The University of Georgia

Department of Biological & Agricultural Engineering

College of Agricultural and Environmental Sciences
TIFTON CAMPUS

Coastal Plain Experiment Station
Tifton, GA 31793-0748-USA

21 December 2011

Gregorio Cruz-CIG
1400 Independence Avenue, SW
Room-5233-S
Washington, DC 20250

Dear Mr. Cruz,

Enclosed is a copy of the final report for NRCS CIG Agreement number 69-3A75-7-121 (UGA Acct Number 2631RE676292), "Extracting Energy from Poultry Waste and Fruit and Vegetable Waste through Anaerobic Digestion Technology". It is my opinion as project director that we completed a successful project. A change had to be made in the middle of the project due to natural causes, but the extraction of energy from agricultural waste was completed with the use of pilot scale anaerobic digesters. As part of the project, information on anaerobic digestion and the conversion of waste materials to methane was disseminated to farmers, professional organizations, NRCS and Extension personnel as well as organizations that work with farmers. I have worked with NRCS personnel to train regional personnel and will continue to work with them to produce additional information that can be used for training purposes.

The grant has been completed, but planning has begun for additional presentations to disseminate information on the use of anaerobic digestion for extracting energy from agricultural waste. These outreach events will include a wide array of constitutes interested in anaerobic digestion for use on their small or large scale farm.

If you have any questions or need additional information feel free to contact me at 229-391-2511 or ghawkins@uga.edu.

Sincerely,

Gary L. Hawkins, Ph.D.
Agricultural Pollution Prevention Specialist - Row Crops and Alternative Energy
Biological and Agricultural Engineering Department
University of Georgia - Tifton
P.O. Box 748, 2329 Rainwater Rd.
Tifton, GA 31793-0748
(P) 229-391-2511
(F) 229-386-3958

XC: Melissa Mottley, Debra Rucker, Stephanie Tucker, Morgan Bennett, UGA; Dot Harris, NRCS

21 December 2011

Gregorio Cruz-CIG
1400 Independence Avenue, SW
Room-5233-S
Washington, DC 20250

Dear Mr. Cruz,

Enclosed is a copy of the final report for NRCS CIG Agreement number 69-3A75-7-121 (UGA Acct Number 2631RE676292), "Extracting Energy from Poultry Waste and Fruit and Vegetable Waste through Anaerobic Digestion Technology". It is my opinion as project director that we completed a successful project. A change had to be made in the middle of the project due to natural causes, but the extraction of energy from agricultural waste was completed with the use of pilot scale anaerobic digesters. As part of the project, information on anaerobic digestion and the conversion of waste materials to methane was disseminated to farmers, professional organizations, NRCS and Extension personnel as well as organizations that work with farmers. I have worked with NRCS personnel to train regional personnel and will continue to work with them to produce additional information that can be used for training purposes.

The grant has been completed, but planning has begun for additional presentations to disseminate information on the use of anaerobic digestion for extracting energy from agricultural waste. These outreach events will include a wide array of constitutes interested in anaerobic digestion for use on their small or large scale farm.

If you have any questions or need additional information feel free to contact me at 229-391-2511 or ghawkins@uga.edu.

Sincerely,

Gary L. Hawkins, Ph.D.
Agricultural Pollution Prevention Specialist - Row Crops and Alternative Energy
Biological and Agricultural Engineering Department
University of Georgia - Tifton
P.O. Box 748, 2329 Rainwater Rd.
Tifton, GA 31793-0748
(P) 229-391-2511
(F) 229-386-3958

XC: Melissa Mottley, Debra Rucker, Stephanie Tucker, Morgan Bennett, UGA; Dot Harris, NRCS

# Final Report

**Submitted to:**
Gregorio Cruz-CIG
1400 Independence Avenue, SW
Room-5233-S
Washington, DC 20250

**Submitted by:**
Gary L. Hawkins, Ph.D.
University of Georgia
Biological and Agricultural Engineering Department
P.O. Box 748
Tifton, GA 31793
ghawkins@uga.edu
229-391-2511

John Ed Smith, UGA - Bacon County Extension Agent

Danny Scanaland and Bob Boland, UGA Extension Agent, retired

Jack Tanner, Poultry/Blueberry Farmer

John Worley, Ph.D., UGA Biological and Agricultural Engineering

Glen Rains, Ph.D., UGA Biological and Agricultural Engineering

Terry Kelley, Ph.D., UGA Extension Horticulturist, left University

Paul Sumner, UGA Biological and Agricultural Engineering, retired

Seven Rivers RC&D Council, Mid-South Georgia RC&D Council

Mid-South Georgia SWCD

**NRCS Agreement Number: NRCS 69-3A75-7-121**

**Grant Title:**
"Extracting Energy from Poultry Waste and Fruit and Vegetable Waste through Anaerobic Digestion Technology"

**Date Submitted:**
24 December 2011

**NRCS CIG Agreement Number NRCS 69-3A75-7-121**
**Final Report Submitted to USDA NRCS CIG Program on Behalf of The University of Georgia**

The following materials are submitted as the final report for the original grant agreement number NRCS 69-3A75-7-121 which was granted to The University of Georgia.

**Summary:**

Animal agriculture and the fruit and vegetable industry produces millions of pounds and gallons of solid and liquid waste annually in Georgia and other states with similar agricultural commodities. As the production of these commodities increases the need for energy also increases. This project was designed to study and demonstrate the use of anaerobic digestion technology as a means to help manage liquid waste from a poultry operation for the production of a methane gas – a gas usable for energy production. The project also had an aspect to use animal waste and fruit and vegetable waste in a co-digestion process to produce bio-gas anaerobically. The project initially began by testing a liquid flush poultry layer operation. Samples from the liquid flush system at a layer operation was collected and tested to determine the characteristics of the wastewater. Two methods of collecting and measuring bio-gas production from the lagoon and wastewater was tried during the initial data collection for the project. Unfortunately, in December 2009 a tornado destroyed the house used for the poultry anaerobic digestion portion of the project. The second portion of the project involved the characterization of the physical and chemical aspects of fruit and vegetable waste and its use as a possible feedstock for bio-gas production. Data was collected for various fruits and vegetables. Fruit and vegetable juice has been used in pilot scale anaerobic digesters to determine the quantity of bio-gas that can be produced from waste fruit and vegetables with onions being the predominate feedstock. Data from the test indicates that if the anaerobic digestion can be managed properly, then the waste fruit and vegetable waste can be used as a feedstock for the production of bio-gas. The use of fruit and vegetable waste in conjunction with animal waste is a good way to manage two different agricultural waste streams while producing a useful by-produce – bio-gas or methane. Data indicates that the average COD of wastewater from the tested poultry lagoon was 10,000 mg $L^{-1}$ whereas the average COD of waste fruit and vegetables ranged from 10,000 mg $L^{-1}$ to 250,000 mg $L^{-1}$. This indicates that there is potentially 25 times more energy available in fruit and vegetable waste than that of animal waste. However, the fruit and vegetable waste has quickly converted carbohydrates whereas the animal waste has a slowly converted carbon source such as proteins. When these two feedstocks are combined, the material that would be introduced to anaerobic digesters has the ability to produce high quantities of biogas quickly with the ability to provide some buffering to maintain the anaerobic digestion system.

Overall, the extraction of energy from fruit and vegetable waste in conjunction with animal waste is very viable, but there are some reservations that should be considered. These include but are not limited to the facts that the anaerobic digestion system should be managed on a daily basis not when time allows if the system is a stand alone system. The introduction of the feedstock needs to be consistent and there should

be no problems, but the consistency of the feedstock should be checked regularly. If a stand alone anaerobic digester is planned for a farming system, there should be a person assigned to the digester with other duties not someone with other duties assigned to the digester. Data and results from the demonstration shows that fruit and vegetable waste can be used in conjunction with animal waste to produce a very useful by-product and that being biogas or methane.

**Introduction:**

Methane is a by-product of the anaerobic (without oxygen) breakdown of organic products. Some of these organic sources can consist of animal waste, fruit and vegetable waste, landfills and other similar organic sources placed in situations that allows breakdown under anaerobic conditions. In Georgia alone there were over 19 million layers and over 1 billion pounds of fruits and vegetables produced annually. As the manure is managed from the animals and as the fruits and vegetables are culled (removed from packing process for disposal) it has the potential to produce methane gas when stored in lagoons, or piles. As the manure and culls breakdown the methane gas is naturally produced. However, if the manure or culls are managed in an anaerobic digestion system the naturally produced methane gas (usually labeled as bio-gas) can be captured and used for energy production. Therefore, this project was designed to demonstrate how energy can be extracted from animal waste and fruit and vegetable culls.

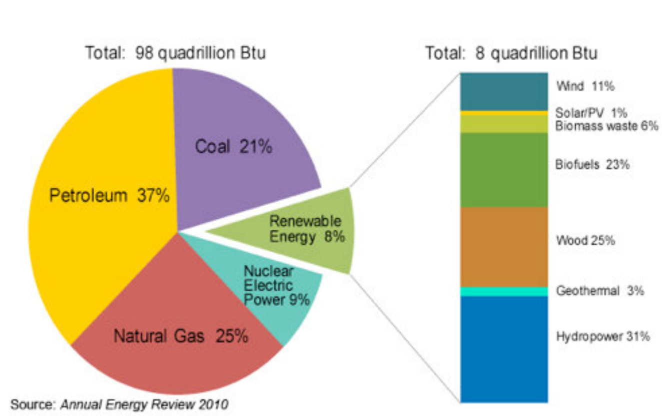



Figure 1. Energy production in 2010 by type. Image taken from Annual Review 2010.

**Reason for Project and Objectives:**

The project was designed to accomplish two different but related issues facing agricultural producers – the management of waste products from the animal industry and the fruit and vegetable industry. Georgia is ranked in the top 10 for the production of both poultry and poultry products and fruit and vegetable crops with the national ranking being in the top 5 for most poultry and fruit and vegetable production. With these large productions there is also a large associated amount of waste material that has to be handled and managed annually see Appendix A.

Therefore, this project was drafted to accomplish the following objectives:

- Install an anaerobic digestion system at a poultry layer operation for treating flush water from a high-rise layer house for production of methane;
- Install an anaerobic digester for demonstrating co-digestion of poultry litter and fruit and vegetable waste,

- Monitor reactor inputs and outputs and use produced gas for on-site operations, and
- Provide Extension education on the anaerobic digestion process, energy availability and operation.

As the project advanced and due to a tornado that destroyed the poultry house with the liquid flush system, the project was modified after two years (with approval from NRCS) to concentrate on demonstrating the gas production from fruit and vegetable waste when combined with animal waste.

**Project Location and Size:**

The location(s) for this project was a poultry/blueberry production site in Bacon County Georgia and the Solar, Anaerobic Digestion and Alternative Energy Lab (SADAEL) at the University of Georgia Tifton Campus.

**What was done to meet project objectives:**

**Characterization of waste:**

*Poultry Waste:*

Liquid poultry waste was collected from the four different containment areas of the lagoon system at the farm being used for the project. A schematic drawing of the lagoons is shown in Figure 2. The lagoon system was a four lagoon system where the flush water first entered a holding pond to settle out most of the solid manure, feathers and eggs. Liquid from the holding pond entered the first real lagoon. A sample of the wastewater was collected at this point (marked as sampling point #1). The liquid in the pond traveled through the lagoon to two separate exit points (a T-pipe through the lagoon walls). Samples of the wastewater were collected at the point where the water entered the second lagoon and the third lagoon (marked as points #2 and #3). The fourth sample was collected at the point liquid entered the third lagoon from the second lagoon (marked as point #4).

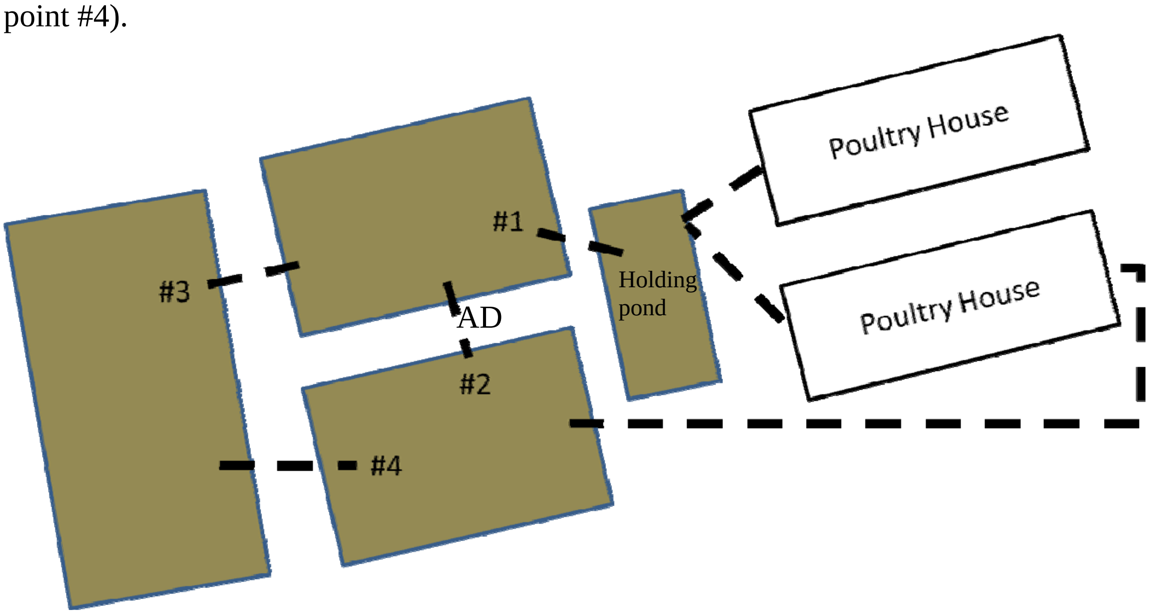



Figure 2. Schematic of poultry lagoon system used in the initial testing and demonstration project.

Collected samples were taken to the lab of Dr. Gary L. Hawkins at the University of Georgia Biological and Agricultural Engineering Department in Tifton Georgia for analysis. The samples were analyzed for pH, Chemical Oxygen Demand (COD), total solids, and volatile solids.

Management of the lagoon system is to recycle water through the three lagoons and the settling basin until a time when the liquid can be spread onto nearby pasture land via a tow irrigation system. The lagoon is pumped down to a level that maintains the integrity of the sludge layer. Once the lagoon has been pumped, fresh water from a well replenishes most of the liquid that was removed. Therefore, the sampling of the lagoon system caught the lagoon in various periods between drain and refill.

*Fruit and Vegetable Waste***:**

Fruit and vegetable waste was collected from various sources when and where possible. The two sources of fruit and vegetable waste were culled fruits and vegetables from packing sheds and harvest from fields after final harvest. The samples as collected were transported to the SADAEL for processing and use in small pilot scale (90 liter) anaerobic digesters. The waste material was processed in a Vincent Screwpress (NOTE**:** use of trade names or specific equipment should not be taken as an endorsement by the USDA-NRCS or The University of Georgia) with the liquid being stored for use in the anaerobic digesters and the pulp added to an onsite compost pile. The liquid and pulp was sampled and analyzed in the wet chemistry lab of Dr. Gary L. Hawkins at the University of Georgia Biological and Agricultural Engineering Department in Tifton Georgia. The samples were analyzed for pH, Chemical Oxygen Demand (COD), total solids, volatile solids, and moisture content

Prior to processing in the screwpress, samples of the whole collected fruit and vegetables were sampled and analyzed. The analysis of these samples was conducted in the wet chemistry lab of Dr. Gary L. Hawkins at the University of Georgia Biological and Agricultural Engineering Department in Tifton Georgia for analysis. The samples were analyzed for pH, Chemical Oxygen Demand (COD), total solids, volatile solids, and moisture content.

**Results of testing:**

*Poultry Waste:*

The poultry waste was analyzed for its Chemical Oxygen Demand (COD), Volatile Solids and pH. As mentioned above, the lagoon management consisted of removing some of the lagoon water for irrigation and replacing with clean water. This had some impact on the COD, solids and pH of the lagoon. However, the data was averaged across the sampling years and accounted for the draining and refilling over time. The average COD concentration of the lagoon water is presented in Figure 3. As can be seen there is a slight reduction in COD as the wastewater passes through the lagoon system, but not a significant change as it goes through the three lagoons outside the settling basin. The solids content of the sampled wastewater is presented in Figure 4. The volatile (VS) and fixed solids (FS) are taken as that of total solids (TS). As can be seen, there is a significant difference in the solids content across the settling pond and the

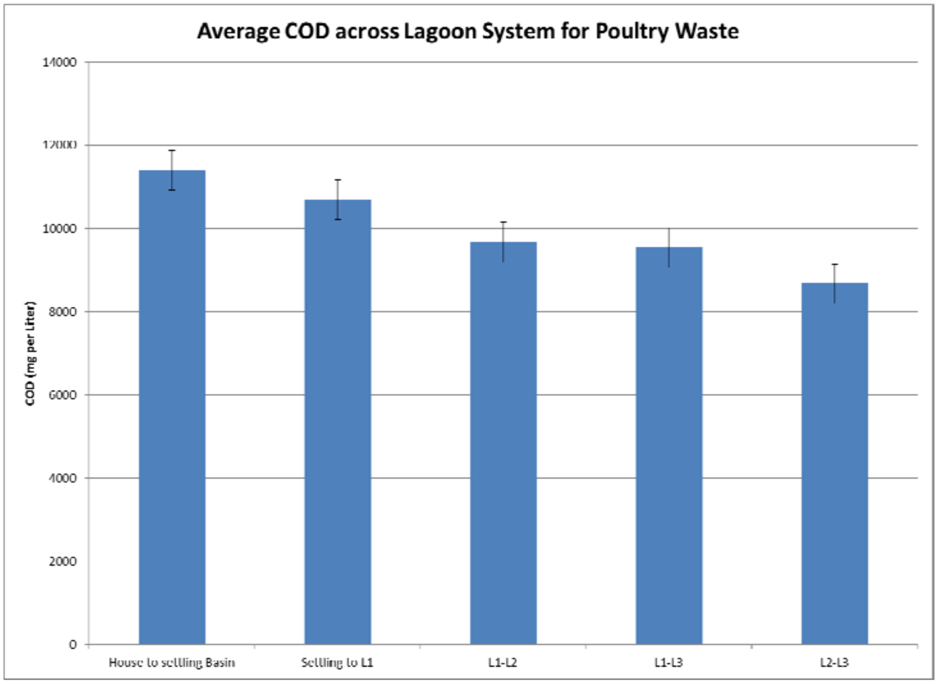



Figure 3. Average Chemical Oxygen Demand of the lagoon system of a poultry (layer) flush system. The data presented in the figure relates to the schematic shown in Figure1.

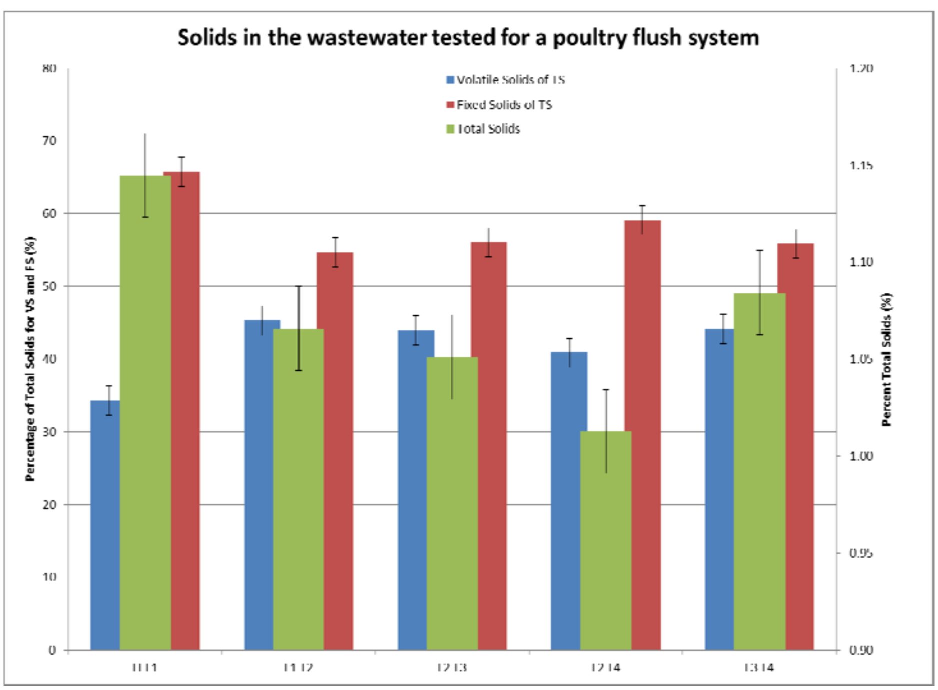


Figure 4. Solids analysis of the poultry waste water samples collected from a flush layer operation. The VS and FS data is reported as that of the total solids in the wastewater.

lagoon system as would be expected. Likewise the average pH of the samples was measured to be 7.8.

*Fruit and Vegetable Waste:*

Fruit and Vegetable culls from various sources were collected and analyzed for COD in the 2008 growing season. The measured COD is shown in Figure 5. The data for all fruits and vegetables analyzed except blueberries was below 100,000 mg $L^{-1}$ with blueberry being 250,000 mg $L^{-1}$. To meet the objectives of the demonstration project, and due to the ease of getting culls year round, onions were predominately used in anaerobic digesters to determine and demonstrate gas production from anaerobic digesters.

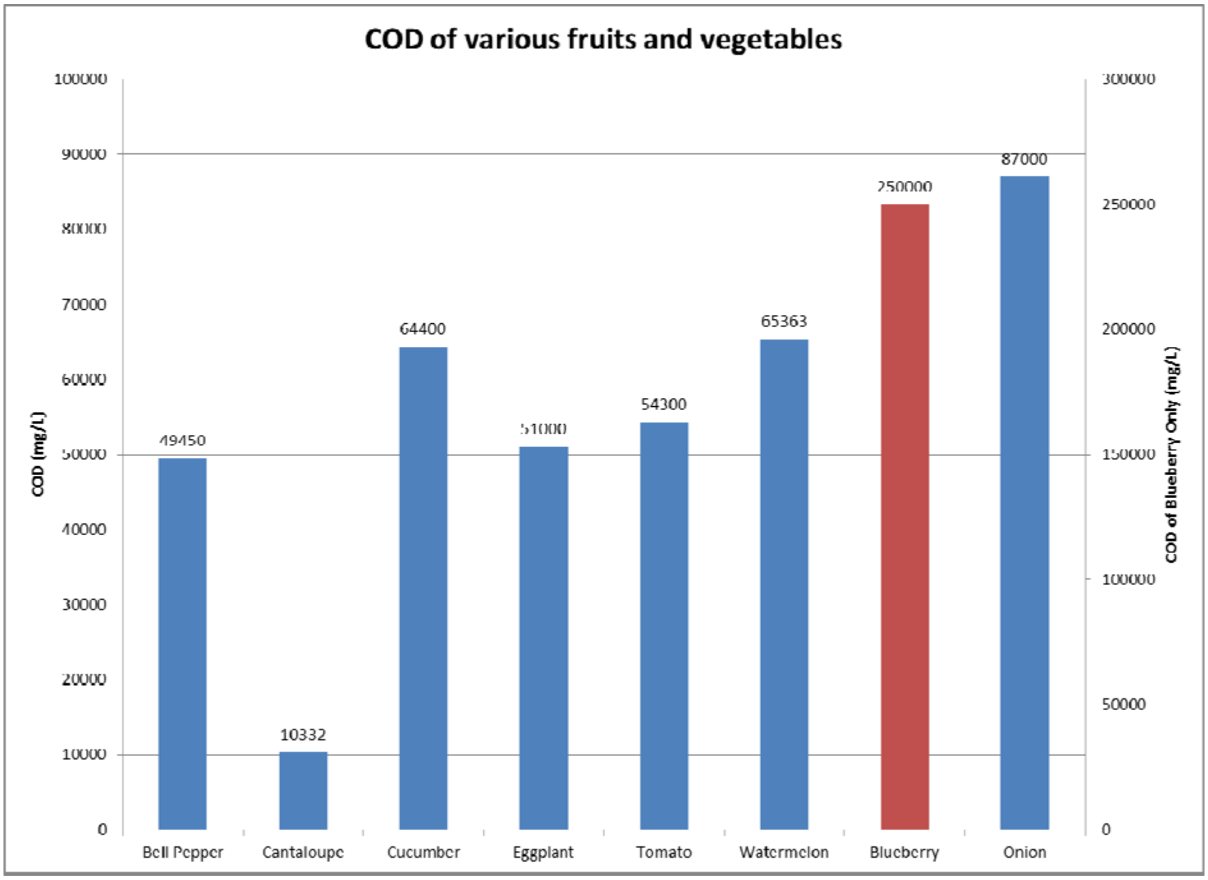



Figure 5. COD values of various fruit and vegetable waste that could be used in a co-digestion anaerobic digester with animal waste to produce bio-gas. The blueberry results should be read on the right axis.

**Results of anaerobic digester operation:**

After the initial test to determine the characteristics of various fruit and vegetable waste, anaerobic digesters were constructed to determine and demonstrate the gas production from poultry waste as well as from a combination of fruit and vegetable waste with animal waste. The anaerobic digesters used in the project were pilot scale digesters of 90 Liter void volume. A picture showing what the digesters look like can be seen in

Figure 6. The digesters are constructed of PVC pipe and filled with lava rock to provide a matrix for bacteria to grow on and convert the organics to biogas. This type digester is a fixed film digester. The specific type used in this demonstration is a downflow anaerobic filter. The digesters are wrapped with tubing to keep them at 35 degrees Celsius and then also wrapped with insulation to maintain the temperature. A digester was placed adjacent to the poultry lagoon (temperature was not maintained at 35 degree Celsius in this digester only ambient temperature) to determine the gas production potential from the lagoon waste water. This was placed between the two lagoons as shown on Figure 2 (noted as "AD"). The digester had problems in maintaining the pump operation due to the lack of power. A DC pump was used to transfer liquid from the lagoon to the anaerobic digester. When the digester was checked over multiple visits the pump had stopped pumping after it was made operational during each visit. It is expected a couple possible issues could have occurred with the pumping system. Since the pump was DC, a solar panel was installed to maintain and charge a battery to operate the pump. However, with the solar panel located outside and downwind of the fans on the poultry house, the solar panel constantly had dust on it thereby caused the panel not to recharge the battery and the battery died. The digester was removed from the lagoon site and operated at the SADAEL in Tifton, GA to continue the demonstration.

Figure 6. Pilot scale anaerobic digesters like the ones above were installed at the lagoon site, with some problems. The ones shown above are operated at the SADAEL in Tifton, GA to monitor gas production from fruit and vegetable waste and animal waste.

The anaerobic digesters have been operated on blueberry and onion juice in combination with animal waste. The data on gas production from blueberry waste in combination with animal waste is presented in Figures 7 and 8. The data is given in number of flips of a tipping bucket. Each flip is 25 mL of bio-gas produced with the composition of the bio-gas being close to 70% methane.

Like the blueberry waste, onion juice was used in combination with animal waste at two different percentages. These percentages were 33% vegetable juice to 66% animal waste and 50% vegetable juice to 50% animal waste. A portion of the data collected from the two different demonstrations can be seen in Figures 9 and 10.

Data collected from the operation of the anaerobic digesters was the result of operating the digesters at multiple organic loading rates and hydraulic retention times. Multiple rates for both OLR and HRT were used to try and find an optimum rate at which the digesters would produce a consistent output of bio-gas per liter of waste water introduced to the digesters. As can be seen in figures 7, 8, 9 and 10 the introduction of feedstock caused a quick response of the digesters to convert the carbon based compounds into bio-gas. The quick conversion typically and consistently occurred in a 3-5 hour time period. As the feed rate was reduced from 24 hours to less than 12 hours, the frequency of bio-gas production was reduced, but the pH and alkalinity of the system were also reduced and caused conditions in the digesters that would normally cause a failure of the system. This can be seen very well in Figure 9 where the frequency and amplitude of the bio-gas production at a feed rate of 12 hours was low and high, respectively. When the feed rate was reduced to 6 hours, both the frequency and the amplitude was reduced. The shorter feed time did result in a higher bio-gas producion at the 6 hour feed rate verses the 12 hour feed rate as would be expected. However, the shorter feed rate resulted in a reduced pH in the anaerobic digester and thereby reducing the bio-gas production.

Another aspect of the anaerobic digester is that the alkalinity, or buffering capacity, should be maintained between 2000 and 4000 mg $L^{-1}$ as $CaCO_3$ (Standard Methods) (indicated by the yellow box). Data collected (Figure 11) from the anaerobic digesters shows that as the alkalinity increased above 4000 mg $L^{-1}$ as $CaCO_3$ which was a result of adding alkalinity in the form of bicarbonate the gas production fell to a very low level. When the digesters are managed daily to account for the alkalinity, the bio-gas production can also be maintained.

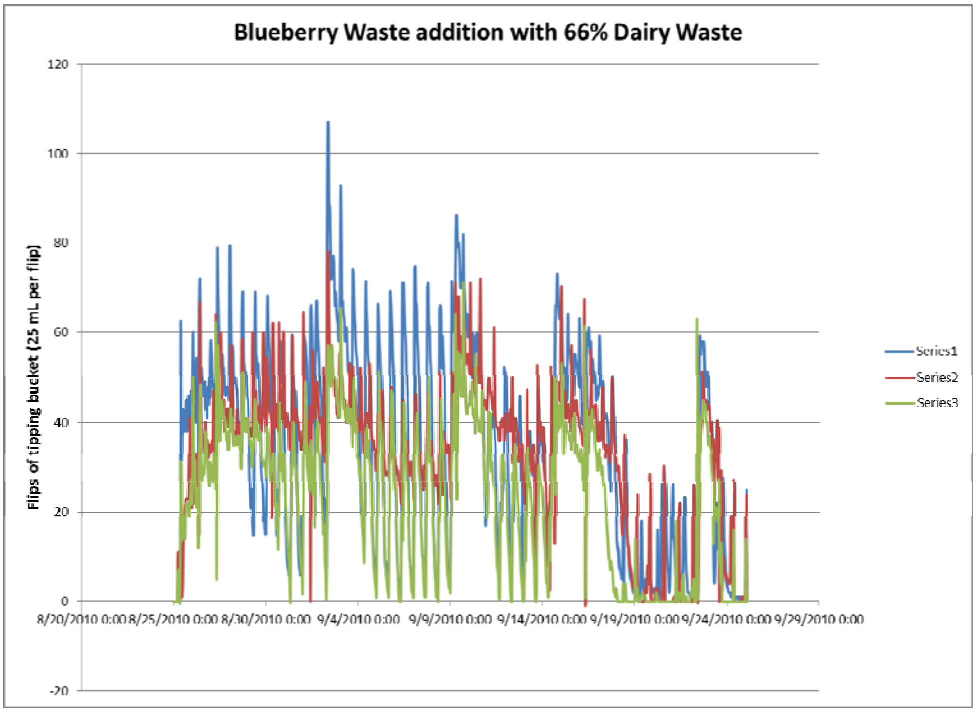



Figure 7. Bio-gas production from the anaerobic digestion of blueberry waste and animal waste.

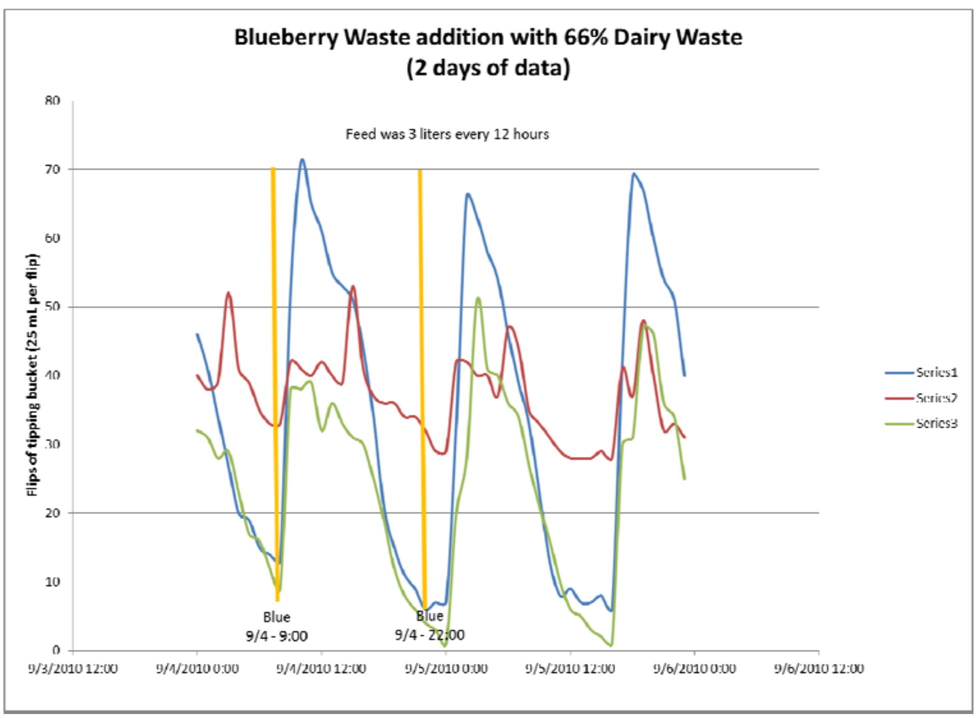



Figure 8. Bio-gas production on a 2 day base. As the data indicates, the blueberry juice (and other juice when used) is consumed in the first couple of hours after introduction to the digester.

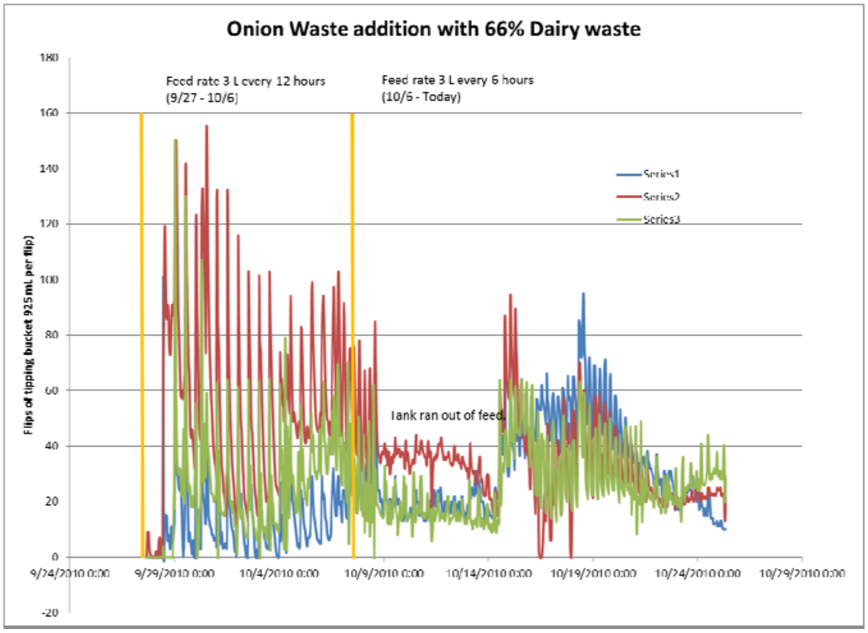



Figure 9. Bio-gas production from feeding a 33% onion juice to 66% animal waste into anaerobic digesters at various feed rates. A can be seen, the faster the feed rate the lower the bio-gas production.

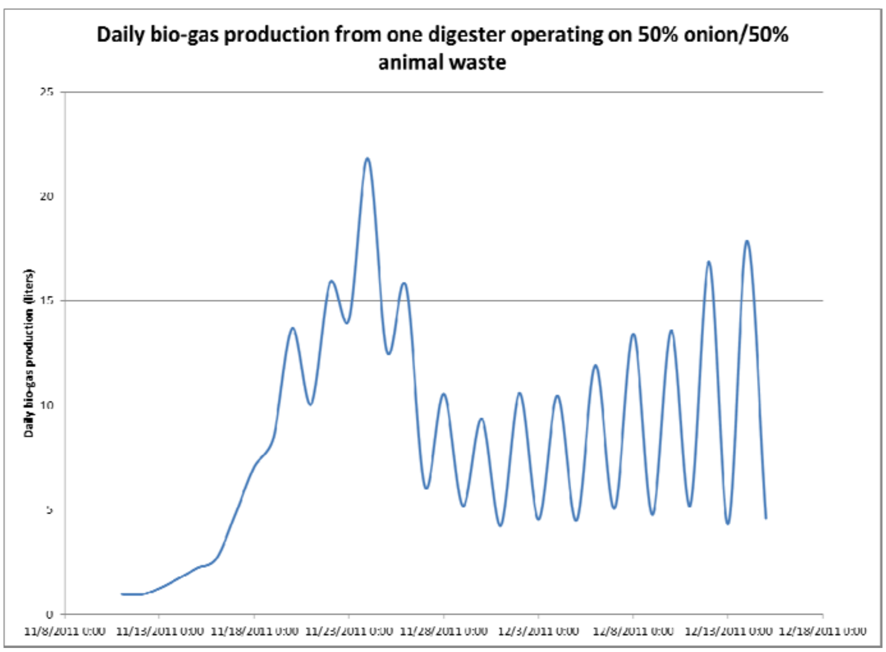



Figure 10. Daily bio-gas production from a digester operating on a 50/50 blend of onion waste and animal waste. The feed rate is 3 liters every 16 hours.

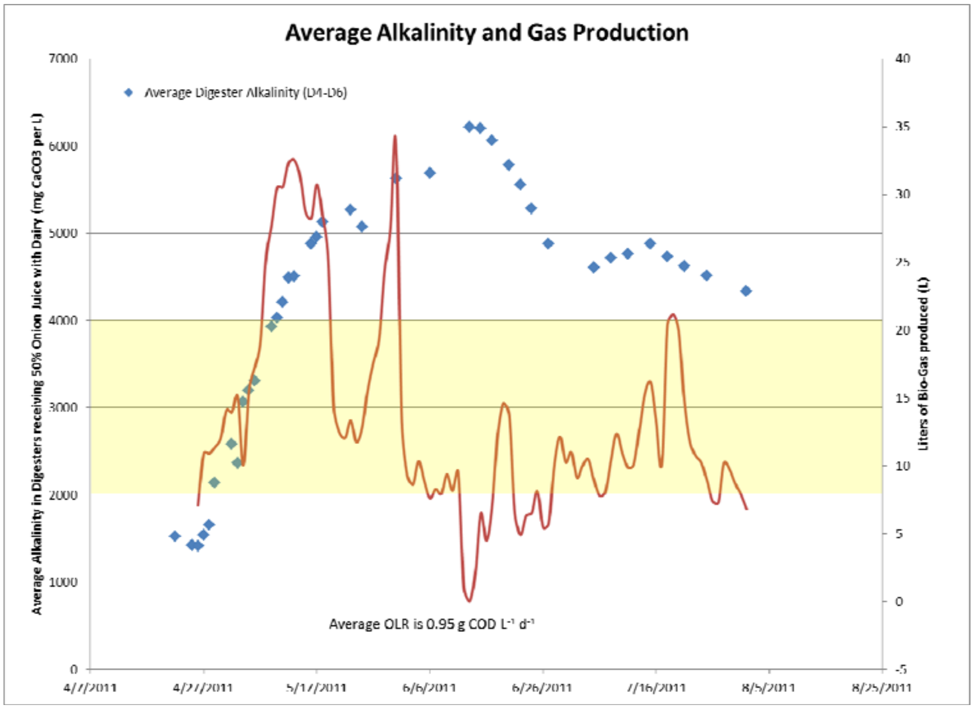



Figure 11. A select set of data showing how gas production is reduced when the alkalinity is allowed to increase above the recommended 4000 mg $L^{-1}$ as $CaCO_3$. Not shown on this graph, but likewise if the alkalinity falls below 2000 mg $L^{-1}$ as $CaCO_3$a reduced gas production results.

**Education and Outreach:**

The Conservation Innovation Grant (CIG) Program is designed to demonstrate an innovative use of technology on farm as well as dissemination of information to other farmers and interested agricultural personnel. To accomplish the dissemination of information various activities have been accomplished. These include the following and are explained in more detail below.

- Extension Publications
- Proceeding papers, abstracts and presentations at conferences
- Articles and citations in popular press and newsletters
- Multiple displays at a national farm show and other meetings and conferences
- Trainings and presentations to NRCS personnel and Extension Agents
- Presentations to professional organizations
- Presentations at various venues
- Webinar
- International presentations
- Multiple presentations to school age kids

*Extension Publications:*

Two extension publications were produced during the time of the project to disseminate information on the management and use of fruit and vegetable waste. Plans are to draft and publish a joint UGA/NRCS publication of the operation of anaerobic digesters. The two publications are listed here:

- **Hawkins, G.L**. 2010. "Managing Fruit and Vegetable Waste". Extension Publication Number B1369, January 2010.
- **Hawkins, G.L.** 2008. "Characterization of Fruit and Vegetable Wastes for Energy Production". 2008 Georgia Vegetable Extension/Research Report

*Proceeding papers at Conferences:*

Other ways of disseminating information to interested agricultural industry personnel is to present at local, regional, national and international venues. The following is a list of those presentations.

- **Hawkins, G.L**. 2010. "Onion Power – Potential Production of Bio-fuels from Onions and Other Vegetables", *Proceedings of the 2010 Southeast Regional Vegetable Conference*, Savannah, GA., 8-10 January 2010, Ed. Alton Sparks. Abstract.
- **Hawkins, G.L.** 2010. Extensions Role in Providing Answers to Agricultural Waste Management. Poster. Presented at the 2010 ANREP Annual Meeting. Fairbanks, AK. 27-30 June 2010.
- **Hawkins, G.L**. 2010. Innovative Tools and Best Practices for Regenerating Small Scale "On the Farm Energy" Projects. Growing Power Conference, Milwaukee, WI. 10-12 September 2010. Abstract.
- **Hawkins, G.L.** 2008. Using Onion Waste to Produce Energy. Abstracts of the 2008 National Alliums Research Conference, Savannah, GA 11-13, 2008, Chaired by George Boyhan.
- **Hawkins, G.L**. and P. Sumner. 2008. "Converting Fruit and Vegetable Waste into Energy", *Proceedings of the 2008 Southeast Regional Vegetable Conference*, Savannah, Ga., 11-13 January 2008, Ed. William Terry Kelly.
- **Hawkins, G.L**. Using Onion Waste to Produce Energy. Abstract in Proceedings of 2008 National Alliums Research Conference. Savannah, GA. 15 December 2008.

*Articles and Citations in Popular Press and Newsletters:*

Multiple articles have been written in popular press magazines to disseminate information on the use of solar and wind where available to provide water for livestock in remote locations.

- **Hawkins G.L**. 2009. Grant to boost Vidalia Onions. Quoted in the Southeast Farm Press. 14 December 2009.
- **Hawkins, G.L**. 2008. Finding Energy in a Typically not Thought of Location – Fruit and Vegetable Waste, Abstracts of the 2008 GACAA Annual Meeting, 17-19 November 2008 (120 persons)
- Geller, D., B. Buchanan and **G.L. Hawkins**. On-Farm Energy Production. Cotton Farming Magazine, Technology for Profits, Now and in the Future Insert. November 2008 issue
- **Hawkins, G.L.** 2006. "Fruit and Vegetable Waste for Alternative Energy Production", Fall 2006 Issue of Georgia Extension Vegetable News

- Using Waste Materials to Produce Energy. Special Clean Energy Insert in the November issue of The Peanut grower. November 2010.
- The Heat is On, the lead story on the UGA Webpage on 28 January 2010. Article written by Stephanie Schupska

*Multiple displays at a National Farm Show and Other Meetings and Conferences:*

The anaerobic digestion system was displayed at the Sunbelt Agricultural Expo three different years. The purpose of the display was to demonstrate how fruit and vegetable waste along with animal waste can be used to convert waste materials into methane gas. All three years the project director discussed the system with over 300 farmers over the three day event. The interested farmers were from locations across the US and represented different parts of the economy from farmers to business personnel with waste products such as fruit and vegetable waste. This means of disseminating information to the public can't be directly measured, but is one very visible means to discuss the use of this technology with the farming community as well as others interested in anaerobic digestion. A picture of the display used for educational outreach can be seen in Appendix B-1.

In addition to the National Farm Show, the anaerobic digestion display has been used at multiple meetings and conferences. The display (Appendix B-1) is a good means to show how the anaerobic digester works and is a hands-on type of display to better explain the process. Some of the locations where the display has been used are**:** Annual Georgia Farm Bureau Commodity Committee Meeting, the Annual Georgia Soil and Water Conservation District Supervisor Meeting, Southeast Regional Fruit and Vegetable Conference, and visits with congressional delegations. These meetings and others like them provides a visual display of the use of solar power to provide water for livestock.

*Trainings and presentations to NRCS personnel and Extension Agents:*

The dissemination of information to NRCS personnel has occurred at National Trainings for NRCS State Level Staff. These were for both the Northeast and Southeast regions of NRCS. Information on anaerobic digestion has been disseminated to field level NRCS personnel through presentations associated with other workshops and meetings. Presentation covers can be seen in Appendix B-2.

To also educate the University of Georgia Extension agents to work with there farmers better, multiple presentations were made to them as continuing professional education trainings.

*Presentations to professional organizations*

Information has been disseminated to National and local professional organizations such as Soil and Water Conservation Society, American Society of Agricultural and Biological Engineers, National Association of Natural Resource Extension Professionals, Georgia Association of Water Professionals, Georgia Environmental Conference and Soil and Water Conservation District Supervisors. Presentation covers from some of the presentations can be seen in Appendix B-3.

*Presentations at various venues:*

Presentations were given at the following locations to disseminate information on the use of anaerobic digestion for the extraction of energy from agricultural waste products (see Appendix B-4 for a few of the first slides):

- **2011 SE Regional Fruit and Vegetable Conference.** Update on Use of Vegetable Waste for Biofuel. Savannah, GA 8 January 2011. 20 mins. 45 persons.
- **2011 SE Regional Fruit and Vegetable Conference.** 7 Ways to manage Fruit and Vegetable Waste. Savannah, GA 8 January 2011. 20 mins. 35 persons.
- **2011 SE Regional Fruit and Vegetable Conference.** Converting the Sweet Onion into an Odorless Gas. Savannah, GA 8 January 2011. 20 mins. 50 persons.
- **National Allium Conference.** Converting Onion Waste into Useful Fuel. December 10, 2010. 30 minutes Reno, NV. 200 persons.
- **National SCRI Conference.** Onion Post Harvesting Management. Presented by Changying Li on behalf of research team. 26 July 2010.
- **ANREP Bi-annual Conference. "**Extensions Role in Providing Answers to Agricultural Waste Management". Fairbanks, AK. 29 June 2010. Poster.
- **2010 SE Regional Fruit and Vegetable Conference.** Onion Power – Potential Production of Bio-fuels from Onions and Other Vegetables. Savannah, GA 8 January 2010. 20 mins. 50 persons.
- **4th Georgia Environmental Conference.** Alternative Uses of Energy in the Future Farmstead. Savannah, GA 27 August 2009. 30 mins. 25 people.
- **Georgia Environmental Conference.** Farming with Alternative Energies – Solar, Wind, Anaerobic Digestion. Savannah, GA. 26 August 2009. 30 mins. 20 persons.
- **Georgia Water Professionals Meeting.** Methane to Energy from Agricultural Waste. Savannah, GA. 11 August 2009. 20 mins. 35 persons.
- **Toombs, Montgomery, Wheeler and Treutlen County Extension Vegetable Training.** Onion Power – Potential Production of Bio-fuels from Onions and Other Vegetables. Mt. Vernon, GA 16 March 2010. 30 mins. 20 persons.
- 2010 Winter School Training (web based). 2010 Energy Update – Busting Myths about Alternative Energy. 22 January 2010.

*Webinar:*

One webinar was conducted in conjunction with NCAT as part of an Energy Training for Extension Professions. The webinar was recorded and is available on YouTube. The citation is (see Appendix B-5)**:**

Onion Power – Potential Production of Bio-fuels from Onions and Other Vegetables. Presented as a webinar as part of ENTAP Training. The presentation was saved on YouTube searchable under "Onion Power". 17 February 2010.

*International Presentations:*

The director has had the opportunity to present work related to the conversion of fruit and vegetable waste at one international meeting. The meeting was held in Torreon, Mexico as part of the Bi-National Symposium of Anaerobic Digestion of Animal Waste. May 10-11, 2009.

*Multiple presentations to school age kids:*

This means of outreach does not directly interface with farmers, but it provides education to the next generation of farmers, land owners and educators. The presentations were designed to make the students aware of how anaerobic digestion work and how the technology can be used by farmers to turn waste materials into useful energy. Anaerobic digestion has also been apart of many different college level classes where bio-fuel processing is taught. This form of outreach has reached over 100 students from the second grade to high school FFA/Agricultural students.

**Production of Biogas:**

The lagoon system as shown in Figure 2 was actively producing biogas in the first lagoon (noted with the #1). The project director tried to capture some of the biogas for a test purpose during the initial testing of the project. A fifty square foot cover was placed on the lagoon system as shown in Figure 12. The cover collected some biogas, but an accurate measurement was not capable with the monitoring system used. The pressure in the monitoring system had to overcome a slight water pressure head. Before the pressure head could be overcome, the biogas would leak out from under the cover. However, this lead to the idea of covering the lagoon system with a cover verses using a stand alone anaerobic digester system. Shortly after this idea, the building was destroyed and the project objectives were redirected to concentrate on the anaerobic digestion of fruit and vegetable waste.

The biogas collection from the anaerobic digesters operating on fruit and vegetable waste has been very successful. The concept is to use an inverted tipping bucket connected to a computer which can monitor tips of the bucket. The data from this biogas monitoring system can be in part in Figures 7-10 above. As can be seen from the graphs above, some of the pilot digesters were producing upwards of 15 liters of gas per day with less than 3 liters of vegetable juice introduced daily.

Therefore, from both the lagoon system observation and testing, the lagoon system should produce ample biogas if designed properly to handle the solids without the need for trying to operate a stand alone anaerobic digester unless there is proper management available from the famer. The production of biogas from stand alone anaerobic digesters was at a level that should be expected. The digesters, when managed properly, were able to handle the introduced vegetable juice while “cleaning” the wastewater as determined by chemical test.

Figure 12. A test floating cover to determine the quantity of biogas that could be produced in a poultry lagoon system.

## Benefits and Drawbacks:

The anaerobic digestion systems studied in this demonstration project had both benefits and drawbacks as would be expected from any project, but specifically from a biological system. Some of these are listed below:

**Benefits:**

1. The lagoon system that was originally considered for the project (seen as a whole in figure 2) was a well operating system. In such a case the lagoon system should be used as designed with a full or partial cover system.
2. The use of stand alone anaerobic digesters makes the management and testing of the system a lot easier if there is someone knowledgeable about what is needed to manage such a system.
3. Fruit and vegetable waste, even though they are 80% or greater water, has a high COD that when introduced to an anaerobic digester has a large quantity of energy.
4. The co-digestion of fruit and vegetable waste with animal waste provided quick carbohydrates for converted energy (carbon based compounds to methane) as well as slowly converted compounds (proteins) for the buffering of the system. The animal waste can potentially provide bacteria for replenishing the digester.
5. The conversion of fruit and vegetable waste provides a means to produce energy from a waste as well as providing a means to mange waste and protect natural resources.
6. Fruit and vegetable liquid can be stored for an extended period with no change in the chemical characteristics of the juice.

**Drawbacks:**

1. Stand alone anaerobic digesters should be managed by someone that has some knowledge of how the system works and knows some of the basics of operating such a system.
2. A person on any farm with a stand alone anaerobic digester should be dedicated to the digester with other duties, nit someone with other duties being responsible for the anaerobic digester.
3. When feeding any digester, lagoon or anaerobic digester, the content of the feedstock should be relatively constant with very few or no large additions of higher or lower COD or VS.

## Lessons Learned:

Some of the lessons learned from this demonstration project are:

1. Working with farmers is great, but to have an anaerobic digester on a farm, the farmer must be fully committed to the operation and management of the anaerobic digester since the chemical parameters need to be checked frequently.
2. Operating an anaerobic digester with fruit an vegetable requires an understanding that the gas production is very variable over time and has a peak as seen in Figures above. The easily converted sugars in the waste tend

to allow a quick conversion of carbon compounds to biogas with a period for no gas production. This is only important if gas is used as it is produced.

3. When using fruit and vegetable waste, the feedstock can be stored for extended periods of time to buffer the need for a continual supply of feedstock and to overcome seasonal production.

I expect there are others, but these are the main lessons that we learned from the operation and demonstration of the anaerobic digestion systems.

**Conclusions:**

The use of anaerobic digesters is a very good way to manage animal waste while producing biogas or methane. The use of fruit and vegetable waste in conjunction with animal waste is a good way to manage two different agricultural waste streams while producing a useful by-produce – bio-gas or methane. Data indicates that the average COD of wastewater from the tested poultry lagoon was 10,000 mg L-1 whereas the average COD of waste fruit and vegetables ranged from 10,000 mg L-1 to 250,000 mg L-1. This indicates that there is potentially 25 times more energy available in fruit and vegetable waste than that of animal waste. However, the fruit and vegetable waste has quickly converted carbohydrates whereas the animal waste has a slowly converted carbon source such as proteins. When these two feedstocks are combined, the material that would be introduced to anaerobic digesters has the ability to produce high quantities of biogas quickly with the ability to provide some buffering to maintain the anaerobic digestion system.

Overall, the extraction of energy from fruit and vegetable waste in conjunction with animal waste is very viable, but there is some reservations that should be considered. These include but are not limited to the facts that the anaerobic digestion system should be managed on a daily basis not when time allows if the system is a stand alone system. The introduction of the feedstock needs to be consistent and there should be no problems, but the consistency of the feedstock should be checked regularly. If a stand alone anaerobic digester is planned for a farming system, there should be a person assigned to the digester with other duties not someone with other duties assigned to the digester.

Overall, data and results from the demonstration shows that fruit and vegetable waste can be used in conjunction with animal waste to produce a very useful by-product and that being biogas or methane.

**References**

Institute for Energy Research. 2011. http://www.instituteforenergyresearch.org/2011/10/28/2010-annual-energy-review/

Standard Methods. 2005. Standard Methods for the Examination of Water and Waterwater. APHA. 21st Edition.

# Appendix A

# Georgia's Rankings in Agricultural Production

## GEORGIA AGRICULTURAL FACTS

USDA,NASS GEORGIA FIELD OFFICE

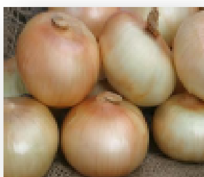
Published Estimates as of September 1, 2010

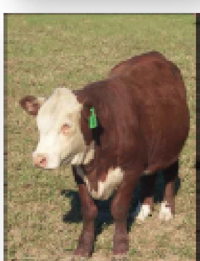
**LARGEST LAND AREA EAST OF THE MISSISSIPPI**

| | | |
|---|---|---|
| 2009 Cash Receipts | $6.85 | billion |
| 1 Broilers | $3.14 | billion |
| 2 Vegetables & Melons | $647 | million |
| 3 Cotton | $473 | million |
| 4 Chicken Eggs | $469 | million |
| 5 Peanuts | $390 | million |

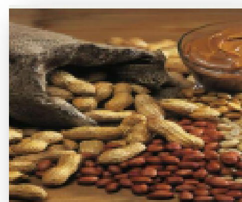
**MOST NUMBER OF COUNTIES EAST OF THE MISSISSIPPI**

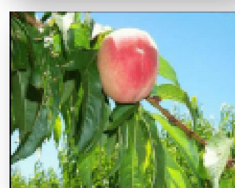
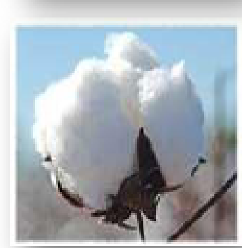
2009 U.S. Rank # 12 in Cash Receipts
# 1 in production of the following commodities:
- Broilers
- Peanuts
- Pecans



| U.S. Rank | WHAT WE PRODUCED IN 2009 | |
|---|---|---|
| 1 | Broilers | 1.32 bil hd |
| 1 | Peanuts | 1.78 bil lbs |
| 1 | Pecans | 79.00 mil lbs (utilized) |
| 2 | Cotton | 1.86 mil bales |
| 2 | Cotton Seed | 539.10 th tons |
| 2 | Cucumbers, Fresh Market | 2.50 mil cwt |
| 2 | Onions, Spring | 2.52 mil cwt |
| 2 | Rye | 560.00 th bu |
| 2 | Snap Beans, Fresh Market | 720.00 th cwt |
| 3 | Bell Peppers | 980.00 th cwt |
| 3 | Cantaloupes | 1.38 mil cwt |
| 3 | Sweet Corn, Fresh Market | 3.25 mil cwt |
| 3 | Watermelons | 6.90 mil cwt |
| 4 | Blueberries | 43.00 mil lbs (utilized) |
| 4 | Peaches | 30.00 th tons (utilized) |
| 4 | Squash | 1.06 mil cwt |
| 5 | Cabbage, Fresh Market | 1.89 mil cwt |
| 6 | Tobacco | 28.00 mil lbs |
| 6 | Tomatoes, Fresh Market | 1.26 mil cwt |
| 7 | Eggs | 4.47 bil eggs |
| 8 | Sorghum for Silage | 132.00 th tons |
| 10 | Grapes | 4.50 th tons (utilized) |
| 12 | Sorghum for Grain | 2.12 mil bu |
| 19 | Farms, All | 47.60 th farms |
| 19 | Oats | 1.12 mil bu |
| 23 | Hogs & Pigs (Dec. 1, 2009) | 195.00 th hd |
| 23 | Soybeans | 15.84 mil bu |
| 24 | Corn for Grain | 51.80 mil bu |
| 25 | Milk Production | 1.40 bil lbs |
| 27 | Wheat | 10.50 mil bu |
| 28 | Land in Farms | 10.30 mil acres |
| 29 | Cattle & Calves (Jan 1, 2010) | 1.06 mil hd |
| 33 | Corn for Silage | 510.00 th tons |
| 34 | Hay, All (Dry) | 1.61 mil tons |



Published by the USDA, NASS, Georgia Field Office, Stephens Federal Building, Suite 320, 355 E Hancock Avenue, Athens, GA 30601
Website: http://www.nass.gov

# Appendix B-1

# Displays at National Farm Shows and Other Meetings and Conferences

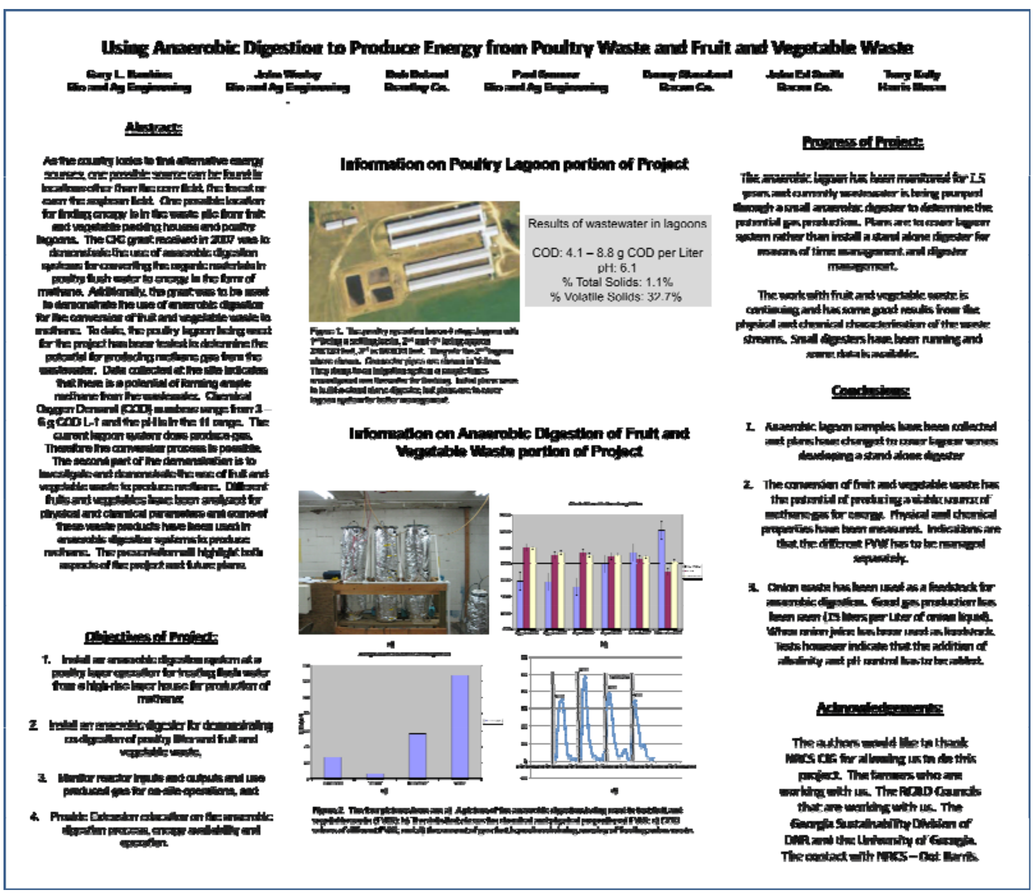
Display used as a hands-on visual schematic of how the anaerobic digestion system works.

# Appendix B-2

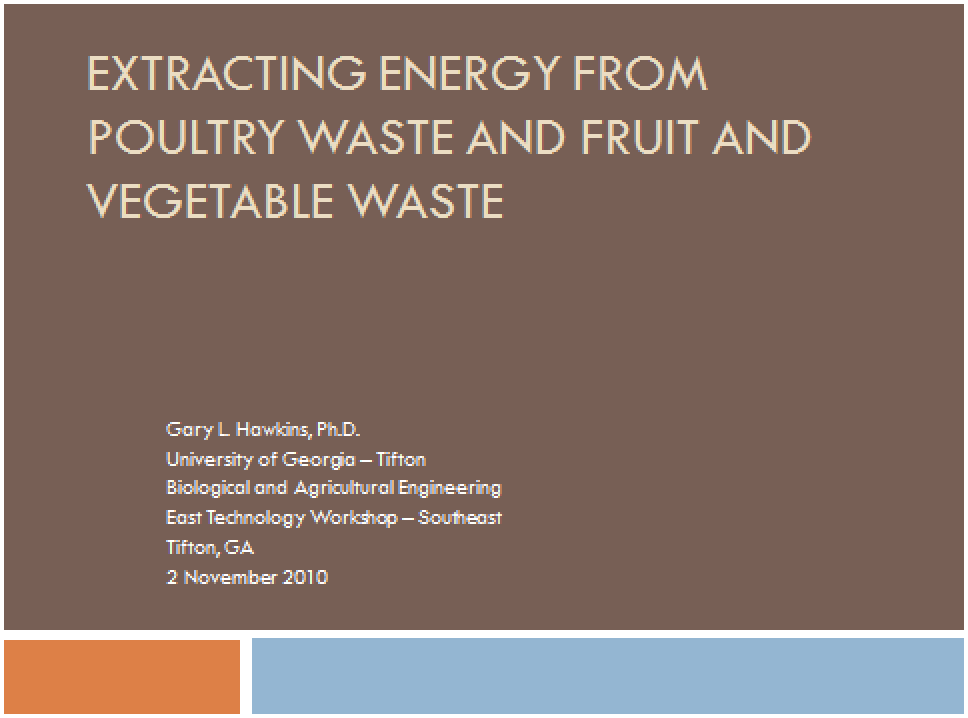
# Poster and First Slides of Presentations for NRCS

2009 Georgia NRCS State Technical Meeting

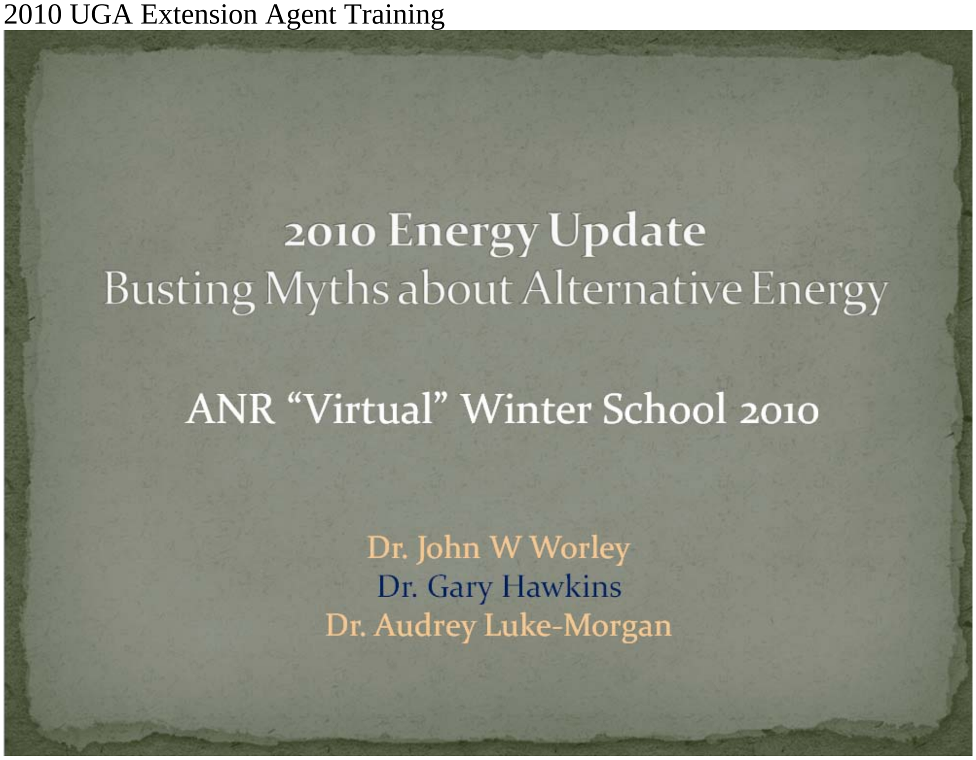

2009 NE NRCS Regional Training – Poster and presentation



2010 SE NRCS Regional Training



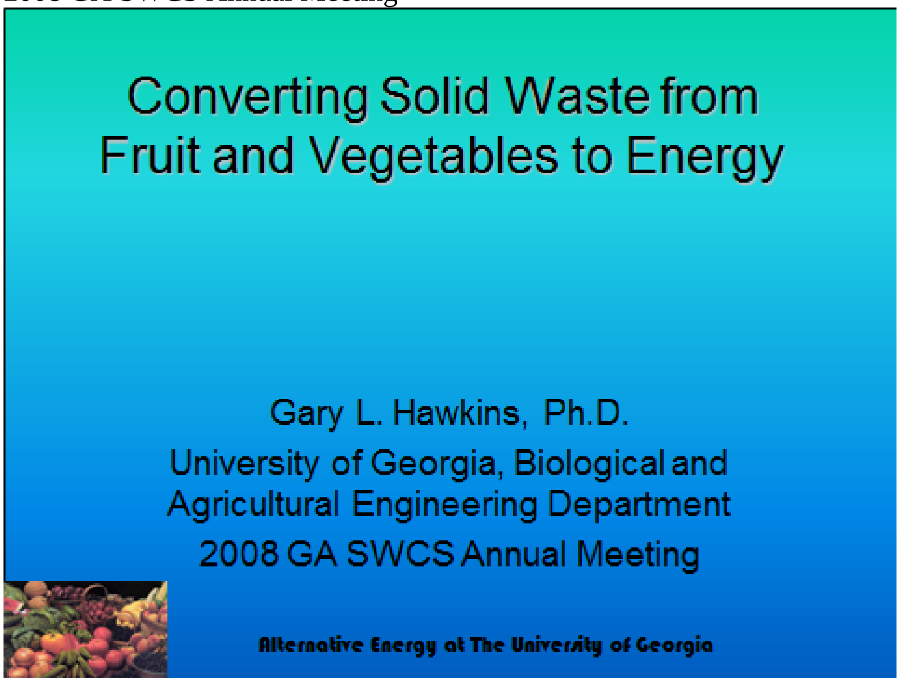

2010 UGA Extension Agent Training



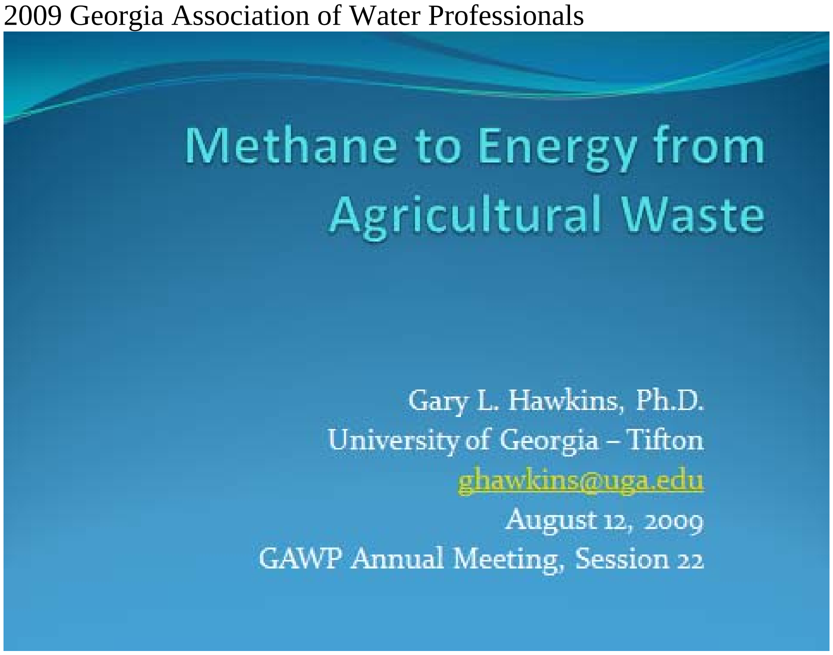
# Appendix B-3

## Posters and First Slides of Presentations for Professional Organizations

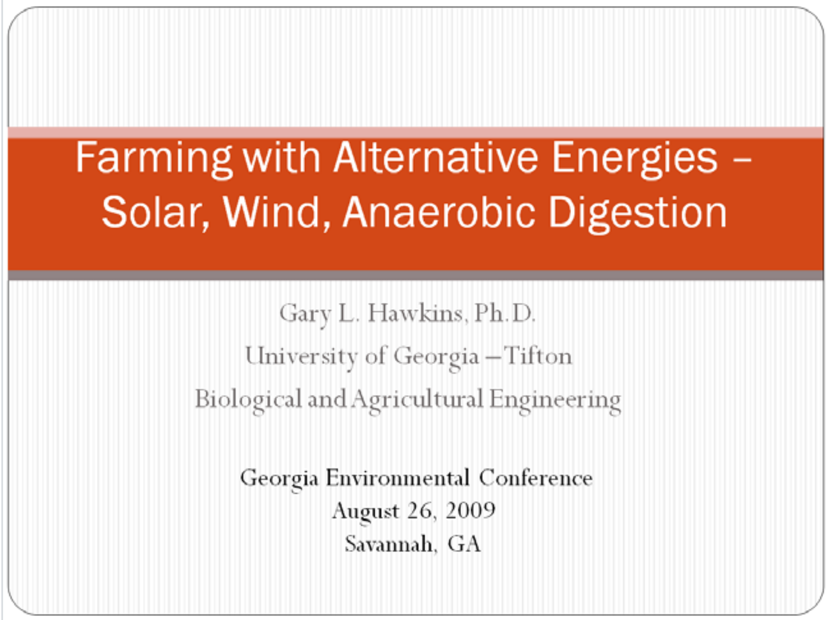
2008 GA SWCS Annual Meeting



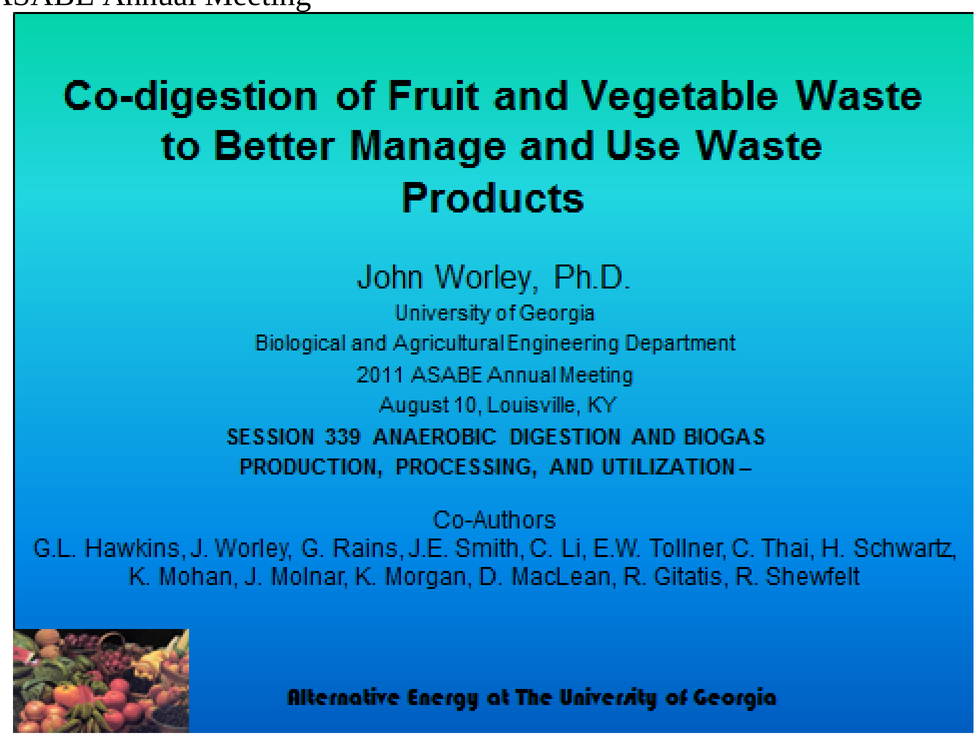

2009 Georgia Association of Water Professionals



2009 Georgia Environmental Conference




2011 ASABE Annual Meeting

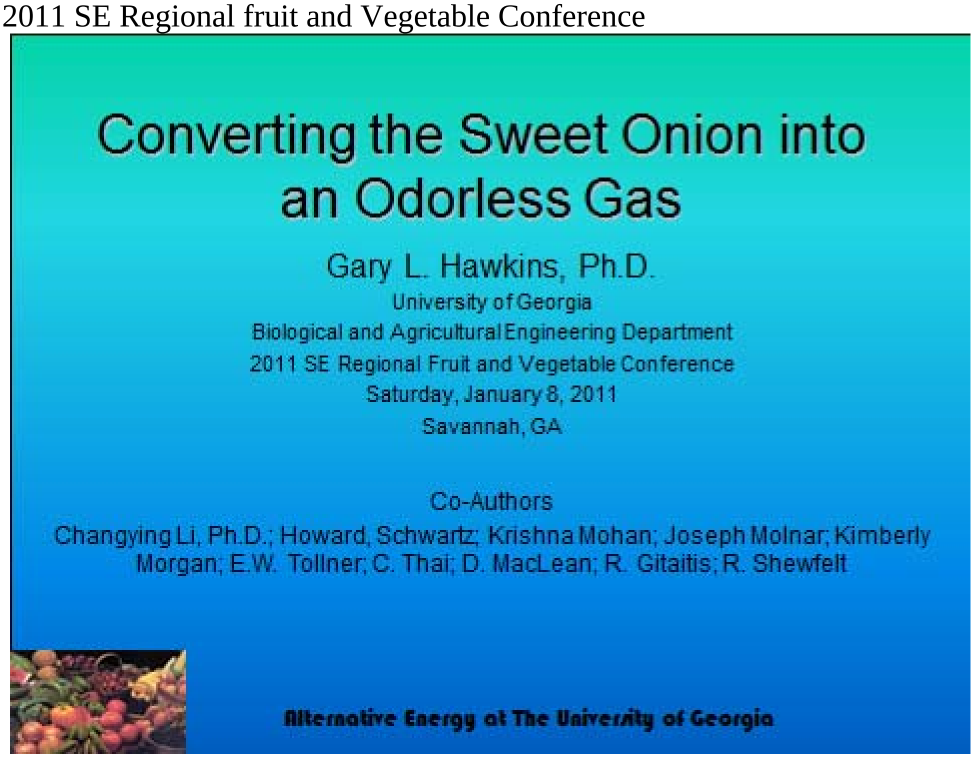


# Appendix B-4

## First Slides of Selected Presentations

2010 Growing Power Conference


2011 SE Regional fruit and Vegetable Conference



# Appendix B-5

# Webinar

2010 ENTAP Webinar on Extracting Energy from Fruits and Vegetables