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October 2005 Report of Progress

Charles Glass

Kimberly L. Jones

M. Katherine Banks

Albert J. Heber

Ernest R. Blatchley

See next page for additional authors

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Authors

Charles Glass, Kimberly L. Jones, M. Katherine Banks, Albert J. Heber, Ernest R. Blatchley, Bruce Applegate, Paul B. Brown, Cary A. Mitchell, Caula A. Beyl, Lisa J. Mauer, Leonard Williams, Joseph F. Pekny, George Chui, Yuehwern Yih, Julia Haines-Allen, Ron Turco, Larry Nies, Dawn R. Whitaker, and Ladisch Mike



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Edible Biomass/Crop Production

Cary Mitchell

Minimizing ESM for ALS Crop Production

- Cary Mitchell presented a talk entitled “**Strategies for Minimizing the Energetic Penalties of Maintaining Human Presence at an Extended-Stay Mars Base**” for the Department of Botany seminar series at Miami University of Ohio, October 7. Cary Mitchell and Dave Kotterman presented “**Artificial Closed Ecosystems for Human Habitation of Space**” at the Rotary club of Lafayette on October 11.
- We received the second lighting array from Orbitec at the end of September. At that time the issue of light uniformity changing with increasing number of engines energized was addressed when the chip containing the software controlling driver function was upgraded with better software coding. This eliminated the problems encountered during preliminary testing of the first system. The first lighting system was upgraded to be identical to the performance of the second system at the time the second system was received. Trial 6 of the first system was ended prematurely due to mistakes with CO2 programming of the growth chamber, which led to uninterpretable results. Construction of a new mounting system to suspend the updated lightsicles (with eight that are 7" longer than the other eight to allow closer, staggered spacing) is underway. The new intracanopy mounting schematic will feature two Y-arrangements in the middle of the tub, and the remaining 10 lightsicles will be dispersed around the perimeter. Mounts have been constructed and mounting is underway. Following installation, new hardware calibration analyses will be performed and a side-by-side study with cowpea stands growing either with intracanopy or overhead LED lights will be conducted. ‘Norland’ potato explants are being cultivated for the second side-by-side IC vs. OH LED lighting experiment.
- Experiments with strawberry and sweetpotato are ongoing in the greenhouse. Strawberry fruit are harvested from the greenhouse and saved for antioxidant studies. Strawberry fruit from the temperature studies in the growth chambers are being harvested and eaten, and fruit are rated for flavor and quality. Ten types of carrots of varying color have been planted in tubs in the greenhouse. These will be used for antioxidant studies by Lisa Mauer's students.
- Preparations for testing of the pH control system are underway. A computer is being set up to log data of the control and monitoring system. Side-by-side tubs of Waldmann's green lettuce will be grown hydroponically in a walk-in growth chamber. One tub will be continuously adjusted for pH at intervals of 5 minutes automatically, with the duration (which can be converted to volume) of added solution (acid or base) logged. The second hydroponic system will be manually adjusted for pH every 48 hours. ESM for both procedures (power, crewtime) will be calculated and edible lettuce biomass produced will be compared after 30 days of growth.



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Caula Beyl

Extending Crop Harvest Index Using Edible Fungi

- **Preparation of manuscripts and abstract**

Two manuscripts were completed and submitted to the scientific journal *Bioresource Technology*, and one abstract titled "Toward improved biodegradation of recalcitrant lignocellulosic wastes by pairing crop residue during fungal composting" was prepared for the upcoming 2006 International Conference on Environmental Systems (ICES). The titles of the manuscripts were:

1. Nitrogen amendment enhances edible white-rot fungal growth and biodegradation of containerized inedible crop residues.
2. Optimizing edible fungal growth and biodegradation of inedible crop residues using various cropping methods.

- **Construction of respirometer**

We have begun the construction of a simple respirometer that will allow us to measure CO₂, O₂ and water vapor dynamics as well as monitor temperature and humidity changes during fungal mycelial growth and fruiting. The CO₂, O₂ and water vapor components will be monitored and analyzed using a PP Systems' CO₂ infrared gas analyzer.

- **Co-culture of species from 3 genera of edible white rot fungi on wheat straw**

As part of our continuing effort to advance the biodegradation of crop residues, a study was initiated to investigate the interaction between species from different white rot fungal genera when co-cultured on crop residue. The goal was to expedite the biodegradation of crop residue for subsequent fish nutrition. The study is being carried out in collaboration with Dr Paul Brown's lab (Fish Nutrition group), which uses fungal predigested crop residues for more efficient nutrition of tilapia and to contribute to further crop waste recycling.

Food Safety and Processing

Lisa Mauer

Novel Storage and Packaging Operations

Radiation effects on oils and antioxidants project:

- Radiation treatment, storage, and analysis of primary lipid and antioxidant samples continuing. Data interpretation is ongoing.
- Continuing M.S. graduate student, Jake Gandolph, is preparing to graduate in the spring. Two abstracts on Jake's work were submitted to *Habitation*.
- New M.S. graduate student started on this project to focus on radiation effects on oils and countermeasures to extend shelf-life of oils: Davida Alexander. The majority of Davida's salary is paid by a fellowship with supplementation from the NSCORT project.
- New M.S. graduate student started on this project to focus on radiation effects on antioxidant capacity and nutrition/acceptability of select fruit and

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vegetable products: Alecia Shand. The majority of Alecia's salary is paid by the LASPAU program with supplementation from the NSCORT project.

Radiation effects on wheat project:

- Work (proximate analysis and basic chemical composition) continued on characterizing Apogee and Perigee and comparing to 3 terrestrial wheat varieties known for quality bread and pasta production.
- Fourth growth cycle of wheat completed
- Continuing M.S. graduate student, Adam Stoklosa, is preparing to graduate in the spring and continue work on a Ph.D. beginning soon thereafter. One abstract on Adam's work was submitted to Habitation.

Education outreach activity:

- Professor in the classroom activity: "Space Foods" presented by Dr. Mauer to a 5th grade class on October 5.

Collaborative activity:

- Abstract to be presented Nov. 2 at the AIChE annual meeting: "Modeling and design of a mini food extruder with high viscous heat generation" by G. Chen, OH Campanella, L Mauer, M. Okos and C. Corvalan. Work was funded through a NASA-SBIR Phase I grant.
- News received that NASA-SBIR Phase II grant on the miniature food extruder project received.

Leonard Williams Optimal Food Safety in ALS

- **Completed Work on Determination of critical points**
Work was completed on determining critical control points for potential hazards on whole tomatoes. Generic HACCP plans are forthcoming.
- **Combined efficacy of pulsed light and sanitizers**
AAMU Graduate Student completed last two objective of thesis research on combination of pulsed light sterilization and sanitizers on inactivation of *Salmonella* on surface of whole tomatoes.
- **Collaborative work with Biomass system is underway**
Preliminary work was conducted to examine the ecology of waterborne pathogens in hydroponic system growing salad crops.
- **Abstracts and Manuscript Submitted:**
English, T., and L.L. Williams. 2005. Combination of UV-Pulsed Light Sterilization and Sanitizers on Reduction of *Salmonella* spp. on surface of Whole Tomatoes. ARD Biennial Meeting. (Submitted)

English, T., Austin, A. and L.L. Williams. 2005. Efficacy of Sanitizers for Inactivating *Salmonella* on the Surface of Whole Tomatoes. ARD Biennial



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Meeting (Submitted)

English, T., N. Austin and L.L. Williams. 2005. Inactivation of *Salmonella* spp. by pulsed light sterilization. *In press*. J. Food Prot.

English, T., N. Austin and L.L. Williams. 2005. Efficacy of a commercial sanitizers of reduction of *Salmonella* on whole tomatoes. *In press*. J. Food Prot.

**Bruce Applegate
Mike Ladisch**

Bioamplification Using Phage Display for the Multiplexed Detection of Pathogens in Potable Water and Food

- **Evaluating Bacteriophage Infectivity in a Food Model**

To optimize the assay for minimal food sample preparation, we utilized a previously developed 2 component system of T4 phage bioluminescent *E. coli* (lux) host strain to evaluate the effect of variables such as food components or laboratory media on phage infection. *E. coli* lux cells were serially ten-fold diluted with sterile peptone water, LB broth, and LB mixed with 10% (w/v) ground beef. Samples were analyzed by addition of serial dilutions of T4 phage and reduction of bioluminescence was monitored over time using a Wallac Microbeta scintillation counter. Results showed decreasing bioluminescence for *E. coli* (10^7 - 10^5) cfu/ml in the presence of increasing T4 phage concentrations over time. At approx. 10^7 cfu/ml of *E. coli* lux, a dynamic range of T4 phage concentration was 10^9 - 10^6 pfu/ml with a detection limit of approx. 10^5 pfu/ml in both LB and LB with ground beef with peptone not exhibiting any decrease in luminescence. However, the rate of decrease in bioluminescence was greater in LB than that in LB with ground beef. This study suggests that incorporating LB into the ground beef for sample preparation facilitates phage infection and replication.

Resource Recovery

Al Heber

Gas-Phase Revitalization Using Biofilters in ALS

- The first experiment for BREATH II is underway to investigate the feasibility of biofilters and biotrickling filters to remove multiple contaminants most commonly found in cabin air during long duration space missions. 10 reactors have been operated in parallel for over two months, daily removal efficiencies were compared between reactors operated with different reactor configurations and packing media. High removal efficiencies were achieved for easily soluble compounds such as acetone, butanol, and ammonia among all the reactors tested. Degradation of ethylene did not occur until after 30 days of startup, while essentially no degradation of methane has occurred to date. Among all the reactors tested, the perlite biofilters have achieved the highest overall removal efficiency, followed by perlite biotrickling filters.
- Profile studies along the height of each bioreactor were conducted on a weekly basis to assess the spatial distribution of each contaminant. Liquid phase nitrogen (NH_4^+ -N, NO_3^- -N, NO_2^- -N) concentrations are being analyzed



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to evaluate whether the reactors experience nutrient limitation and to understand the mechanism of ammonia removal.

- Selection and purchase of a GC-MS instrument is underway for identification and quantification of unknown trace compounds potentially generated from the ALS reactors.
- Modified the code of the ALS biofiltration modeling for ethylene degradation.

Paul Brown

Waste Treatment Using Tilapia

- Tilapia compost consumption study to be terminated on Nov.5th. This 8 week study was designed to evaluate the potential effects on nutrient retention capabilities of Nile tilapia fed composted waste residue.
- Micro-nutrient mass balance study is currently on third week. This study is designed to determine the mass balance of 4 micronutrients in an integrated fish plant production system.
- Protein Digestive Study underway. This study is designed to determine what proteins are regulated as a result of increasing levels of cellulose. The results may improve our understanding of the digestive mechanisms that result in reduced performance in fish as cellulose concentrations in diets increase.

Cary Mitchell/ Dawn Whitaker

Solid-Phase Thermophilic Aerobic Reactor (STAR) Processing of Fecal, Food, and Plant Residues

- Bench scale studies on lignin degradation continue. Results show higher lignin degradation in STAR than other published biological degradation results.
- Filtrate recycle improves both total solids and lignin degradation.
- Enzyme analysis is underway. Induction of enzymes and the evolution of the enzyme consortium over the 24-hour cycle is being evaluated for both individual components and combinations.
- STAR continues to operate at 8% loading, to be increased as a second "failure" study in Nov.
- Abstracts accepted for ASCE Earth and Space 2006, and Habitation 2006.
- Outreach at New Community School for 5th and 6th grade - presentation on Solid Waste in Space and rover-building activity.

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Charles Glass

Nitrogen Cycling in ALS

- **Equipment Needs for Year 3 Experiments**

Due to the limited budget presented to the PI initially for year three only one 5L working volume sequencing batch reactors (SBR) has been ordered from Broadley-James, for a total cost of approximately \$14,000, including the vessel, motor, motor controller, pH and dissolved oxygen probes and their respective meters. Hopefully the equipment will arrive by late June. With the appropriation of a second allotment of funding a second reactor will be ordered within the next week to fulfill the two reactor requirement for the experiments this year.

- **Continued Methodology Development for Year 3**

While equipment orders are in route we will continue to review the literature and plan the experiments in as much detail as possible. The goal of the experiment will be to acclimate a single sludge nitrification-denitrification activated sludge to the highest initial ammonia concentration achievable. We plan to begin with ammonia concentrations found in the local wastewater treatment plant, where the activated sludge is originating from, to hopefully 1,200 mg/L NH_4^+ -N.

Kim Jones

Membrane Processes in ALS

- **Microfiltration Membrane System.** Focus of year 3 will be on modifying commercially available MF membranes to reduce fouling. Two different grafting techniques will be evaluated for fouling reduction and flux. When considering mode of modification, ease of replacement and stability in zero-gravity environments will also be considered.
- Biofouling studies are also being analyzed by type of bacterial suspension by relating microbial attachment as a function of number of cells in suspension. On going studies include studying biofouling as a function of membrane surface roughness (via AFM), pore size and hydrophobicity.
- Grafting via interfacial polymerization is being investigated as a method to reduce membrane biofouling while maintaining high flux.
- **Reverse Osmosis/Nanofiltration Membrane System.** System is being retrofit to allow for more stable operation. Unstable pressure differences have hindered steady state operation of the RO system. Concurrent modeling studies are being developed to determine the rate of replacement of the RO membranes as a function of rate of fouling (as quantified by buildup of irreversible fouling layer). Surfactant monomers and trace organics are surrogate foulants for this system.

Kathy Banks

Treatment of Grey Water Using Gas Biofilters

- Abiotic mass transfer phenomena were analyzed under various gas-phase and liquid-phase flowrates to allow quantification of a model describing bioreactor transport. The experiments were conducted in the presence and

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absence of the three target surfactants of concern to determine the effect of surfactants on gas absorption. The model is based on a combination of previous residence time distribution experiments and separate mass transfer experiments. Gas partitioning effects and potential ESM-reducing operating conditions were examined using previously determined optimal media type (Jaeger rings). Adsorption of gases is currently being included for mathematical model validation.

- Shaker flask studies were conducted to determine potential non-biodegradable compounds within the wastestream. This set of experiments was conducted in response to concerns raised by previous TOC and COD effluent data.
- Analytical analysis of ethylene glycol (EG) by HPLC methods is currently under way to determine biodegradability of EG. EG may be a potential non-biodegradable product with human toxicity issues.
- Present work includes modeling/optimizing gas transfer under biotic conditions. Reactors have been inoculated with microbes and gases will be delivered to the system under various operating conditions to analyze the effects of gas flowrate, liquid flowrate and gas partitioning on system mass transport under biotic conditions. The biotic transport model will aid in quantifying gas mass transfer and possible subsequent biodegradation.

Chip Blatchley

Potable Water Disinfection Subject to Extended Space Travel Constraints

- **Inactivation Model based on Phenotypic Variations**
Inactivation models were developed to describe the dose-response behavior of *B. subtilis* spores to UV irradiation and sequential disinfection using UV irradiation and iodination. The models account for “tailing” behavior, which previous models have not adequately addressed.
- **Two Conference proceedings were prepared for presentation at the Water Quality and Technology Conference (WQTC) in Quebec, Canada,.**
One conference presentation will focus on inactivation modeling efforts, emphasizing the synergism exhibited by UV radiation and iodine when used in combination. The second conference presentation will focus on dual use of the iodide/iodate actinometer to serve as a UV monitor and to provide a residual disinfectant.
- **Irradiance Field Models for Excimer Lamp**
Two numerical models were developed to estimate the irradiance field of the XeBr (282 nm) excimer lamp. One of the models was developed using a continuous form equation to estimate the irradiance field emitted from the lamp. This model was simplified version of the second model, which calculates the UV radiation received at any point around the cylindrical excimer lamp as a contribution from a large number of point sources



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radiating from the interior annular space of the excimer lamp. This model, named the Surface Power Apportionment for Cylindrical Entities (SPACE) model, also accounts for the refraction, reflection and absorbance effects of the quartz lamp envelope and the media surrounding the lamp.

Ron Turco/
Larry Nies

PAABLO and WAABLO in ALS

- ***Plant-based Anaerobic-aerobic Bioreactor Linked Operation (PAABLO)***. The objective is to develop and optimize anaerobic-aerobic bioreactor system to allow the production of methane from plant-based waste materials and greywater. This will allow reduction in plant waste biomass and remediation of greywater and the formation of a possible source of energy.
- ***PAABLO biosolids study***. Methods for the optimization of the PABLO biosolids for use in fungal and plant cultivation will be investigated. This will require an evaluation of the makeup the aerobic reactor's microbial population to maximize the formation of soluble carbon for use in the anaerobic portion of PABLO and the need to develop a biosolids recovery system.
- ***Waste-based Anaerobic-aerobic Bioreactor Linked Operation (WAABLO)***. The objective is use a bioreactor system to optimize production of methane from human waste materials and to provide a means of drying and storing the material.
- ***WAABLO biosolids study***. This will require an evaluation of the makeup the aerobic reactor's microbial population to maximize the formation of soluble carbon for use in the anaerobic portion of WABLO and minimize the formation of residual biosolids. For biosolids that are formed, we will optimize the procedures for sterilization and compactions.
- ***Progress to date***.
- We have constructed a work plan for the project that will be implemented as soon as our post-doc is on board.
- We have met with the systems group to discuss their information needs and to give them a better understanding of what we are trying to accomplish.
- We have written and circulated an advertisement for a post-doc. The advertisement has resulted in many responses but 4 individuals are being evaluated (outside letters etc) for a campus interview.
- Major equipment to be used for the assessment of bioreactor diversity has been ordered.



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Integrated Systems and Analysis Group

J. Pekny, G. Chiu, Systems Modeling of ALS
Y. Yih

- **A Simulation Approach to Minimize Water Supply, Water Storage Capacity and Water Treatment Capacity Requirements in ALSS for Mars Mission**

In this work, the relationship among crewmembers and crops water consumption and production, water treatment capacity, water storage tank capacity and water supply required from Earth is explored to optimally reduce the mission cost. Two mission durations are studied to evaluate the impact of mission duration on water subsystem cost. Two scenarios are investigated to determine the effect of crops addition into the system. Crops are grown to meet crewmembers' energy requirements. Crewmembers and crops water consumption and production, number of crewmembers and mission type are assumed based on educated guesses and references to documented sources and real life scenarios. Results show that increase in water treatment capacity can effectively reduce water storage tank ESM to a certain extent. After that the ESM value remains constant although water treatment capacity increases. Mission duration affects water storage tank ESM. However, it is not if water removal technology and ISRU is added into crewmembers-only and crewmembers-and-crops scenario, respectively, in addition to the water treatment process at optimal capacity. Introduction of crops into the system increases the ESM by 1.3 times when compared to crewmembers-only scenario. Although the results are system specific, it demonstrates that trade study analysis can be performed to evaluate the trade off of water treatment technologies, water removal technologies and ISRU technologies against water storage tank and supply using ESM.

- **Systems Workshop on Oct 18th and 19th**
The purpose of the Systems Workshop is to provide guidance to ALS NSCORT by unifying our position on ALS system analysis and by explicitly documenting potential project collaborations.
- **Guest Speaker: Dr. Luis Rodriguez**
Dr. Luis Rodriguez from University of Illinois was invited to ALS NSCORT to present a seminar titled: Considerations in Life Support Systems Analysis for Research, Development and Design. He also participated in the Systems Workshop and shared his experiences with ALS NSCORT PIs and trainees.



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ALS NSCORT Education

Julia Hains-Allen Education

- ALS/NSCORT is partnering with Indiana Technical Community College to provide distance education professional development workshops for teachers in Indiana via the college's distance learning network. To promote additional partnerships with Community Colleges nationwide, Julia Hains-Allen presented Mission To Mars at the annual convention for the National Council for Continuing Education and Training held in Jacksonville FL October 17-19, 2005. The Mission To Mars presentation was attended by 45 representatives from Community Colleges nationwide
- ALS/NSCORT Mission To Mars Professional Development Workshop presented by Macon Beck for 25 6-8th grade educators was held on October 24-25, 2005 at Kansas Cosmosphere, outside Wichita Kansas. This is the second Mission To Mars workshop at the Cosmosphere. The first workshop was September 26-27, 2005 for 35 educators in Kansas.
- ALS/NSCORT along with Exploration Systems Mission Directorate will be supporting a booth at the National Convention for 4-H Extension Educators in Seattle Washington October 31 - November 4, 2005. Over 1200 Extension Educators throughout the country attend this convention. Mission To Mars, curriculum developed by ALS/NSCORT and disseminated by 4-H, will be presented in the booth along with information about 4-H partnership possibilities.