Comparative Analysis of Aerobic Composting of Fresh Cut Floral Waste[1]

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Abstract

Increased levels of pesticide applications are used when growing cut flowers in many developing countries where most are grown and where they are less restrictive on pesticide use when compared to regulations in the United States. Therefore, special consideration should be given to cut flower disposal from floral shops that utilize flowers from other countries due to the potential for pesticide leaching into land and waterways. Most retail florists in the industry dispose of their floral waste in municipal dumpsters. While the United States Department of Agriculture (USDA) has stringent guidelines to prevent the importation of insect and disease pests, there are no regulations regarding residual pesticides or other harmful chemical contamination on imported floral crops. Composting is one technique used as an alternative waste management method to traditional landfill dumping and can produce a valuable commodity for agricultural, horticultural, and related industries. The main objectives of this study were to compare the physicochemical properties of two different compost protocols that incorporated cut flower and foliage waste and to determine whether pesticide residues remained in the finished compost. Analysis of results were based on the U.S. Composting Council's Tests Methods for the Examination of Composting and Compost used by the U.S. Composting Council's Seal of Testing Approval (STA) program. When compared to STA standards, both compost samples pH, total nitrogen, C:N ratio, and bioassay were found to be within normal ranges for compost sold in the horticulture industry. Chemical analysis found the levels of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc all to be well below set industry standards. Additionally, the compost was tested for 23 herbicides and insecticides. Of those, two herbicides (clopyralid and MCPA) and one insecticide (lufenuron) were found in the sample in trace amounts, though well below USDA standards for food crops after the composting process. Results indicated floral waste collected from retail flower shops has the potential to be incorporated into a composting system to create a quality compost suitable for use in the horticulture industry.

Index words: compost, environmentalism, floriculture, flowers, sustainability, waste management.

Significance to the Horticulture Industry

The floral industry is currently undergoing a transformation as it attempts changes to become more environmentally friendly (Papas 2021, Thursd 2020). Over the past several years, more environmentally conscious products have been developed to allow florists to construct floral designs in a more environmentally friendly manner. However, little research has been conducted investigating what can be done with the waste produced as a result of floral design. This research sought to further understand how floral waste can be used within a compost system. Results suggest floral waste has the potential to be used in a mound compost system to create a quality compost suitable for use in the horticulture industry.

Introduction

In recent years there has been a push in the floral industry towards sustainable practices and an environmental awareness of the impacts of the business given current production and management standards and strategies (Papas 2021, Thursd 2020). At the biennial Trend Summit 2020 Conference, Symposium, and Workshop in which professionals within the floral industry meet to discuss current trends and the direction in which floral design should be guided to keep pace with an ever-changing world, the first statement on sustainability was crafted which states, in part, a belief in the zero-waste hierarchy to rethink, redesign, reduce and repurpose (Thursd 2020).

Research investigating retail flower shop owners' perceptions of environmentalism and willingness to compost found 82.3% of florist surveyed indicated a willingness to sort compostable floral waste produced at their shop from non-compostable material if it meant the floral waste produced at their retail flowers shops could be recycled by composting through collaboration with other organizations such as master gardener programs, universities, community gardens, and city composting programs (Etheredge and Waliczek 2020). During a personal interview with the manager of The University Florist, a full-service retail flower shop, located on the campus of Mississippi State University (Mississippi State, MS), it was found, on average, that 27 kg (60 lb) of fresh cut floral is disposed of weekly, an estimated 1,415.20 kg (3,120 lb) / per year. It was also found that most retail florists in the industry dispose of their floral waste in municipal dumpsters in plastic garbage bags (T. Bowden, personal communication, University Florist, Mississippi State). There are an estimated 13,200 retail flower shop locations in the United States, comprised of single and multiple location companies (Dun and Bradstreet 2019). States with the highest employment levels of florists include California, Texas, Florida, Missouri, and New York (Bureau of Labor Statistics 2018).

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Of the top ten fresh cut flower exporters to the U.S., seven (Colombia, Ecuador, Mexico, Guatemala, Costa Rica, Peru, and Thailand), are considered developing nations (United Nations 2019, World City 2020). While the United States Department of Agriculture (USDA) has stringent guidelines to prevent the importation of insect and disease pests , there are no regulations regarding contamination with residual pesticides and other harmful chemicals on imported floral crops (USDA 2020). Also, there is a lack of regulation regarding the maximum residue limits allowed on cut flowers, which has led to cut flowers often getting sprayed at the maximum recommended dosage of pesticide up until the time of harvest and then shipped directly to market (Toumi et al. 2017). Research investigating residual pesticides on fresh cut flowers found, on average, 10 active residual pesticides per sample and a pesticide load of 15.72 $mg \cdot kg^{-1}$ of flowers (Toumi et al. 2016). The three most frequently detected insecticides on fresh cut flowers were clofentezine, lufenuron, and flonicamid, which were found on 90% of samples tested (Toumi et al. 2017).

Composting is one technique used as an alternative waste management method to traditional landfill dumping and has the means to produce a valuable commodity for agricultural, horticultural, and related industries (Walker et al. 2006). It contributes to reducing waste transportation, treatment cost, and landfill volume, and can also be an innovative way to involve waste generators in their own waste treatment, raising community environmental awareness (Arrigoni et al. 2018). Compost has also been found to break down pesticides through "mineralization," the breakdown of organic compounds into their inorganic and organic components, volatilization into the atmosphere, and undergoing biotransformation, rendering the pesticide inactive (Michel and Doohan 2003). Past research investigating the composting potential of retail floral waste in the U.S. or residual chemicals from floral shop waste in compost could not be found. The main objectives of this study were to compare the physicochemical properties of two different compost protocols that incorporated cut flower and foliage waste and to determine whether pesticide residues remained in the finished compost.

Materials and Methods

A case study approach was used in this research and is considered appropriate when collecting data in an applied setting in which little information is known regarding the topic at hand (Noor 2008).

Material collection. Floral waste was collected from two retail flower shops located in Starkville, MS and from floral design classes taught at Mississippi State University. Floral waste was sorted from non-compostable material and stored in 121 L (32 gal) trashcans until enough floral waste had been collected to start the compost piles. No garbage bags were used in this study. Flowers used in this study were sourced primarily from South American cut flower farms in Colombia and Ecuador and consisted of rose (*Rosa* spp. L.), carnation (*Dianthus* spp. L.), snapdragon (*Antirrhinum* spp. L.), gerbera daisy (*Gerbera* spp. L.), daisy (*Chrysanthemum* spp. L.), baby's breath (*Gypsophila* spp. L.), leather leaf [*Rumohra adiantiformis* (G.Forst.) Ching], and salal (*Gaultheria shallon* Pursh).

Horse (*Equus caballus* Linnaeus, 1758) manure was collected to be used as an amendment to the compost system. The manure was collected from free range horses located in Starkville, MS and fed predominantly on grass that was not treated with insecticides or herbicides. Horse manure has been found to be an excellent composting material due to its ability to decompose quickly while having a low odor potential (Rynk et al. 1992).

Tree branches, predominantly *Pinus* (pine), were collected from the cut flower garden located at Mississippi State University and passed through a woodchipper (SuperHandy Wood Chipper Shredder Mulcher Ultra Heavy Duty 7HP 212cc, Great Machinery Corp., Ontario, CA) at a reduction ratio of 1:15 to produce the dried carbon component of the compost piles. The garden from which the dried material was collected is not treated with insecticides or herbicides.

Compost pile creation and management. Four compost piles, each measuring 0.91 m^3 (1.0 yd^3), were created. The piles were managed given standards outlined by the U.S. Department of Agriculture (USDA) for passive composting where individual piles were kept small to allow for passive air movement throughout and for ease of turning the compost by hand to reestablish porosity (USDA 2010).

Piles were constructed on the Mississippi State University campus in Starkville, MS. Two piles were created using floral waste (25%), horse manure (25%), and dried woodchips (50%). Two piles were created using floral waste (50%) and dried woodchips (50%). Materials were thoroughly mixed using a hand shovel and were turned and monitored for moisture content, pH, and temperature every seven days (Sembera et al. 2019). Moisture content was maintained between 40% and 65% (Soil Moisture Meter; Guangzhou Amittari Instruments Co., Guangzhou, China). Additionally, the pH was monitored to ensure it stayed between 5.5 and 9.0. No amendments were required to maintain the pH within desired range (pH meter, Gain Express Co., Kowloon, Hong Kong). The temperature was monitored to determine when the compost had entered the curing phase. The curing phase occurs at temperatures between 10-40.5 C (50-105 F), when the internal pile temperature is close to that of the ambient outdoor air temperature (Rynk 1992). The beginning of curing is observable by a sustainable drop in temperature and lack of reheating after turning. (REOTEMP Heavy Duty Compost Thermometer, San Diego, CA, Rynk 1992). The piles remained in an active composting stage for approximately 16 weeks and cured for 4 weeks to complete the composting process after the active composting stage (Dougherty 1999, Rynk 1992).

Pre-composting pesticide sampling and determination. Cut flower and foliage samples representative of all the different materials used in the two different compost samples were collected and sent to a commercial lab before composting (Anatek Labs, Moscow, ID) to determine the initial concentrations of selected herbicides and insecticides. Sampling techniques adhered to specifications by the lab contracted for testing (Anatek Labs, Moscow, ID). Samples from 20 places in each compost pile were collected. Samples collected from piles using the same protocol were mixed thoroughly to make one 3.7 L (1.0 gal) composite samples representative of each compost protocol. Samples of pre-composted cut flowers and foliage were analyzed by Anatek Labs for methiocarb, 2,4,5-T, 2,4,5-TP, 2,4-D, 2,4-DB, acifluorofen, bentazon, chloramben, clopyralid, dalapon, dimethyl tetrachloroterephthalate (DCPA), dicamba, dichlorprop, dinoseb, 4-chloro-2-methylphenoxy (MCPA), methylchlorophenoxypropionic acid (MCPP), pentachlorophenol, picloram, triclopyr, clofentezine, flonicamid, lufenuron, and N,N-Diethyl-3-methylbenzamide (DEET). Determination of herbicides and insecticides analyzed for were made based on a review of past research (Atwood 2017, Barrows 2021, Toumi et al. 2016, Toumi et al. 2017, U.S. Composting Council 2022).

Compost quality sampling and analysis. Once the compost piles had sufficiently cured, samples representative of each of the two compost protocols were taken. Sampling techniques for the finished compost adhered to specifications by the Agricultural Analytical Services Laboratory at the Pennsylvania State University (State College, PA). For each of the two compost protocols, cured compost samples were collected from three different depths at five locations, for a total of 5 samples per protocol and 10 overall. The 5 samples per protocol were combined to make one 3.7 L (1.0 gal) composite sample representative of each compost protocol. Two 3.7 L (1.0 gal) composite samples were collected and analyzed. The Agricultural Analytical Services Laboratory's at the Pennsylvania State University tested the samples for percent solids, bulk density, organic matter, pH, soluble salts, total nitrogen, particle size, total carbon, carbon:-nitrogen ratio, phosphorus, potassium, calcium, magnesium, aluminum, iron, manganese, sodium, sulfur, arsenic, cadmium, copper, lead, molybdenum, mercury, nickel, selenium, and zinc. Bioassay tests and respirometry (CO2 evolution) conducted by the Pennsylvania State University were used to measure the overall stability and maturity of the compost sample at the compost quality testing laboratory. Bioassay tests analyzed 'Marketmore 76′ cucumber (Cucumis sativus L.) seedling emergence and vigor to identify potential phytoxin presence. Respirometry was used to measure the relative microbial activity which is an indicator of stability in the sample (U.S. Composting Council 2002).

Finished compost samples were also gathered and sent to be evaluated for herbicide and insecticide residues by a commercial lab (Anatek Labs, Moscow, ID), analyzing for the same herbicides and insecticieds for which the pre-composted cut flower and foliage samples were tested. The same sampling techiques were used as stated previously.

Data analysis. Frequency and descriptive data were reported for each protocol on compost quality standard attributes. No true control pile of compost was included within the study since, in compost quality testing, compost samples are compared to overall compost quality standards for the industry. The U.S. Composting Council does not have established normal ranges for all herbicides and insecticides found within compost. Rather, the USDA has established maximum herbicide and insecticide residue limits allowed for a wide variety of food commodities (U.S. Composting Council 2002, USDA 2021). These figures were used as a reference regarding pesticide residue limits during analysis.

Results and Discussion

When compared to STA standards, all compost samples had values for the variable of pH, total nitrogen, carbon, and bioassay tests within normal ranges for compost sold in the horticulture industry (Table 1). Chemical analysis found the level of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc all to be well below set industry standards.

The pH for both compost protocol samples was 7.4, slightly alkaline. A pH of 7.4 falls within the U.S. Composting Council's (2002) ideal range (5.0-8.5) for compost pH.

Compost soluble salt levels typically range from 1 to 10 mmhos·cm^{-1}. High salinity may be toxic to plants. Soluble salts for both compost protocol samples were found to be less than 1.0 mmhos.cm^{-1} (Table 1). Ideal soluble salt levels will depend on the end use of the compost (US Composting Council 2002).

Overall percent solids for samples from both protocols were low while moisture was high when compared to industry norms (Table 1). The samples from the compost protocol with horse manure (48% solids, 52% moisture) aligned more closely to industry standards when compared to samples from the protocol comprised of floral waste and woodchips (33.3% solids, 66.7% moisture) (Table 1). The overall low percent solids and high moisture level when compared to industry standards are most likely due to the nature of floral waste being high in moisture content. This indicates a need for a higher ratio of dried material in relation to floral waste when creating the initial protocol to achieve ideal norms for compost as set by the U.S. Composting Council (2002). These findings also indicate compost created using floral waste may produce a more desirable finished product using additional compost amendments such as horse manure.

The organic matter content (dry weight basis) of finished compost should be in the range of 30-70 % (U.S. Composting Council 2002). Analysis of the compost samples found the compost protocol containing horse manure fell within the expected range (Table 1). The samples from the compost protocol comprised of just floral waste and woodchips had an organic matter content of 80.2%, higher than the standard range for finished compost. Compost with a high level of organic matter is an indicator of compost that may not be fully composted/cured (Sullivan et al. 2018). The addition of horse manure may have increased the rate of composting by creating a more balanced C:N ratio, thereby increasing microbial activity within the compost piles (LeBlanc et al. 2009).

The total nitrogen and carbon content were within ideal ranges for both protocol samples (Table 1). The total

Table 1. **Compost quality test results of compost created from floral waste collected from a retail flower shops using the U.S. Composting Council's Seal of Testing Approval program standards in the study of a comparative analysis of aerobic composting of fresh cut floral waste.**

	Floral waste woodchip protocol		Floral waste, horse manure, woodchip protocol		
Variable (units)[z]	Results (as is basis)	Results (dry wt. basis)	Results (as is basis)	Results (dry wt. basis)	Normal range (USCC)[y]
pH	7.4	-	7.4	-	5.0-8.5
Soluble salts (mmho.cm^{-1})	0.76	-	0.58	-	1-10
Solids (%)	33.3	-	48	-	50-60
Moisture (%)	66.7	-	52	-	40-50
Organic matter (%)	26.7	80.2	16.9	35.2	30-70 (dry wt.)
Total nitrogen (%)	0.4	1.2	0.4	0.9	0.5-2.5 (dry wt.)
Carbon (%)	13.4	40.1	7.6	15.8	<54 (dry wt.)
Carbon-to-nitrogen (ratio)	34.10	34.10	18.20	18.20	<21:1 (dry wt.)
Phosphorus (%)	0.09	0.27	0.17	0.36	-
Potassium (%)	0.11	0.34	0.15	0.32	-
Calcium (%)	0.55	1.64	0.52	1.09	-
Magnesium (%)	0.06	0.18	0.08	0.18	-
Arsenic (mg·kg^{-1})	0.7	2.2	0.6	1.6	<75
Cadmium (mg·kg^{-1})	0.4	1.2	0.3	0.6	<85
Copper (mg.kg^{-1})	5.8	17.4	16.3	33.9	<4300
Lead (mg·kg^{-1})	1.6	4.7	1.9	4.0	<420
Mercury (mg·kg^{-1})	0.014	0.014	0.011	0.023	<840
Molybdenum (mg·kg^{-1})	1.2	3.5	4.1	8.5	<57
Nickel (mg·kg^{-1})	1.8	5.3	2.0	4.2	<75
Selenium (mg·kg^{-1})	0.9	2.6	1.2	2.6	<100
Zinc (mg·kg^{-1})	62.3	187.0	80.0	166.7	<7500
Bioassay: emergence (% of control)	100	-	100	-	>90 (very mature)
Bioassay: seedling vigor (%)	100	-	100	-	>95 (very mature)
Respirometry (mg carbon dioxide/ g organic matter/d)	2.2	-	1.1	-	1-2 (stable)

[z]1 mmho·cm^{-1} = 1 dS·m^{-1}, 1 mg·kg^{-1} = 1 ppm, 1 mg·g^{-1} = 1,000 ppm.

[y]U.S. Composting Council (2002).

carbon to nitrogen ratio for the compost sample that included horse manure was (18.21:1) the ratio was within ideal ranges set by the U.S. Composting Council (2002). The compost sample collected from piles created from just flower waste and woodchips had a carbon to nitrogen ration of 34.10:1, slightly higher than recommended by the U.S. Composting Council (2002). Compost with carbon to nitrogen ratios of 30:1 or higher tend to immobilize nitrogen when added to soil, while compost with lower carbon to nitrogen ratios tend to mineralize organic nitrogen, making it available to plants (U.S. Composting Council 2002).

Bioassay tests evaluated the maturity of the compost samples based on emergence of cucumber seedlings and their overall vigor. Compost is rated as ''very mature'' if emergence readings are greater than 90% and seedling vigor readings are greater than 95% (U.S. Composting Council 2002). Measurements of both seedling emergence and vigor for the compost samples were 100%, indicating both compost protocols to be very mature (Table 1).

Respirometry (CO_2 evolution) tests provides a measurement of the relative microbial activity in a compost and can therefore be used as an estimate of compost stability. Compost stability is measured on a stability scale ranging from <1(very stable) to >11(raw feedstock). A stability rating between 1 to 2 is "stable" compost, while a rating ranging between 2 to 5 is considered to be "curing compost" (U.S. Composting Council). The sample that included horse manure was found to have a stability rating of 1.1 while the sample containing only floral waste and woodchips had a stability rating of 2.2.

Pre-composted versus composted cut flower and foliage pesticide residue levels. Of the 23 insecticides and herbicides for which tests were conducted, two herbicides (clopyralid and MCPA) and one insecticide (lufenuron) were detected in either the pre-composted floral waste and/or the finished compost samples (Table 2).

Trace amounts of MCPA were detected in both pre-compost floral waste samples. MCPA is classified as a systemic postemergence phenoxy herbicide used to control broadleaf annual and perennial weeds (Pohanish 2015). The maximum residue limit on food commodities in the U.S for MCPA is 0.5 ppm (USDA 2021). After composting, no trace amounts of MCPA were detected in either finished compost samples.

Clopyralid is listed as a persistent herbicide by the U.S. Composting Council and has an estimated half-life of 1-2 years in compost (U.S. Composting Council 2015). Compost containing clopyralid residues of 0.003 ppm or less has been deemed safe for plant use (U.S. Composting Council 2015). Clopyralid was detected in the pre-compost cut flower and foliage sample that included the addition of horse manure. No trace amounts of clopyralid were found in finished compost samples.

Lufenuron was found only in the compost protocol made from floral waste and dried woodchips. Lufenuron is classified as a benzoylureas and acts as an insect growth regulator which attacks an insect's nervous system (Ware

Table 2. Concentrations of herbicides and insecticides detected in shredded floral waste, horse manure, and shredded woodchip protocol both before and after composting in the study of a comparative analysis of aerobic composting of fresh cut floral waste.

	Floral waste woodchip protocol		Floral waste, horse manure, woodchip protocol		
Pesticides[z]	Concentration before composting	Concentration after composting	Concentration before composting	Concentration after composting	Acceptable residue limit[y]
Clopyralid ($ug{\cdot}kg^{-1}$)	0.00	0.00	9.07	0.00	3.00
MCPA ($ug{\cdot}kg^{-1}$)	144	0.00	76.5	0.00	500.00
Lufenuron ($ug{\cdot}kg^{-1}$)	0.00	18.2	0.00	0.00	1360.00

[z]1 $ug{\cdot}kg^{-1} = 0.001$ ppm.

[y]Acceptable residue limits are in the unit of (ug/kg) (USDA, 2021).

and Whitacre 2004). It is taken up by ingestion rather than by contact (Ware and Whitacre 2004). Within the finished compost protocol constructed from floral waste and woodchips, 0.0182 ppm of lufenuron was found, a concentration well below acceptable limits (Table 2). The maximum residue limit on food commodities for lufenuron is 1.36 ppm (USDA 2021). Past research has found analytical errors of about 30% in compost field studies . This could explain why clopyralid and lufenuron were not found in all samples (Brandli et al. 2006, Kupper et al. 2008).

In conclusion, while individual floral shops are unlikely to compost their own organic waste produced at their shop, past research has found florists are willing to collaborate with other organizations such as master gardener programs, universities, community gardens, and city composting programs if it meant floral waste produced at their shops could be composted (Etheredge and Waliczek 2020). Such collaborations would not only serve to offset floral waste from entering landfills but could also give florists the chance to promote their business as more environmentally friendly. A growing number of consumers, especially younger consumers, are starting to make purchase selections based on how ‘‘green’’ a company is (Nielsen 2018).

Results from this study indicated floral waste collected from retail flower shops has the potential to be used in a composting system to create a quality compost suitable for use in the horticulture industry and free from residual pesticides. However, to meet ideals on some compost quality variables, research investigating various floral waste proportions should be further investigated. Furthermore, results from this study indicated additional amendments such as manure or alternative urban or agricultural wastes may be used to help create a higher quality compost.

While the amount of floral waste composted in the study was small scale, the findings are valuable given that no research was previously conducted. Additionally, little research has been conducted on best practices for disposing of cut floral waste created by retail flower shops or on how the retail florist might contribute to making the industry more environmentally sustainable. Overall, this research is a first step towards understanding best disposal practices for floral waste. Future studies may increase the scale or proportions of composted waste to examine if herbicide and insecticide concentrations vary in larger studies.

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