Compostable Rigid Plastic Packaging Containers, Bags, and Food Service Packaging in Commercial Composting Environments

Interested Parties Meeting
CIWMB

January 24, 2006

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Agenda

- Research Project Scope
- Project Management
- Materials
- Testing Methods
- Results
  - Laboratory Environment
  - Cow Manure Compost Environment
  - Green Yard Waste Compost Environment
- Conclusions
- Recommendations

Scope

- California Integrated Waste Management Board (CIWMB) initiated a research project to study
  - Degradation rates, byproducts, and performance of compostable plastics that can be used in rigid packaging plastic containers, trash bags, film liners, and food service products.
- The project is broken down into four areas
  - Detailed work plan and budget,
  - Literature review,
  - Demonstration project, and
  - Evaluation report.
- Research benefits are
  - To help manufacturers of compostable products, government agencies and consumers better evaluate environmental claims of compostable plastic materials.

Project Management

- The project is broken down into four areas,
  - Detailed work plan and budget,
  - Literature review,
  - Demonstration project, and
  - Evaluation report
- Start date was September 30, 2004
- Ending date was December 31, 2005

Compostable Rigid Plastic Packaging Containers

STEP 1: *Create detailed work plan and budget*

Dec 31, 2004

1.1. Review of the current compostable plastics programs in the U.S., Europe, and Australia
1.2. Establish key features of successful compostable programs and the related materials and testing methods.
1.3. Identify steps necessary to demonstrate compostable plastics at CSU, Chico.
1.4. Identify test methods necessary to evaluate effectiveness of compostable plastics use.
1.5. Meet with California Integrated Waste Management Board and with the advisory group as directed by CIWMB.

➔ Detailed Work Plan and Budget

STEP 2: Literature Search

Jan 31, 2005

2.1 Review the research methods and procedures for evaluating and testing compostable plastics in the U.S. and Europe
2.2 Establish key features of successful demonstration uses of compostable plastics.
2.3 Identify various compostable RPPCs, food service products, bags, and technologies.
2.4 Identify the performance of various compostable RPPCs, food service products and bags, product cost information, degradation rate and extent, residuals, toxicity, etc.
2.5 Present progress report of the results of this step to key stakeholders as directed by CIWMB.

➔ Summary of current technology of compostable plastics.

STEP 3: Demonstration Project

Nov 30, 2005

3.1. Acquire three commercially available compostable RPPCs, food service products and bags that meet ASTM 6400-99 standard specifications.
3.2. Provide the compostable products to the Associated students recycling group and have them available to use in the food court.
3.3. Collect the compostable products after they are used.
3.4. Bury the compostable products in the compost area at the farm.
3.5. Bury the compostable products in a commercial compost environment.
3.6. Develop, in consultation with the AG, an evaluation methodology and protocol consistent with ASTM 6400-99 methods and other appropriate scientific testing and methods including the use of a control.
3.7. Test the compostable products after the appropriate timeframe subject to approval by the

STEP 4: Evaluation Report

Dec 31, 2005

4.1 Submit final report to California Integrated Waste Management Board
4.2 Submit paper to national plastics journals and trade magazines

➔ Final report to California Integrated Waste Management Board

Materials

Compostable Product	Plastic Material Source	Company	Cost
Trash bag: 49.2 L (13-gallon)	Corn starch	Eco-Products Inc. (Boulder, CO)	$4.95 per 12 bags
Cup: 300 ml (10-oz)	Natureworks PLA	Eco-Products Inc. (Boulder, CO)	$65.60 per 1000 cups
Clamshell container	Natureworks PLA	Biodegradable Food Service, LLC (Oregon)	$56 per 250 count
Plate: 25.4 cm (10 in)	Sugar cane	Stalk Market (China)	$69.90 per 500 plates
Cellulose Control			
Kraft Paper Control			

End-Use Performance

Object	Company	Thickness, mm	Test	Performance
Trash bag: 49.2 L (13-gallon)	Eco-Products Inc.	0.05	Moisture and weights	The trash bag held food and paper waste without leaking for 2 days. The bag held 200 ml of water for 12 hours without leaking. After 20 hours the bag leaked approximately 20 ml. After 30 hours exposure the bag held 10 pound weight without breaking The bag broke with a weight of 15 pounds.
Cup: 300 ml (10-oz)	Eco-Products Inc.	0.18	Fluid testing	The cup help water, apple juice, orange juice and milk without leaking but deformed when boiling water was put in it. It did not leak.
Clamshell container	Biodegradable Food Service, LLC	0.20	Food storage	The food container held water meat, rice, and vegetables with out leaking but deformed when put in the microwave for 55 seconds on high power.
Plate: 25.4 cm (10 in)	Stalk Market (China)	0.53	Food use	The plate held hot pizza without leaking and held meat and vegetables while being heated in a microwave for 55 seconds on high power without leaking. The plate was unaffected by freezer temperatures, but warped slightly after exposure to boiling water.

Testing Methods

- Laboratory Environment
  - ASTM 5338 Standards

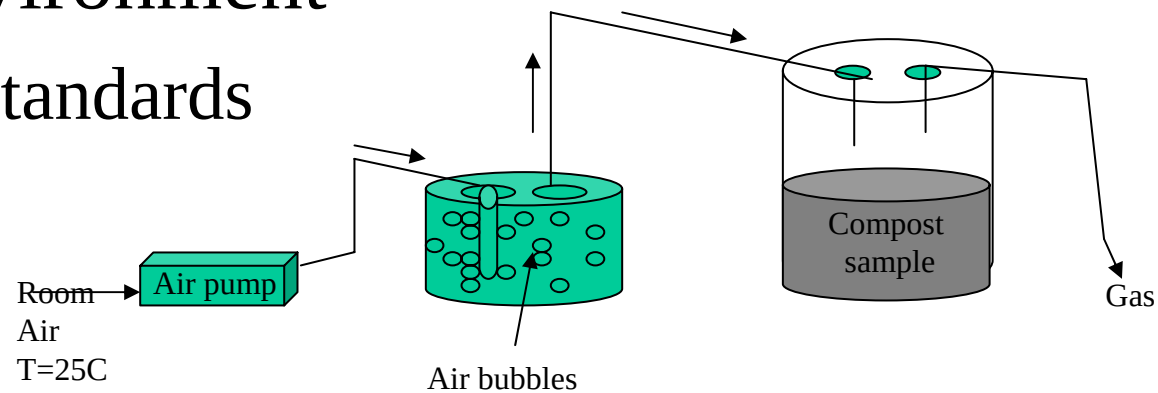


Figure 1. Experimental set-up for laboratory environment.

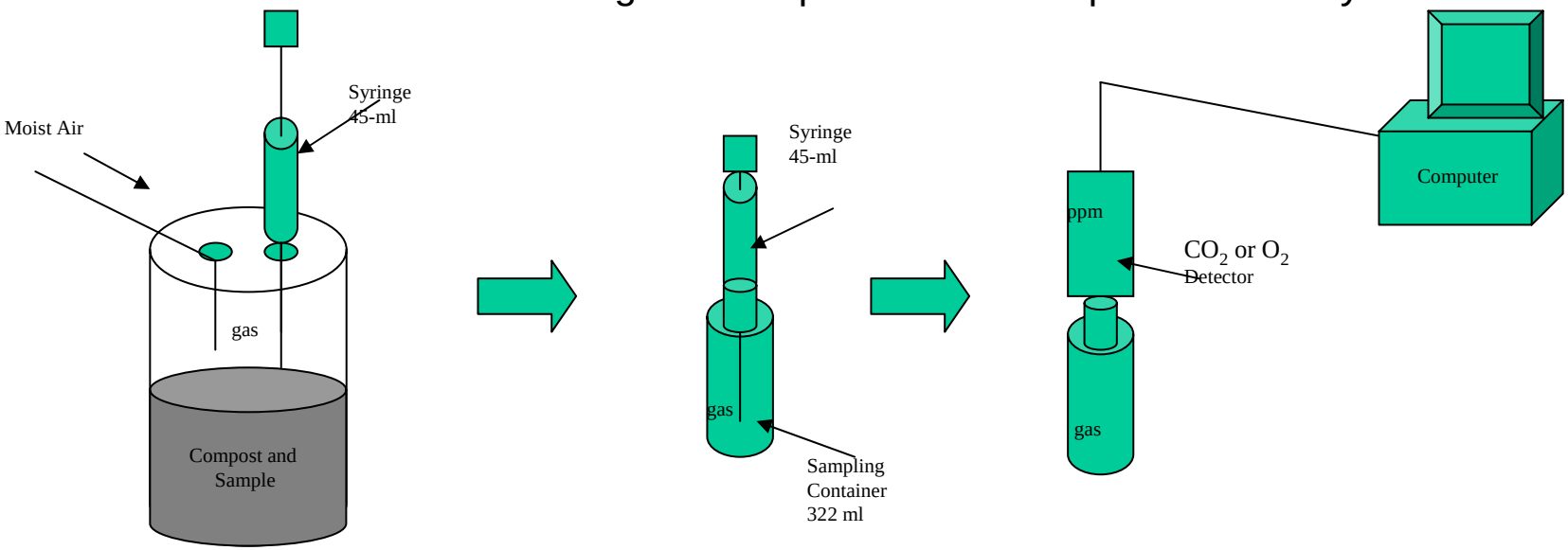


Figure 2. Sampling process schematic.

Results

- Results
  - Laboratory Environment
    - 45-day degradation of compostable samples including controls per ASTM 6400 standards
    - Plant growth test with tomato seeds
    - Heavy metal testing for Lead
  - Cow Manure Compost Environment
    - Disintegration tests
    - Compost maturity tests
    - CO_2 measurements inconclusive
  - Green Yard Waste Compost Environment
    - Disintegration tests
    - Compost maturity tests
    - CO_2 measurements inconclusive

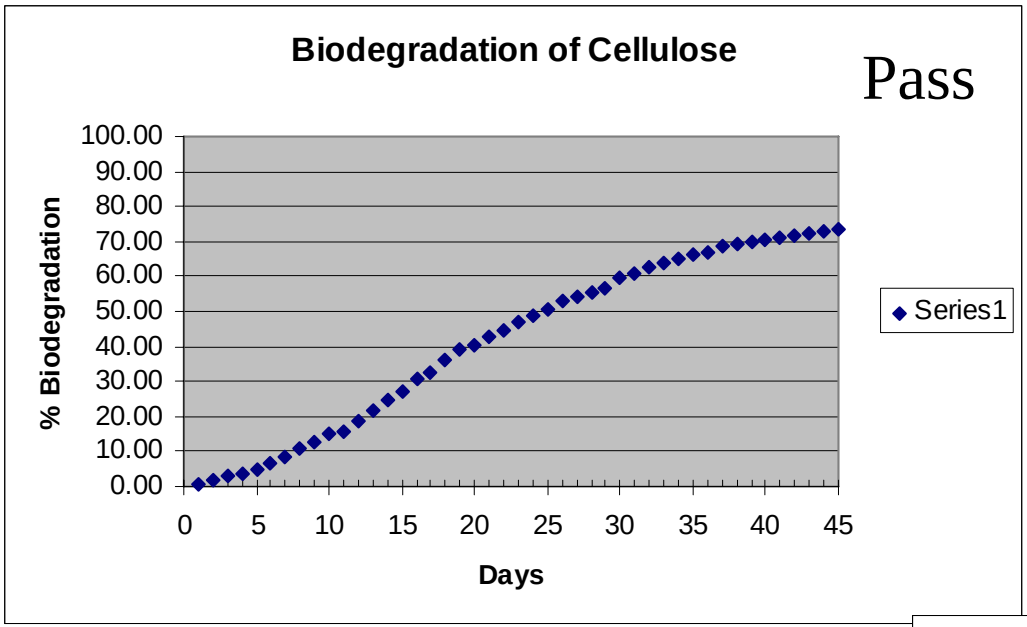
% Carbon Testing with Bomb Calorimetry

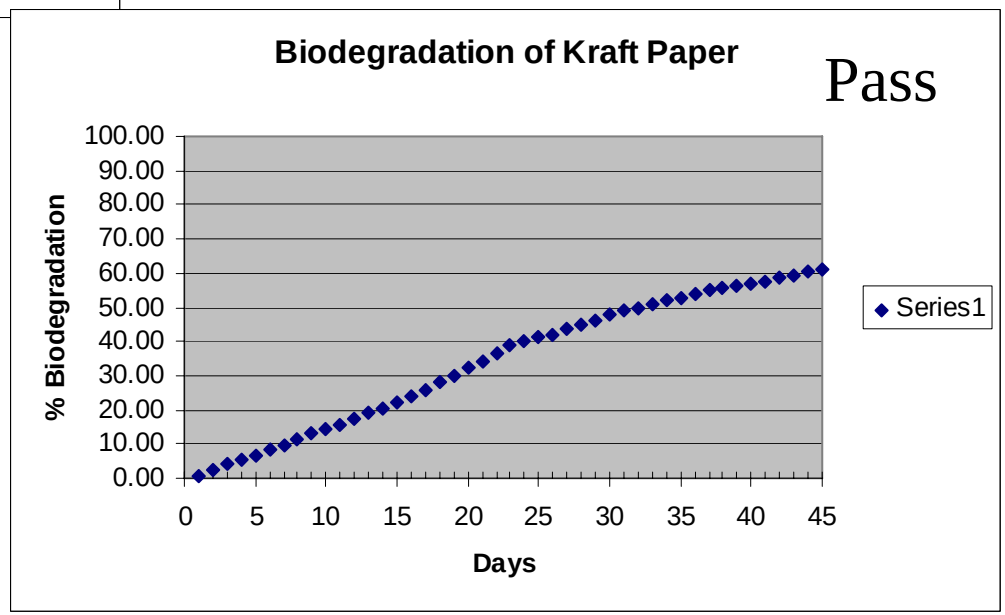
Material	Heat of Combustion KJ/g	Bomb Calorimetry % Carbon Content	Moisture %
Cellulose	-14.42	16.35	6.09
Kraft paper	-12.62	16.53	7.19
Corn-based trash bag	-20.25	21.94	1.03
PLA container	-16.31	18.65	0.56
PLA cup	-17.10	17.01	0.37
Sugar cane plate	-13.22	15.11	6.74

45-day Degradation Results

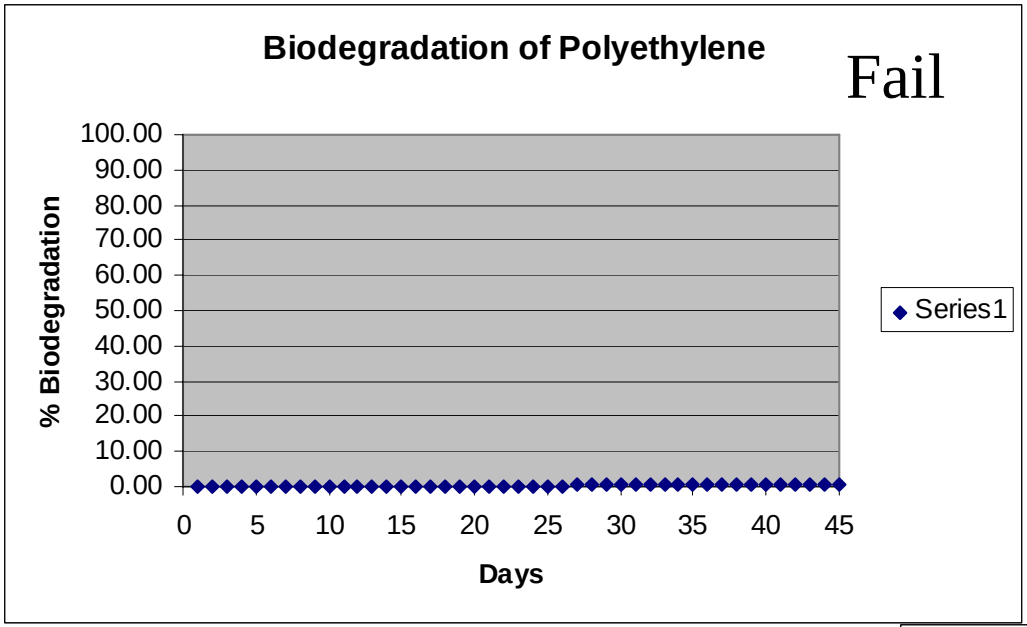
Material	Biodegradation Conversion %	Degradation rate g/day
Cellulose positive control	73.66	0.0164
Sugar cane plate	63.48	0.0141
Kraft paper positive control	61.28	0.0136
PLA container	62.77	0.0139
PLA cup	61.01	0.0136
Corn-starch based trash bag	24.40	0.0054
Polyethylene negative control	0.58	0.0001
Compost	0.33	0.0001

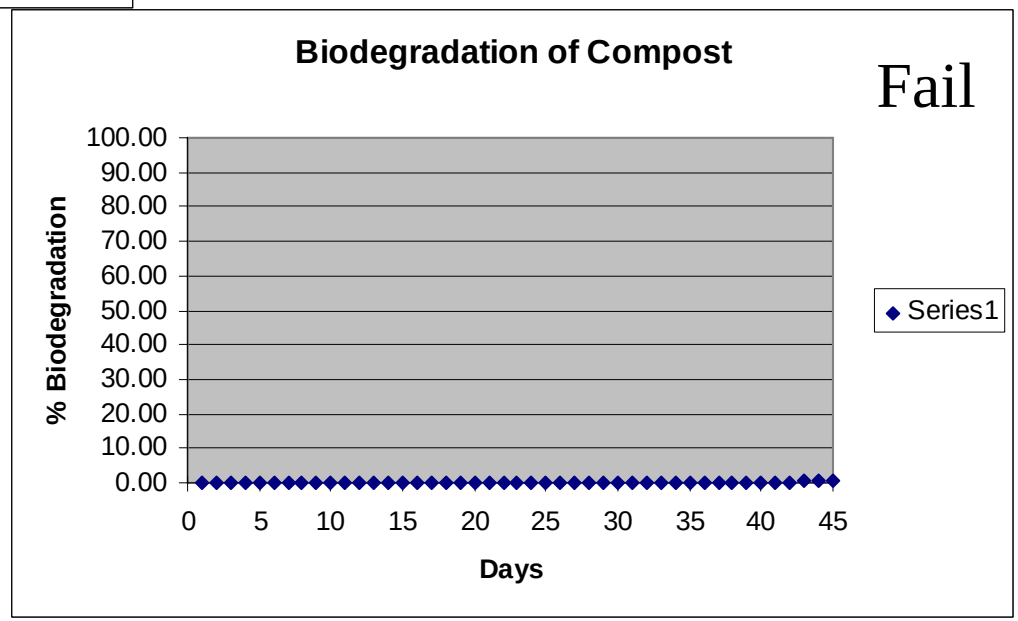
45-day Degradation Results- Controls



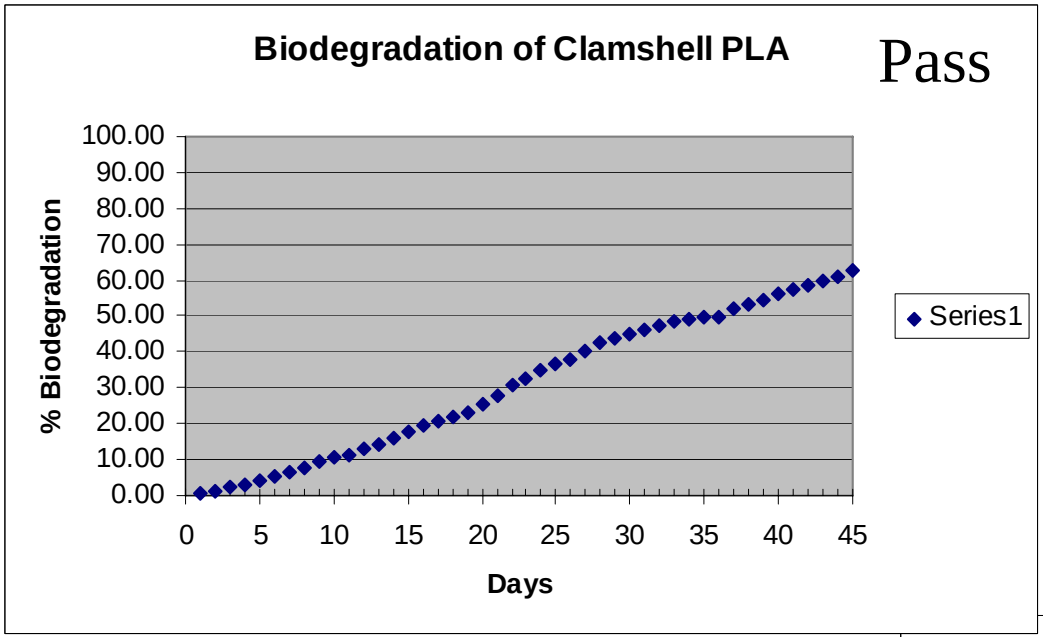


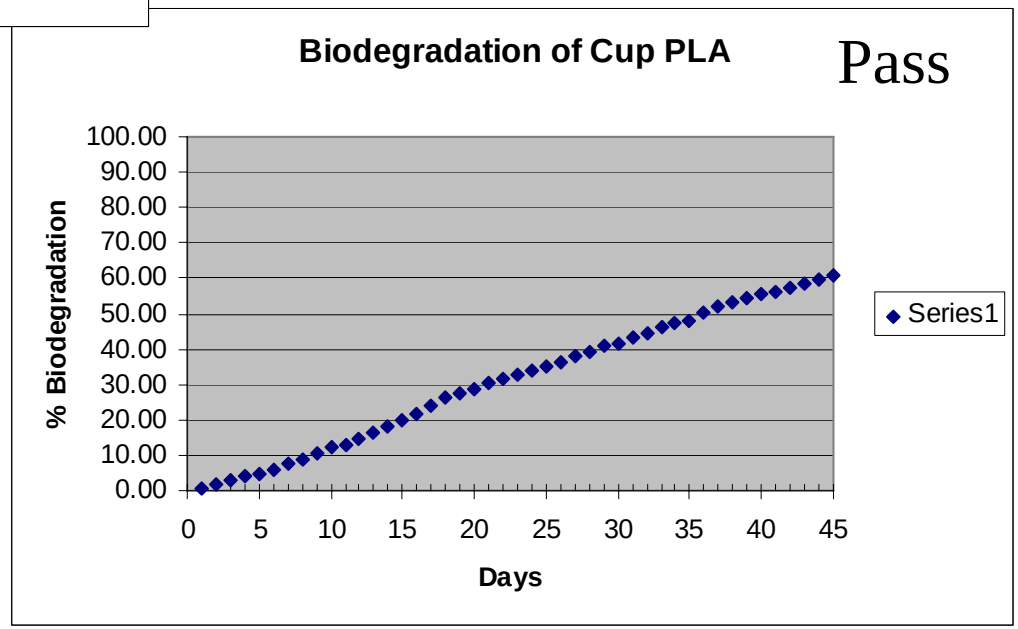
45-day Degradation Results-Control





45-day Degradation Results





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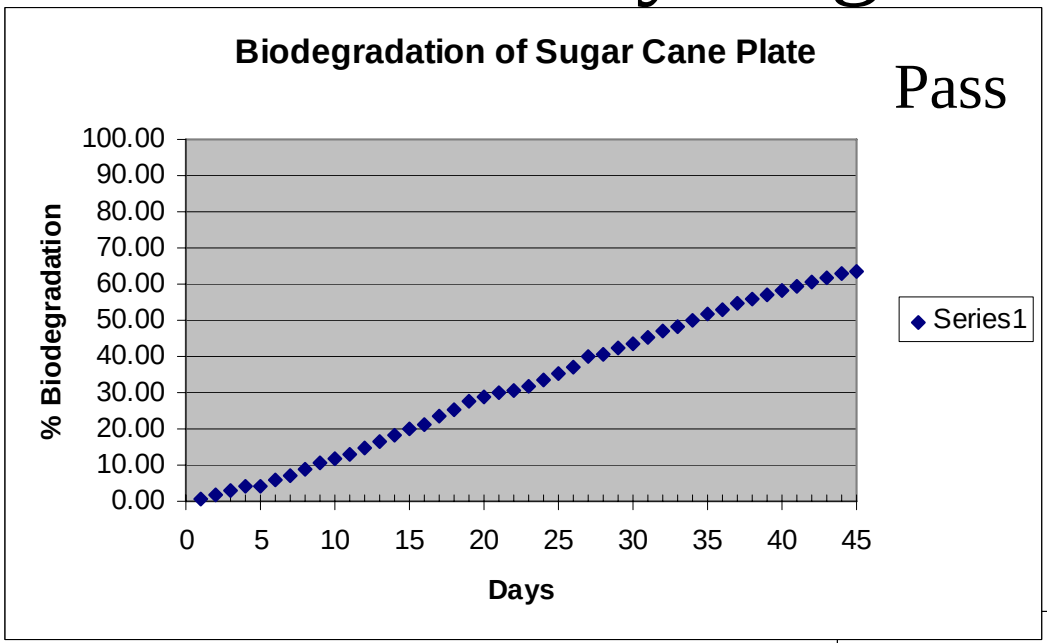
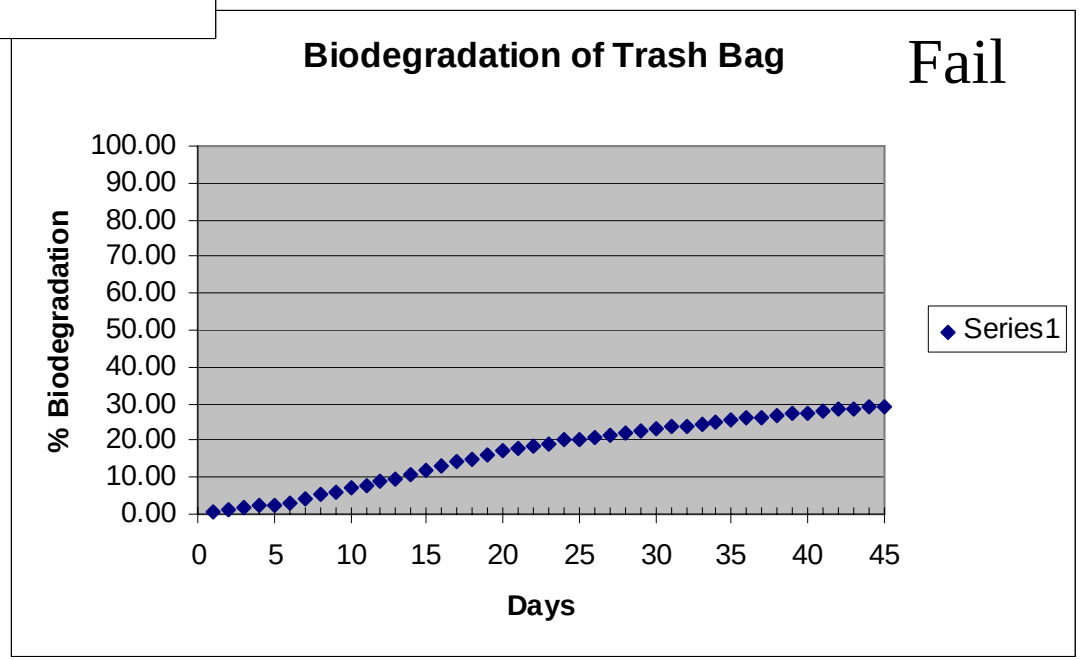




Plant Growth Results

Sample	Material	Number of Seedlings	Average Length, mm	Average, pH	Result
1	Compost	7	25	8.73	Pass
4	Cellulose	7	6	8.7	Pass
7	Kraft Paper	4	12	8.93	Pass
10	Polyethylene	4	12	8.6	Pass
13	Trash Bag	4	12	8.93	Pass
16	PLA Container	3	12	8.8	Pass
19	**Sugar Cane**	**0**	**0**	**8.27**	**Fail**
22	PLA Cup	1	3	8.97	Pass

Heavy Metal Testing

Material	Average Lead Concentration	Result
Compost	0.02 mg/kg	Pass
Cellulose	0.02 mg/kg	Pass
Kraft Paper	0.02 mg/kg	Pass
Polyethylene	0.02 mg/kg	Pass
Trash Bag	0.02 mg/kg	Pass
PLA Container	0.02 mg/kg	Pass
Sugar Cane	0.02 mg/kg	Pass
PLA Cup	0.02 mg/kg	Pass

Note: Maximum limit of Pb is 30 mg/kg

Testing Methods

- Cow Manure Compost Environment

Figure 3. Sample plus Compost plus Bag

Figure 4. University Farm Manure Compost

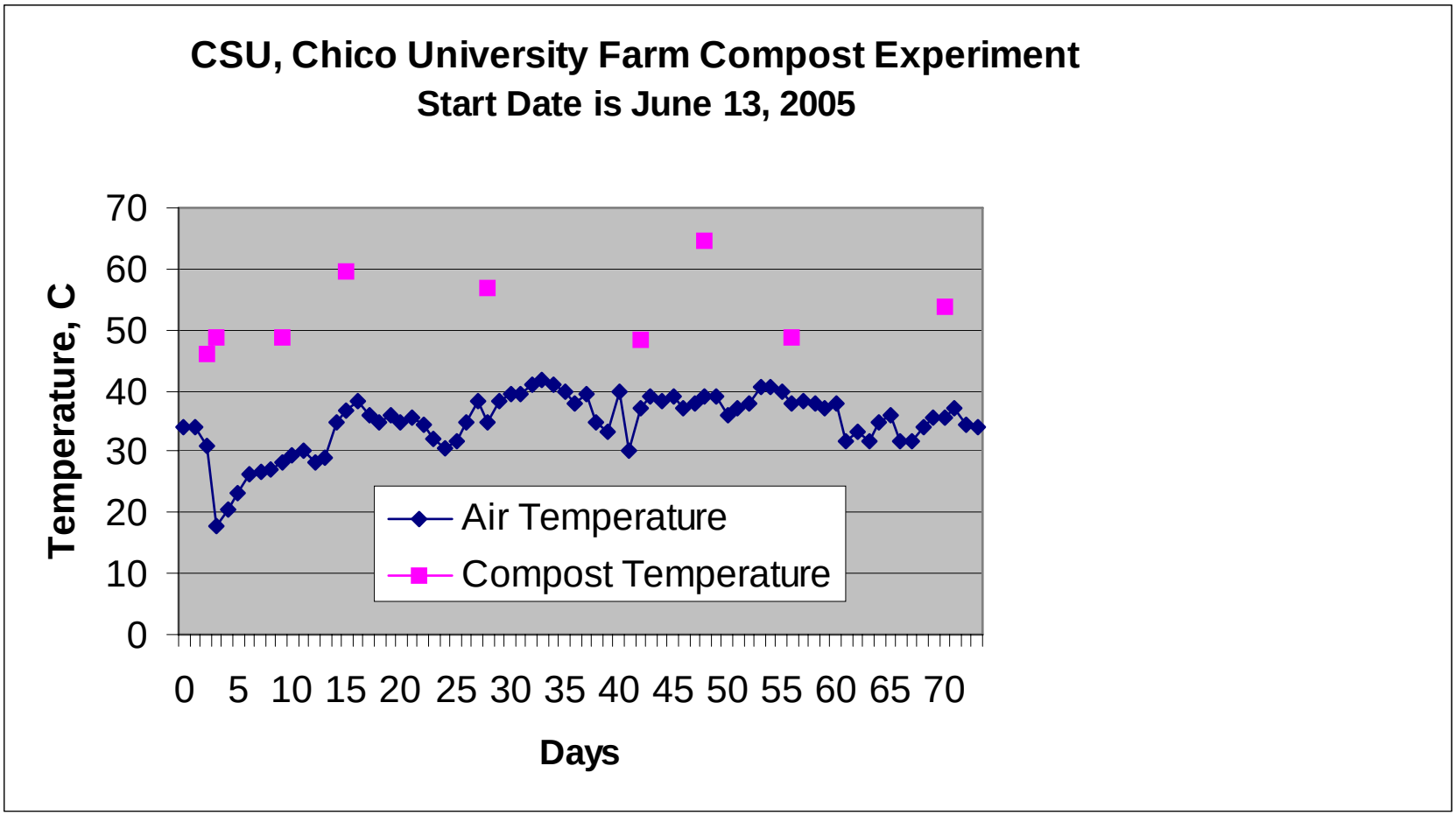
Start Date: June 13, 2005
End Date: August 25, 2005 (70 days)

Results

- Results
  - Cow Manure Compost Environment
    - Disintegration tests
    - Compost maturity tests
    - CO_2 measurements inconclusive
  - Green Yard Waste Compost Environment
    - Disintegration tests
    - Compost maturity tests
    - CO_2 measurements inconclusive

Disintegration Test Results

Cow Manure Compost Environment



Disintegration Test Results

Cow Manure Compost Environment

		Initial				
		14-Jun				
		Start	12-Aug	59 days	25-Aug	72 days
Item	Hole No	Mass, g	Mass, g	% disintegration	Mass, g	% disintegration
Cellulose Control	2	1.1	0	100	0	100
Tray-starch	3	5.6	0	100	0	100
Plate-PLA	4	19.3	0	100	0	100
Straw-PLA	5	0.9	0	100	0	100
Bag-starch	8	19.2	0	100	0	100
Avicel* Control	10	250	0	100**	0	100***
Container*-PLA	9	23.7	15.4	35**	0	100***
Cup-PLA	7	14	7.5	46	0	100
Fork-PLA	6	4.2	1.4	67	0	100

*Start date = July 18

** 25 days of disintegration

*** 38 days of disintegration

Picture Results

Cow Manure Compost Environment

Cellulose Control Initial June 28, 2005 (15 days)

Potato Starch Tray Initial June 28, 2005 (15 days)

Corn PLA Plate Initial June 28, 2005 (15 days) August 1, 2005 (49 days)

Picture Results

Cow Manure Compost Environment

PLA Fork Initial

June 28, 2005 (15 days)

August 1, 2005 (49 days)

PLA Cup Initial

June 28, 2005 (15 days)

August 1, 2005 (49 days)

Picture Results

Cow Manure Compost Environment

PLA Container Initial

August 1, 2005 (14 days)

August 29, 2005 (43 days)

Starch Trash Bag Initial

June 28, 2005 (15 days)

August 1, 2005 (49 days)

Testing Methods

- Green Yard Waste Compost Environment

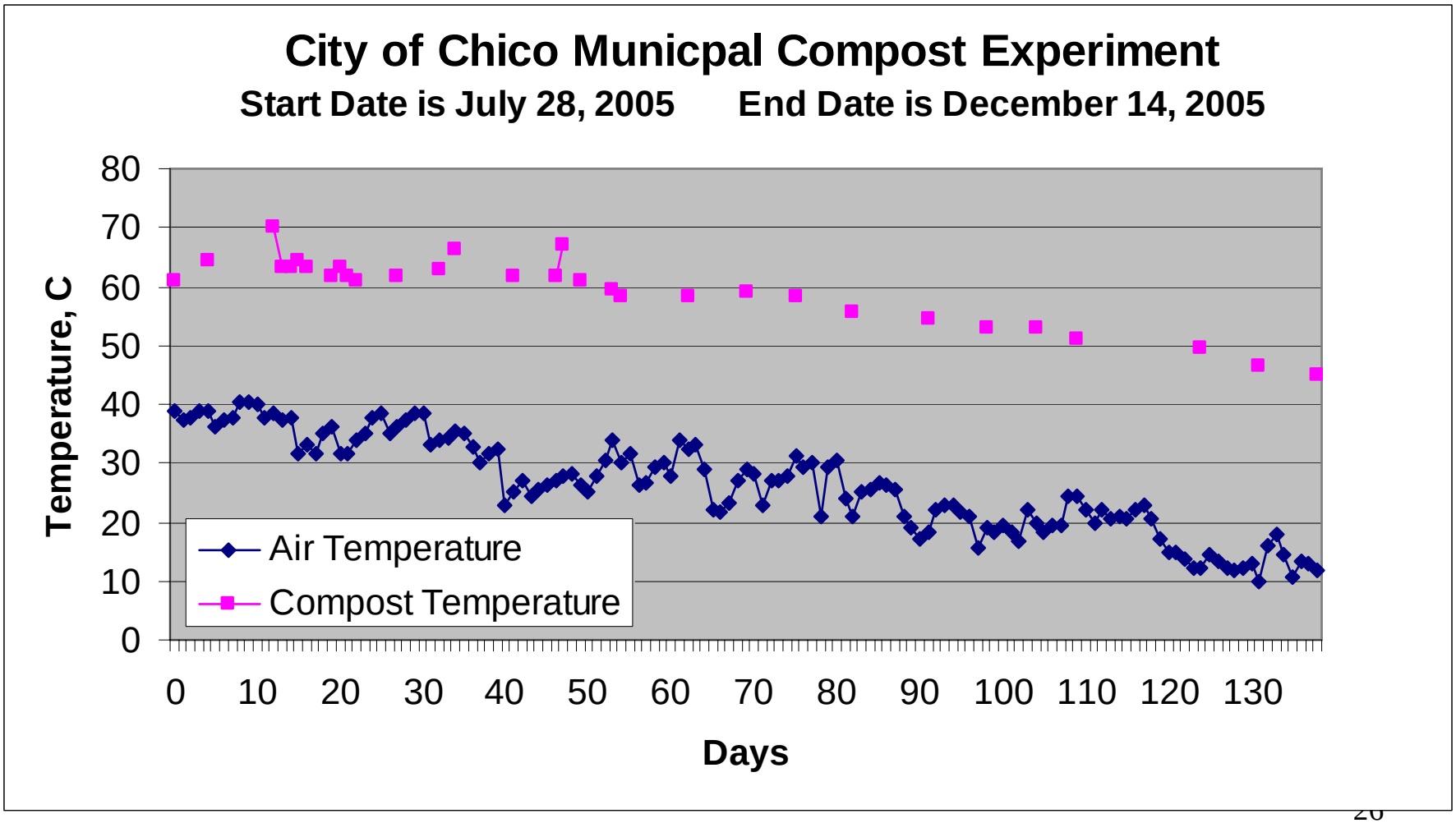
Figure 5. Sample plus Compost plus Bag

Figure 6. City of Chico Green Yard Waste Compost

Start Date: July 28, 2005
End Date: December 14, 2005 (140 Days)

Disintegration Test Results

Green Yard Waste Compost Environment



Disintegration Test Results

Green Yard Waste Compost Environment

	Initial 28-Jul	9-Aug	2 weeks	14-Sep	7 weeks	20-Oct	12 weeks	4-Nov	14 weeks	14-Dec	20 weeks
Item	**Mass**	**Mass**	**% disint.**	**Mass**	**% disint.**	**Mass**	**% disint.**	**Mass**	**% disint.**	**Mass**	**% disint.**
Avicel cellulose cor	28.30	20	29	0	100	0	100	0	100	0	100
Cup- PLA	13.98	10	28	0	100	0	100	0	100	0	100
Knife- PLA	3.88	2	48	0	100	0	100	0	100	0	100
Container- PLA	22.64	20	12	0	100	0	100	0	100	0	100
Kraft Paper Control	20.90	15	28	10	52	6.4	69	5.56	73.4	2.47	88
Trash bag- corn sta	18.86	15	20	13	31	6.6	65	5.51	70.79	3.03	84
Plate- Sugar Cane	23.42	20	15	19	19	14.8	37	13.61	41.88	5.11	78

Conclusions

- Compostable materials degrade under compostable conditions as defined in the ASTM D6400 standards.
- Cellulose positive control met requirement of 70% degradation after 45-days.
  - ASTM specifies that the test results are valid if the cellulose control degrades 70% or more.
- Degradation rates of the materials are listed according to highest rates as follows,
  - Cellulose control,
  - Sugar cane plate,
  - Kraft paper control,
  - PLA container,
  - PLA cup, and
  - Corn-starch based trash bag.

Conclusions

- Sugar cane and PLA materials
  - Degraded at rates similar to the Kraft paper control, and
  - Meet the compostability criterion of 60% degradation after 45-days.
- Trash bag
  - Degraded at rates lower than the Kraft paper control
  - Did not meet the compostability standards specified by ASTM.
- Polyethylene negative control and the compost inoculum demonstrated negligible degradation.

Conclusions

- PLA cup and container and the trash bag
  - Met the phytotoxicity requirements and support growth of tomato seedlings after 10-days.
- Sugar cane plate did not support growth and thus failed the phytotoxicity requirements of the ASTM compostability standards.
- All of the soil samples from the compostable materials had lead concentrations of 0.02 mg/kg, which is lower than the limit of 30 mg/kg.

Conclusions

- Degradation and disintegration results at the university farm demonstrate that
  - Compostable materials degrade under moist manure-based compost.
  - All of the materials disintegrated after 72 days.
  - Potato-starch based tray, corn-starch based trash bag, PLA plate, PLA straw, and PLA container degraded at a similar rate as the cellulose control.
  - PLA fork and PLA cup degraded completely after 72 days.

Conclusions

- Degradation and disintegration results at the municipal compost facility demonstrate that
  - Compostable materials degrade under moist green-waste compost.
  - PLA container, PLA cup, and PLA knife degraded at a similar rate as the Avicel cellulose control and were degraded completely in 7-weeks.
  - Cornstarch-based trash bag and sugar cane plate degraded at a similar rate as the Kraft paper control.
  - The three materials degraded between 80 and 90% after 20 weeks.

Conclusions

- Three compost environments demonstrated similar results.
  - PLA degraded very well in cow-manure and green waste compost.
  - Trash bag experienced higher degradation in the moist cow manure compost than in the green waste compost.
  - Laboratory and municipal compost had similar degradation results, where the PLA materials degraded very quickly and the starch based plastic bag degraded more slowly.
  - Trash bag had similar degradation rates after 45 days in the laboratory and in the municipal compost facility of around 30% degradation.

Conclusions

- Three compost environments demonstrated similar results.
  - Kraft paper sample also had similar degradation in the laboratory environment (61%) as in municipal compost facility (52%).
  - Sugar cane plate had the biggest difference in degradation rates between the two compost environments with higher degradation in the laboratory (63%) versus the municipal compost (19%).
  - The moisture content was significantly higher in the laboratory experiment than at the municipal compost facility. The sugar cane plate is hydrophilic that can affect the degradation rate.

Recommendations

- The research work will help the expanded use of compostable plastic materials for selected applications.
- The compostable materials should be certified as compostable by BPI and included in procurement standards.
- The compostable plastic materials should perform well in simple applications, e.g., food service ware, lawn and leaf refuse bags that have dry contents, grocery bags, department store bags, and pet bag products.
- The compostable plastics would not most likely perform well in trash bag uses due to the likely exposure to moist debris.
- Trash bag use is not recommended at this time.

Recommendations

- Lawn and leaf bags might not be suitable for compostable plastics in wet environments.
- Compostable plastic materials could be very economical for organizations and institutions that service a controlled population, e.g., hospitals, correctional facilities, schools, and cruise lines.
- The cost of disposal of waste at these locations can be offset by the use of compostable plastics, which have a compost nutrient value.
- Compostable plastics can be a benefit to compost operators by having an organic nutrient source that does not have the bacteria problems of food waste.

Recommendations

- Compostable plastics can reduce the amount of plastic in the landfills.
  - In 2003 for California, plastics accounted for roughly, 10% by weight of the materials in the waste stream.
  - Compostable plastics make the most sense as replacements for clamshell and other rigid containers, which account for 24,627 tons and 22,081 tons respectively.
  - If compostable plastics were implemented at several large institutions, the amount of plastic waste that can be diverted from the waste stream could approach 5,000 to 10,000 tons.

Recommendations

- Appropriate labeling of compostable plastics is essential for effective use.
  - The standard plastics recycling numbers should not be used to indicate compostable plastics.

  - Rather, a colored (e.g., green) label that is similar to the BPI logo would be appropriate with a circle and a “C” in the middle.

  - The symbol should not be on the same location as the recycling symbol, but should be on the side of the container.
  - A recycling symbol with a red line through it indicating that the plastic is not recycled would be helpful.
- Collection practices would have to be modified to include the use of compostable plastics.
  - The compostable plastics should not be collected with recycled materials, but rather included with the yard waste compostable materials.