Evaluation of Aerated Container Composting of University Preconsumer and Postconsumer Food Waste

Britt Faucette, K.C. Das, and Mark Risse
Biological and Agricultural Engineering, Bioconversion Research and Education Center,
University of Georgia, Athens, Georgia 30362, USA

ABSTRACT

Composting of food waste generated from the University of Georgia's cafeterias was evaluated using an agitated aerated composting system. The goal of the project was to determine if all of the University's food waste could be recycled using six Earth Tubs. Secondary evaluations investigated the amount of leachate produced, odor generated, speed of composting, quality of compost, cost savings to the University, and amount of waste diverted from the Clarke County Landfill. Three mixes of food waste and yard waste were evaluated, namely 1:2 (food waste to yard waste) 1:1 and 2:1. Temperature, percent oxygen, moisture content, compaction rates, and aeration rates were monitored in order to compare composting strategies. Temperatures exceeded 55 degrees C for more than 72 hours to ensure pathogen reduction. Total contaminants and human-made inerts averaged 0.5%. A ratio of 2:1 was determined to work best under experimental conditions. Ammonia (NH_3) concentrations peaked at 560 ppm. Leachate production was highest in the 2:1 mixture generating 117 liters for the duration of the study.

INTRODUCTION

In 1990, 13.2 million tons (11.88 billion kg.) of food waste amounting to nearly 7% of the municipal solid waste stream was landfilled in the United States (US-EPA, 1993). As demands on landfills increase, tipping fees continue to climb, and valuable resources are wasted, the University of Georgia's Engineering Outreach Program of the Department of Biological and Agicultural Engineering is experimenting with ways to reduce waste and prevent pollution. At the Bioconversion Research and Education Center on the University of Georgia (UGA) campus a pilot study was initiated in the fall of 1999 to begin recycling pre and postconsumer food wastes. The study involved all four of the university cafeterias which produce 19,000 meals a day. The paper reports on a pilot study of all food waste (preconsumer and postconsumer) produced from the University of Georgia's cafeterias for four days.

The objectives of this study were: 1) to determine if the agitated aerated composting system can be used to recycle all the universities food waste; 2) evaluate the speed and function of the agitated aerated system; 3) evaluation of mixing ratios to asses their impact on the composting process; 4) determine the amount of leachate produced per unit volume of food waste; 5) evaluate odor levels based on ammonia and hydrogen sulfide concentrations; 6) to determine if the system meets the US-EPA temperature requirement to eliminate plant and human pathogens; and 7) to determine air flow rates based on amount of food waste in an in-vessel system. The paper reports on a pilot study of all food waste (preconsumer and postconsumer) produced from the University of Georgia's cafeterias for four days

In 1998 the total throughput of composted food residuals totaled 230,000 tons (Goldstein, Glenn, Gray, 1998). This included 250 food waste composting projects nationwide, with 187 in full scale operation, 37 pilot projects, and 26 in development (Goldstein, Glenn, Gray, 1998). Of the 250 projects, 115 were on-site institutional projects, 10 were university pilot projects, 7 were full scale university operations, and 1 was located in the state of Georgia (Goldstein, Glenn, Gray, 1998). On site composting systems at universities may be the fastest growing area of food service composting (Kunzler, Roe, 1995). A University of Maine study demonstrated that an in-vessel compost system can reach required temperatures faster than open windrow systems, as well as decrease the likelihood of vectors including odors (Donahue, Chalmers, Storey, 1998). In addition, growing numbers of cafeterias and restaurants are installing pulpers for volume reduction and to create a feedstock for composting (Kunzler, Roe, 1995). A 10% decrease in initial food waste moisture content can result in nearly half as much compost, which may be of greater importance to groups who are more interested in waste reduction rather than marketing the final product (Lowe and Bockmaster, 1995). A recent study at a midwestern university found the total cost in disposal fees for service waste at one cafeteria including water, energy, and sewer (excluding tipping fees) was $3,582 a year. If local landfill tipping fees ($35) are included with the estimated total weight of food waste generated by a university the size of UGA (1,122 tons), annual tipping fees would be $39, 287.

MATERIALS AND METHODS

System Description

The aerated composting containers are designed to hold 3.5 cubic yards of compost (Green Mountain Technologies, 1998). The design of the Earth Tubs includes a 2 horsepower auger for mixing feedstocks and a blower for forced aeration. The container is a circular tapered fully enclosed tub that is four feet deep. The base of the tub is 64 inches and the lid is 89 inches in diameter. It is made of durable double walled plastic with polyurethane foam insulation. Feedstock is loaded through a hatch on the lid as the vertically mounted auger mixes the incoming material. While the auger itself is motorized, it is manually rotated around the tub and from center to outer edge. Compost is removed manually through two trap doors on opposite sides of the tub. The aeration system pulls air through the compost from the top and is discharged from the tub after passing through a perforated floor chamber. The floor chamber also collects leachate and discharges it through the same aperature as the blower. Two temperature thermisters per tub were connected to a central computer that monitored temperature in the middle of the pile and outer portion of the pile.

Feedstocks

The university food waste was a mixture of preconsumer and postconsumer food waste at the time of collection. University Food Services pulps the food waste at the cafeteria before it is discarded into a separate dumpster. The pulping process removes between 10% and 20% of the moisture content from the food waste. The University Physical Plant collected the food waste and transported it to the University of Georgia Bioconversion Research and Education Center. The food waste was dumped on a concrete pad and immediately weighed and loaded into the three compost containers.

Yard waste from the university was used as the bulking agent. The yard waste consisted mainly of chipped stems and leaves. The three containers were partially loaded with yard waste prior to delivery of the food waste.

Mixing Ratios

Initially, three recipes were selected for investigation. These included volumetric mixing ratios of 1:1 (food waste : yard waste), 2:1, and 1:2. Table 1 provides analytical information on the raw substrates prior to mixing. Each of these ratios were expected to maintain appropriate C:N ratios (30:1) and moisture contents (60%) (Lowe and Buckmaster, 1995). Incoming food waste was loaded in the aerated containers over four days. Table 2 shows the mixture ratios and actual composition of each container.

Table 1: Selected Properties of Food Waste and Yard Waste

Material	Food waste	Yard waste
Carbon, %	51.3	50.2
Nitrogen, %	5.7	1.1
Sulfur, %	0.4	0.1
C:N	10:1	50:1
Moisture, %	70.9	52.8
Bulk Density (wet) kg/m^3	760	358

*Moisture content of un-pulped food waste is 80-90%

Table 2: Target and Actual Mixing Ratios (food waste: yard waste), and Initial Contents of Aerated Containers

	Container 1	Container 2	Container 3
Target Ratio	2:1	1:2	1:1
Actual Ratio by weight (kg)	1:1.3	1:4.3	1:2.3
Actual Ratio by volume (L)	2:1.1	1:1.8	1:1

C/N Ratio	24.3	35.7	30.0
Moisture content, %	61.83	59.24	64.43
Total weight (kg)	1623.5	1361.6	1530.2
Total volume (L)	2611.3	2736.4	2668.2
Total food waste (kg)	1286.9	758.3	1074.5

Process and Procedures

Once the containers were filled to capacity based on individual mixing ratios the raw ingredients were mixed using the auger. The containers were kept inside a building to limit extreme ambient temperature fluctuations. Each aerated container had two thermisters that were inserted into the compost pile. One was placed in the center of each pile, the other was placed in the outer portion of the pile. The thermisters measured temperature readings every 5 minutes and were connected to a Central InterfaceUnit that logged and graphed the readings. Each container had a 10 watt blower that provided forced aeration to the compost. The blowers were continually run at maximum power unless the compost seemed to dry too quickly at which point the blowers were turned off until moisture and temperature levels returned to optimum levels. The aeration rate was based on recommendations provided by the manufacturers of the containers. A 2 inch PVC pipe was attached to the blower to monitor air flow rates and air velocity rates. A 5 gallon (18.95 L) bucket was attached to the PVC pipe to collect and measure leachate quantities.

Each container was mixed twice a week. Leachate quantities were measured using a graduated cylinder (leachate was measured daily for the first two weeks and less frequently thereafter). Compaction rates were monitored by measuring the height of each pile in three locations before each agitation and after each agitation. Percent oxygen inside the compost matrix was measured prior to agitation by using a portable O_2 analyzer with a stainless steel probe. Readings were taken from the center of the pile and from the blower discharge pipe. Air velocity and air flow rates were measured from the center of the PVC pipe attached to the blower using a hot-wire anemometer. Following this, each pile was turned using the motorized auger. After agitation Drager tubes were used to measure ammonia (NH_3) and hydrogen sulfide (H_2S). Gas readings were taken from the discharge pipe of the blower. Finally, a sample from each pile was obtained and oven dried to estimate moisture content. If moisture content fell below 40% water was added to the pile while agitating. Enough water was added to increase the moisture content to 60%.

Once temperatures decreased to ambient levels composite samples were taken for physical, chemical, and agronomic analysis. The compost was removed from the containers, weighed, and screened to remove contaminants like plastic film. Finally, the compost was put outdoors and covered for stabilization. The finished compost will be land applied in demonstration plots at UGA’s Bioconversion Research and Education Center.

RESULTS AND DISCUSSION

Temperatures and Pathogen Reduction

All three mixes reached temperatures in excess of 55 degrees C (Figure 1) for three days to ensure reduction of human pathogens (EPA, 40 CFR Part 503). Temperatures fluctuated with moisture content and aeration. When moisture contents fell below 35%, temperature levels decreased significantly. Forced aeration was continual for the first 16 days and then ceased because of excessive drying. Moisture contents stabilized and temperatures increased immediately after blowers were turned off. All three mixes maintained ambient temperature levels after 73 days. The 2:1 treatment experienced temperatures at or above 55 degrees C, more frequently than the others, for 29 days in total. The 1:1 maintained temperatures at or above 55 degrees C for 21 days. Temperatures fluctuated quite drastically between the center and outer edges of the piles. The center heated faster, however the outer portions of the pile maintained heat longer. This may be due to drying effects occurring more rapidly at the center of the pile. Figure 1 shows the average daily temperatures for container 1 (all three containers were similar).

Weight and Volume Reduction

All three experiments exhibited 75 to 80% wet weight reduction from beginning to end with container 1 demonstrating the greatest weight reduction (Table 3). Container 3 showed the greatest volumetric reduction at 61%. All three experiments had volumetric reductions between 55 and 61%. Container 1 had the heaviest mixture but produced the lightest compost.

Table 3: Total Weight and Volume Changes After Composting

	Container 1	Container 2	Container 3
Initial (wet)	1623.5 kg/ 2611.3 L	1361.6 kg/ 2736.4 L	1530.2 kg/ 2668.2 L
(dry)	487.1 kg/ 783.4 L	544.6 kg/ 1094.6 L	535.6 kg/ 933.9 L
Final (wet)	321.9 kg/ 1114.3 L	344.5 kg/ 1224.2 L	373.5 kg/ 1034.7 L
(dry)	231.8 kg/ 780.0 L	244.6 kg/ 869.2 L	190.5 kg/ 527.7 L
% Reduction (wet)	**80.0% / 57.4%**	**74.7% / 55.3%**	**75.6% / 61.2%**
(dry)	**52.4% / 0.1%**	**55.1% / 20.6%**	**64.4% / 43.5%**

Water Additions

Water was added to a container if the moisture content fell below 40%. Container 1 only required one moisture amendment, while the other two containers required three (Table 4). This was probably due to the higher initial moisture content due to the use of a greater amount of food waste in the treatment. Container 3 required the most water over the duration of the study at 1363.95 kg compared to 815 kg and 664 kg for containers 2 and 1 respectively. Figure 2 indicates the moisture content fluctuation of each reactor.

Table 4: Water Added to Containers during Composting

Date	Container	*Amount (Kg.)	% Increase
12/16/99	2	271.8	**21%**
1/3/00	3	600.8	**39%**
1/5/00	2	241.6	**20%**
1/13/00	3	457.2	**32%**
1/24/00	2	271.8	**18%**
1/27/00	1	664.2	**45%**
2/10/00	3	306.0	**18%**

*Water additions are based on faucet hose dispensing 16.65 kg/min.

Leachate Production

All three experiments produced leachate ranging from 35 liters in container 2 to 117 liters in container 3 (Table 5). Most leachate was produced in the first week with virtually none produced after two weeks (Figure 3).

Table 5: Leachate Production Totals from Food waste

Container	Food Waste	Leachate Produced	kg (food waste)/L (leachate)
1	1286.9 kg./ 1625.9 L	**117.43 L**	**13.85: 1**
2	758.3 kg./ 970.2 L	**35.69 L**	**27.18: 1**
3	1074.5 kg./ 1334.1 L	**73.82 L**	**18.07: 1**

Odor Production

Odor problems were persistent on all reactors. Hydrogen sulfide (H_2S) monitoring stopped after 21 days because of no detectable concentrations. Container 1 produced the most ammonia and was often difficult to work with (Figure 4). This was probably caused by the higher moisture content. Ammonia levels decreased over time. After the first month odor levels decreased dramatically but increased with moisture additions.

Oxygen, Air flow rates, and Compaction

Percent oxygen in the exhaust air remained near ambient concentrations (21%) throughout the study with occasional low readings near 18% oxygen. Air flow rates through the containers decreased over time as the feedstocks broke down decreasing pore space (Figure 5). Air flow rates stabilized after the first month of composting. Compaction rates were fairly uniform between the three treatments with all decreasing in height of pile by nearly 15 inches from start to finish.

Selected Physical, Chemical, Agronomic, and Human-made Inerts Analysis

Table 6 shows a detailed comparison between the feedstocks and the cured compost. Human made inerts levels were measured according to U.S. Composting Council recommendations using a 4mm sieve. Inerts were lowest in Container 2 at 0.4%. All three compost mixtures met the recommendation of total human-made inerts under 1.5% of the total dry weight of the compost (U.S. Composting Council, 1996). Identified inerts included straws, condiments packaging, candy wrappers, gum wrappers, glass shards, and plastic shards. Table 6 also compares bulk densities, moisture contents, nutrient levels, pH, and C:N ratios for the feedstocks and the cured compost.

The nutrient content of the 2:1 mixture was greater than the other two treatments especially with plant available nitrogen and calcium. Soluble salts are also significantly higher in the 2:1 mixture, probably due to the high salt content of processed foods. All three mixtures exceeded the Georgia Department of Agriculture's soluble salt standards for horticultural grade compost. The C:N ratio for the 1:2 mixture is also above recommended levels for quality compost.

Table 6: Analysis of Feed stocks vs. Compost

	FOOD WASTE	YARD WASTE	COMPOST (cured)		
			C1	C2	C3
Moisture, %	70.91	52.75	17.08	15.40	26.40
Carbon, %	51.26	50.19	37.00	41.70	37.80
Nitrogen, %	5.68	1.09	1.58	1.23	1.64
C:N ratio	10:1	50:1	23:1	34:1	23:1
Ammonium N, ppm	-	-	404.0	139.0	184.0
Nitrate N, ppm	-	-	42.0	8.0	7.0
Total N, ppm	-	-	15,800	12,300	16,400
Plant Available N, ppm	-	-	446	147	191
Sulfur, %	0.41	0.09	0.32	0.24	0.30
Bulk density, g/ml	0.76	0.36	0.58	0.58	0.71
Phosphorous, ppm	-	-	203.4	147.8	103.0
Potassium, ppm	-	-	588.6	574.8	504.4
Calcium, ppm	-	-	172.8	83.7	93.4
Soluble Salts, mmhos	-	-	8.2	4.9	5.1
Magnesium, ppm	-	-	45.5	25.5	23.1
pH	-	-	7.1	6.7	7.4
Contaminants and Total human-made Inerts, %	-	-	0.64	0.42	0.47

CONCLUSIONS

The University of Georgia would need 58 containers to compost all of its food waste on a continual basis. Stable compost was achieved in all three treatments after 73 days. Wet volume reductions averaged near 60%. Mixture ratios proved beneficial for varying situations. All used pulped food waste which had 10 to 20% less moisture than food waste that has not been pulped. A mixture of 2:1 was optimum for composting the most food waste in the same amount of time, however ammonia and leachate problems were a concern. At times ammonia levels were so high as to make working with the compost uncomfortable, particularly with the 2:1 mixture. Leachate production averaged 1 liter per 20 kg of food waste. A mixture of 1:2 may be suitable if there is an abundance of yard waste, however moisture contents must be monitored closely as this mixture tends to dry out quickly.

All treatments attained U.S. EPA temperature recommendations of 55 degrees C for 72 hours. All three mixtures contained less than 1.5% total human-made inerts according to U.S. Composting Council recommendations. The compost ranged from 0.4% to 0.6% contaminants and inerts. Generally, the more food waste in the initial mixture the higher the nutrient content was in the finished compost. However, the soluble salt content was higher which may restrict its use for commercial horticultural purposes.

REFERENCES

Compost Facility Operating Guide: A Reference Guide for Composting Facility and Process Management. The Composting Council. Virginia. 1996.

Donahue, D., Chalmers, J., Storey, J. Evaluation of In-Vessel Composting of University Postconsumer Food Wastes. *Compost Science and Utilization. Spring*, 1998.

Earth Tub Composting Operators and Maintenance Guide. Green Mountain Technologies. Seattle, WA. 1998.

Ferris, D.A., Flores, R.A., Shanklin, C.W., Whitworth, M.K. Proximate Analysis of Food Service Wastes. *Applied Engineering in Agriculture*. Jan., 1995.

Goldstein, N., Glenn, J., Gray, K. Nationwide Overview of Food Residuals Composting. *Biocycle*. Aug., 1998.

Kunzler, C., Roe, R. Food Service Composting Projects on the Rise. *Biocycle* Apr., 1995.

Lowe, E., Buckmaster, D. Dewatering Makes Big Difference in Compost Strategies. *Biocycle*. Jam., 1995.

Steuteville, R. The State of Garbage in America. *Biocycle*. Apr., 1994.

US-EPA. *Summary of Compost Markets. Office of Solid Waste.* Washington D.C. 1993.

Youde, J., Prenguber, B. Classifying the Food Waste Stream. *Biocycle*. Oct., 1991.

FIGURE 1: CONTAINER 1: AVERAGE DAILY TEMPERATURES

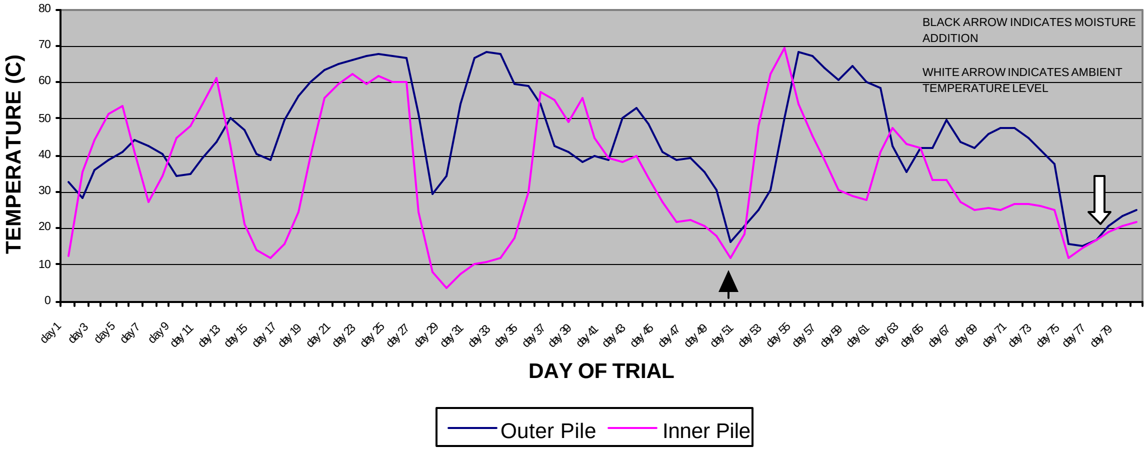

FIGURE 2: MOISTURE CONTENT BY CONTAINER

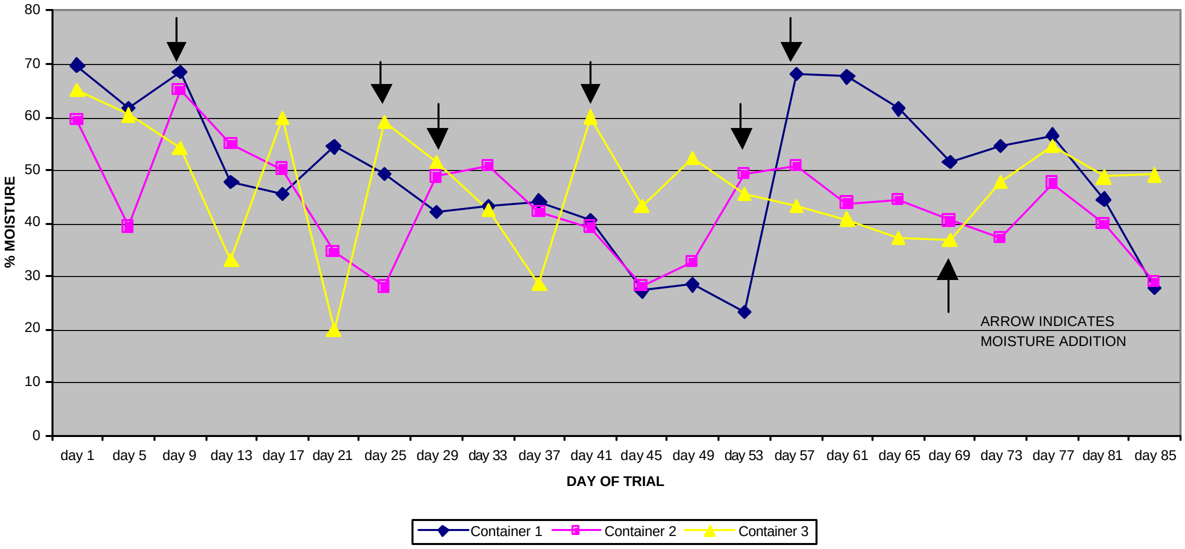

FIGURE 3: LEACHATE PRODUCTION BY CONTAINER

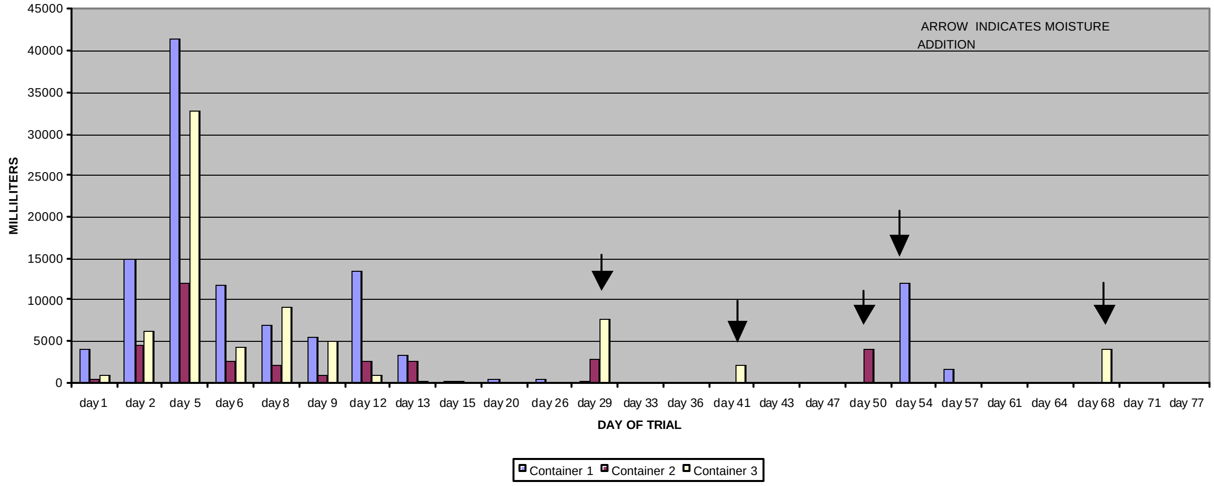

FIGURE 4: ODOR ANALYSIS OF AMMONIA (NH3) BY CONTAINER

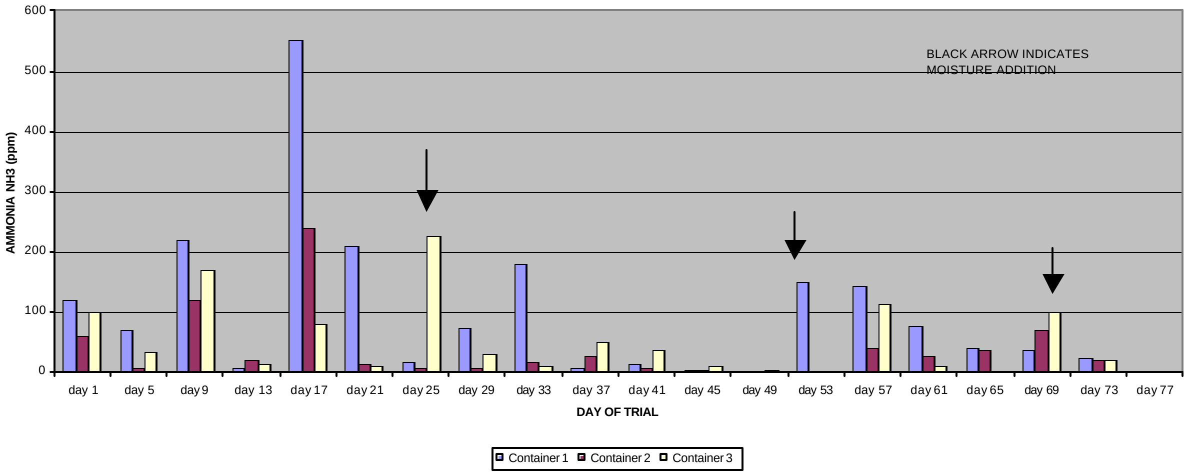

FIGURE 5: AIR FLOW RATE OF CONTAINERS