_ds/m)	3.6	0.5	9.7
Total N (%)	2.03	0.03	2.84
Total P (%)	0.25	0.00	2.63
Total K (%)	3.47	2.81	2.21
Total Ca (%)	0.47	0.62	11.93
Total Mg (%)	0.10	0.10	0.76
Total Na (%)	0.00	2.30	0.70
Total S (ppm)	1,402.3	17.7	6906.2
Total Zn (ppm)	17.0	11.7	654.1
Total Fe (ppm)	45.7	3,369.2	132.0
Total Mn (ppm)	20.4	204.5	557.8
Total Cu (ppm)	18.6	2.2	63.8
Total B (ppm)	37.8	5.4	44.3

Chemical properties of grape pomace, zeolite, and poultry manure: The table 1 below give a complete overview of the composting materials chemical properties.

Treatments:

1) 100% grape pomace
2) 60% grape pomace + 40% PM
3) 60% grape pomace + 30% PM + 10% zeolite

Each treatment had a total weight of total of 60 Ibs which was divided into two parts (30 Ibs each) for aerobic and anaerobic composting with three repplicates. The anaerobic treatments was sealed in three layers of plastic and stored in an air-tight plastic container for 15 weeks, while the other part was left in open with 30 galons plastic containers (19.4 inc W, x 31.6 in L x 17.1 in H) with covers that do not limit air circulation and turned bi-weekly.

Minerals and pH analysis: The pH was measure directly using a probe (Bluelab Combo Meter Plus, Bluelab Cooperation Limited, New Zealand) at week four, six, eight, eleven, and fifteen. For minerals analysis, composite samples were collected on week eight, eleven, and fifteen for the aerobic and week fifteen for the anaerobic and sent to Texas A & M AgriLife Extension Service lab micronutrients analysis. Total N was measured with an elemental analyzer (Elementar, Hesse, Germany). Total P, K, Ca, Mg, Na, and S were measured with a Mehlich-3 extractant (Mehlich, 1978 and 1984) and determined by Inductively Coupled Plasma (ICP) spectrometer (Spectro Analytical Instruments GmbH, Kleve, Germany). Micronutrients were extracted using diethylenetriaminepentaacetic acid (DTPA) extraction solution (Lindsay and Norvell, 1978) followed by ICP measurement.

Data analysis: Data comparing more than two factors were analyzed using GLM procedure for one-way ANOVA by SAS University Edition version 3.8 (SAS Institute Inc., Cary, NC, USA), with the means separated at $p \leq 0.05$ using the Turkey test. Data comparing just two factors were analyzed using a t-Test.

Results and discussion

The effects of poultry manure and zeolite on grape pomace pH during composting

Adding PM and Zeolite to GP is a good way to increase the GP pH, which will increase microbial activities for fast compost maturity. According to Westover (2006), pH above six is required to activate compost microbes. The composting process of GP took fifteen weeks to raise the pH from 3.9 to 6.4 with slight drops at week 4 and 6. Adding 40% PM to GP increased the pH to 6 at week four with slight drop at week 6. , and with even higher and stable pH with 30% PM and 10% zeolite (Fig. 2). The zeolite has high pH (Table 1) and cation exchange capacity (Mpanga et al. 2020), which may be responsible for the stable pH increase of the GP composts.

The effects of poultry manure and zeolite on physical characteristics of grape pomace compost

The aerobic composting and the anaerobic composting with poultry manure and zeolite changed the GP color to dark brown indicating a mature compost. However, the anaerobic condition with only GP still had similar color as the original GP used at the start of the experiment (Fig. 3), which is an indication of non-decomposition due to limited bateria population in such conditions.

The effects of poultry manure and zeolite on grape pomace compost minerals concentrations

Adding poultry manure or poultry manure and zeolite

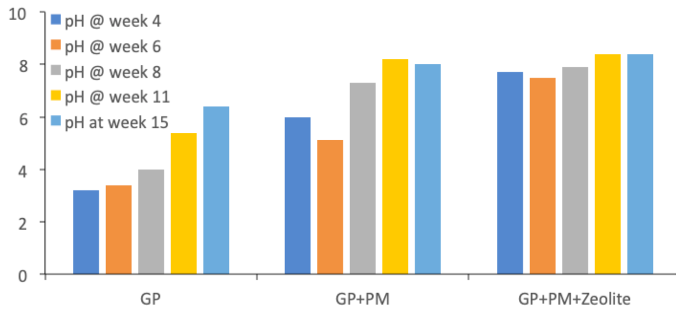

Figure 2: Effects of poultry manure and zeolite on grape pomace pH during aerobic composting. The red line is the pH of the fresh uncomposted grape pomace before composting started.

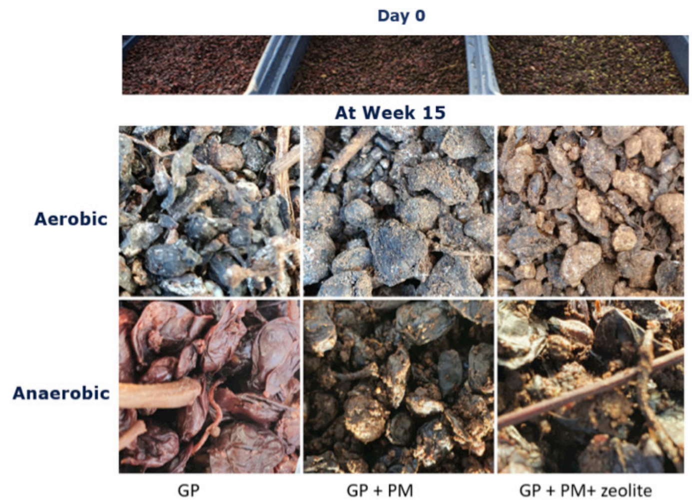

Figure 3: Physical characteristics of composted grape pomace with manure and zeolite under aerobic and anaerobic conditions for fifteen weeks.

improved the macro and micro mineral composition of grape pomace compost at week eight, eleven, and fifteen compared to only grape pomace (Table 2a, b, c, and d) and the base analysis of GP in Table 1. The physical appearance and mineral composition of composting GP with PM or PM plus zeolite were similar for both week eight and fifteen while decomposing only GP saw improvement at week fifteen when compared to eight, an indication of the prolonged time required in this case without PM or PM and zeolite (Table 2a, b, and c). In summary, adding PM or PM and zeolite increased GP pH (Figure1), potentially reduce the decomposing time (Table 2 a, b, and c, and improved the macro-and micro-nutrient components of the GP (Table 2d). Most composting microbes that help break down the organic material are active at pH above six (Westover, 2006), so the longer it takes for the GP to get to that pH means a delay in composting, as observed in the case of only GP (Fig. 2 and Table 2a).

Aerobic versus anaerobic grape pomace composting

For GP alone, aerobic composting gave better macro-and micro-nutrient availability at week fifteen than anaerobic composting (Table 3a). In summary, the aerobic and anaerobic compost did not give a distinctive difference between the two processes (table 3d).

Table 2: Poultry manure and zeolite effects on grape pomace compost minerals minerals concentrations (DM=dry mayer, PM=poultry manure, and GP=grape pomace).

		Macro and other minerals (Total (%))							Micro-nutrients (Total (ppm))				
	DM (%)	N	P	K	Ca	Mg	Na	S	Zn	Fe	Cu	Mn	B
a. Week 8													
GP	48.7	1.93	0.27	3.32	0.44	0.12	0.00	0.13	21.81	53.13	19.77	25.17	45.49
GP+PM	58.1	2.86	1.95	3.56	7.95	0.58	0.49	0.54	460.65	129.35	54.72	410.65	53.96
GP+PM+Zeolite	61.1	2.42	1.34	3.43	6.15	0.47	0.83	0.42	337.29	407.11	43.72	345.09	45.73
b. Week 11													
GP	54.5	2.03	0.13	1.5	0.19	0.05	0.00	0.07	11.08	26.24	8.97	11.05	18.81
GP+PM	62.6	2.88	0.81	1.56	2.94	0.24	0.21	0.23	197.18	59.85	24.31	169.91	20.62
GP+PM+Zeolite	67.5	2.28	0.55	1.65	2.49	0.20	0.36	0.18	144.42	214.72	18.35	146.94	15.66
c. Week 15													
GP	59.9	2.46	0.36	3.83	0.53	0.14	0.01	0.19	42.79	67.02	29.8	31.37	72
GP+PM	53.6	3.29	1.93	3.7	7.88	0.60	0.54	0.58	484.31	138.44	61.61	421.85	69.03
GP+PM+Zeolite	54.1	2.49	1.18	3.73	5.66	0.44	0.85	0.41	337.43	406.01	46.54	408.04	54.8
d. Averages of all weeks													
GP	54.4 a	2.1 b	0.3 b	2.9 a	0.4 b	0.1 b	0.0b	0.13 b	25.2 b	48.8 b	19.5 b	22.5 b	45.4 a
GP+PM	58.1 a	3.0 a	1.6 a	2.9 a	6.3 a	0.5 a	0.4 a	0.45 a	380.7 a	109.2 ab	46.9 a	334.1 a	47.9 a
GP+PM+Zeolite	60.8 a	2.4 b	1.1 a	2.6 a	5.2 a	0.4 a	0.7 a	0.34 a	295.6 a	272.9 a	35.9 a	291.4 a	34.8 a
Data for the weeks were obtained from composited samples with no data analysis. All weeks averages were analyzsed using the weeks as replicates (Same letters mean no significant difference when compared at p=0.05 turkey test)													

Table 3: Effects of aerobic and anaerobic conditions on grape pomace composting on available macro-and micro-nutrients (DM=dry mayer, PM=poultry manure, and GP=grape pomace).

		Macro and other minerals (Total (%))							Micro-nutrients (Total (ppm))				
	DM (%)	N	P	K	Ca	Mg	Na	S	Zn	Fe	Cu	Mn	B
a. Grape pomace													
Aerobic comp	59.9	2.46	0.36	3.83	0.53	0.14	0.01	0.19	42.79	67.02	29.8	31.37	72
Anaerobic comp	40.4	2.10	0.28	3.3	0.39	0.11	0.01	0.16	33.49	53.65	21.73	22.77	57.89
b. Grape pomace + Poultry manure													
Aerobic comp	53.6	3.29	1.93	3.7	7.88	0.6	0.54	0.56	484.31	138.44	61.61	421.85	69.03
Anaerobic comp	54.6	2.74	2.02	2.67	9.32	0.7	0.55	0.53	542.24	350.25	58.51	501.5	40.81
c. Grape pomace + Poultry manure + Zeolite													
Aerobic comp	54.1	2.49	1.18	3.73	5.66	0.44	0.85	0.41	337.43	406.01	46.54	408.04	54.8
Anaerobic comp	53.7	2.57	1.54	2.81	7.04	0.49	0.78	0.42	405.19	196.86	45.76	382.09	42.93
d. Averages of all treatments													
Aerobic comp	55.9	2.7	1.2	3.8*	4.7	0.4	0.5	0.4	288.2	203.8	46.0	287.1	65.3
Anaerobic comp	49.6	2.5	1.3	2.9	5.6	0.4	0.4	0.4	327.0	200.3	42.0	302.1	47.2

**= means significant difference t-test at p=0.05*

Comparison of anaerobic and anaerobic GP compost	
Aerobic compost	Anaerobic compost
1. Labor intensive on turning the compost pile	1. No labor for turning the compost pile
2. Could produce a foul smell and during composting	2. Less foul smell during the composting process
3. May attract bugs and flies	3. Fewer flies and bugs because it is covered
4. Requires turning equipment	4. No turning equipment required
5. The final compost is moist but not wet due to the open environment.	5. The final compost could be wet due to the enclosed environment for the process that does not allow moisture loss
6. More precautions need to be taken to avoid environmental pollution and volatile ammonia gas loss	6. Liquid and mineral leakages can be minimized due to the enclosed system
7. It has a low initial facility cost as the composting can be done in open space	7. It may require some investment into air-tight facilities (containers and concrete)

Recommendations for composting grape pomace

These are based on the recommendations made by Westover (2006) as follows;

- Compost microbes prefer a pH of 6.2 to become active (pH >6 desired), so add manure, lime, or other feedstock to your grape pomace to increase the pH for a faster composting
- Grape pomace has a C: N of 1:17 to 1:30, which is appropriate for composting.
- Feedstock added to pomace should also have C: N ratio suitable for composting (1:20 to 1:30)
- Grape pomace has high lignin content in the seeds (17% to 35%), which may limit aerobic decomposition if unturned
- Avoid more than 60% moisture in aerobic composting to prevent continual fermentation and acetic acid production, resulting in low-quality compost
- Application of 1-5 tons GP per acre each year is considered to be maintenance depending on the initial soil fertility and specific plant requirements
- Turn the pile once every two weeks, or once a week. Turning two times per week or more can result in an undesired reduction in nitrogen and organic matter content.

- In aerobic composting, temperatures of 130-140oF need to be attained in the compost pile for the first 1 to 2 weeks, in order to kill grape seeds and potential pathogens
- Keep pile temperature under 160oF (by reducing turning frequency) to reduce the risk of combustion and loss of beneficial organisms
- Grape pomace composting may take up to 6 months to mature, dependent upon composition of the pile, turning frequency, moisture, and temperature of piles or windrows. Mature compost is crumbly and dark brown such that you can not identify the original materials (GP skin). It should smell earthy with in active microbial activities, hence the temperature of the pile is drastically low.

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