8. Project Overview *(max. 2 pages)*

The project ferments poultry manure to produce biologically active nutrient solutions for greenhouse and field applications. A foremost goal is to have the technology known. The project would welcome companies or associations to participate in future projects or grant applications.

An organic Ontarian hops producer inquiry initiated the project investigating the technology's potential for organic status. The technology may be rated as organic – of course it needs to be vetted by qualified authorities (greater detail is given in Section 9 Progress to Date. The Alberta Organic Producers Association has been contacted for their interest.

The producer research group CARA is conducting a number of field trials to investigate the product's impact on soil health in addition to its influence on barley and pea growth. A robust scientific experiment is underway at our tree farmer client in Strathmore, AB where the solution is being compared to fertilizer applications complete with experiment controls and baseline assessments.

Technology Highlights:

i. Control pH to minimize nutrient losses
ii. An inherent thermophilic step serves to pasteurize, if not, eliminate pathogens
iii. Hypothesis: fertile soils are so, in large part, due to microbial activity
 the same is true for biologically active fertilizer water - we don't sterilize anything
iv. There's a 'liquid and solids' fraction [soil remediation professionals are interested in the solids
v. All water is recycled - We typically don't discharge water
 but (after a couple of years) sodium buildup can be an issue
 Hypothesis: microbial activity mediates plant uptake of sodium

The final report will contain greater detail of the technology's bio-energy potential. Typically, fermentation broth pH is prone to rising to such an extent that considerably more acid is required than base to maintain a pH below neutral. At times the opposite occurs where considerably more base is required than acid to maintain a below neutral pH; lower oxygen levels and higher bioreactor loading rates appear to select the microbes responsible for releasing the protons to produce this acidity. Microbial Electrolysis Cells utilize such microbes to generate hydrogen from the digestion of organic matter; the project's infrastructure could be used for hydrogen production.

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a) Background

The project focuses on the aerobic digestion of poultry manure to produce plant fertilizer solutions. This fermentation process utilizes oxygen enhancement and pH control to minimize nutrient losses due to irreversible chemical precipitates and ammonia off gassing.
An inherent thermophilic step (the fermentation broth "heats up" just like compost piles) serves to pasteurize, if not, eliminate warm blood animal pathogens. To date the project rigorously tests for Salmonella, E. coli and fecal coliforms. A research consultant, contracted by the tree farmer trialing the nutrient solutions, had the solution DNA tested for 30 soil pathogens – the solution was free from all whereas soil amended with poultry manure tested positive for four pathogens.

The project is considered important because:

I. It provides an alternative to 'field and garden composting' of poultry manure and thereby

i. *eliminates the likelihood of surface and ground water contamination*
ii. *reduces the potential of pathogen outbreaks especially true for market gardens*

II. *It develops and demonstrates a new technology that can utilize other manures and organic wastes to produce safe and effective plant nutrient solutions*

III. *It places Alberta in the forefront of addressing a food safety concern given by a recent FDA request for comment.*

"The original request for comment, Risk Assessment of Foodborne Illness Associated With Pathogens From Produce Grown in Fields Amended With Untreated Biological Soil Amendments of Animal Origin; Request for Scientific Data, Information, and Comments, appeared in the Federal Register on March 4, 2016... The use of raw manure (or other untreated biological soil amendments of animal origin) as fertilizer in growing crops is covered by the final produce safety rule mandated by the FDA Food Safety Modernization Act." HortiDaily April 26, 2016

b) Objectives of the Project

I. *Produce safe and effective plant nutrient solutions from poultry manure*
II. *Develop a robust and industrialized manure fermentation technology*
III. *Facilitate industry adoption of the technology by:*
i. *demonstrating the use of these fertilizer solutions to grow greenhouse and field crops*
ii. *detailing process design including 'scale-up' considerations*
iii. *providing detailed SOP's, batch records and data presentation*

c) Key Results Expected

I. *A detailed characterization of the fermentation process including in-depth nutrient analysis to document the optimization path and process scale-up considerations.*

Process variables controlled or manipulated	*Process variables NOT controlled nor manipulated to date*
i. pH control agents ii. pH setpoints iii. dO, dissolved oxygen iv. gas (oxygen) flowrate v. antifoam agents vi. % DM, the amount of manure per batch vii. duration viii. agitation ix. mother liquor	i. manure feedstock variability project will try to process manures containing antibiotic residues ii. microbiology - the project will investigate: - if nutrient solutions impact the Rhizobium inoculation of legumes - the continual use of mother liquor to optimize the fermentation iii. temperature

II. *Industry trials and assessment of plant nutrient solutions derived from poultry manure. The project currently has a tree farmer and vegetable market grower trialing the solutions.*
III. *Demonstration and assessment of greenhouse strawberry production techniques using nutrient solutions derived from poultry manure. Echinacea raft and substrate culture will also be trialed.*
IV. *Quantify the microbial contribution to the nutrient profile.*

9. Progress to Date *(max. 2 pages)*

a) Provide a concise report of the results achieved to date. It should contain a summary of the data collected and any preliminary conclusions made. The report should clearly state whether the results expected under the action plan for the proceeding year have been achieved. If they have not been achieved, please provide explain. Please also include all changes/modifications that have been made to the original plans and provide clear explanation for the changes.

With regard to organic certification: the list given below denotes the substances we use and have used. Also, all microorganisms are native to the manure itself – we do not add any organism. Highlights denote substances used in Alberta Agriculture and Forestry's poultry manure fermentation project.

Excerpts : National Standard of Canada;… Organic production systems Permitted substances lists

Fish meal, fish powder, fish wastes, hydrolysate, emulsions and solubles	….Chemical treatment is prohibited, except that liquid fish products may be pH adjusted with the following, in preferential order: 1. a) vinegar; 2. b) non-synthetic citric acid; 3. c) synthetic citric acid; 4. d) phosphoric acid; or 5. e) sulphuric acid. The amount of acid used for pH adjustment shall not exceed the minimum needed to stabilize the product.
Iron	The following sources of iron are permitted, to correct documented iron deficiencies: ferric oxide, ferric sulphate, ferrous sulphate, iron citrate…
Surfactants	Non-synthetic substances. See Table 4.2 Formulants, Table 4.2 Wetting agents, and Table 4.3 Soaps; table 4.3 Vegetable oils.

Table 6.5 - Processing aids

Oxygen	No annotation.
Potassium hydroxide (caustic potash)	For pH adjustment. Prohibited for use in lye peeling of fruits and vegetables.

The project experimented with reagent additions (tabulated below) as a means to enhance the product.

Reagent Proposed Effect	Pro's	Con's
Methanol Increase soluble carbon content	Increases microbial density from 1x 10^8 to 1x 10^{12} cells per mL Can be used to increase the citric acid concentrations in stock solutions	expensive

Vinegar, CH_3COOH Antifoam agent	Greatly delays the need for antifoam especially if added at the start of the fermentation allows broth to attain 70°C temperatures	Appears to create a buildup of compound(s) that negatively impact the fermentation (stalled reactions) Especially pronounced in the carryover of Mother Liquors Additions late in the fermentation run may trigger exceptionally large "foam outs" leading to major nutrient losses
Iron sulphate Increase the iron concentration ideally sequestered in microbial biomass	Iron concentrations increased upto10 fold Unknown if sequestered in microbial biomass Appears to be plant available since chlorosis has not been observed	Appears to create a dense and thick foam - suspect the '+' charge is bridging '-'charged cells and / or cell debris. These foam layers (nearly crusts) can easily be 6" thick.
Citric acid, $C_6H_8O_7$ An organic pH control agent	To be assessed – greater concentration if mixed with alcohol – may serve as enhanced soluble carbon	To be assessed

To date 16 fermentation runs were conducted, two "baseline runs" without pH control; all other runs had pH control in which four runs utilized phosphoric acid, three runs utilized nitric acid and one recent run that utilized sulphuric acid, 4 runs utilized mixtures of sulphuric and phosphoric acids. The last two runs were aborted due to a lack of a thermophilic step; there appears to be a negative consequence to vinegar carry over in the Mother Liquor.

Without pH control [the first two fermentation trials] the cultures become 'self-limiting' by attaining pH 8.5 and do not attain thermophilic pasteurization temperatures. Significant nutrient losses were observed.

Most runs have easily met the minimum pasteurization requirement of 3 days at 55°C or greater. Pathogen kill due to residence time in the quarantine tank was observed; likely due to competition with other organisms. This may be another option with regard to pathogen kill.

The project will likely not be able to quantify nutrients derived from microbial biomass since the project is financially focusing on field trials. However the solution's impact on soil microbiology will likely be feasible once CARA's lab is operational.

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The optimal fermentation pH setpoint is a tradeoff between:

i. *near neutral pH 7 for maximum thermophilic pathogen killing temperatures and*
ii. *lower pH's near or below pH 6 to prevent nutrient loss from ammonia off gassing and phosphate cation precipitates*

The use of a screw press to harvest the solutions was a significant achievement.

10. Research and Action Plans for Upcoming years (*max. 1 page*)

Specify by calendar year

Year 3, April 2017 to December 2017

Determining the bio-solutions impact on soil health is a priority; the project is entering into the 2nd year of a field assessment by a producer research group, CARA. A preliminary field assessment of tree growth does seem to indicate greater intermodal growth for the trees treated with bio-solutions. At worst case the bio-solutions are as good as synthetic fertilizer applications.

The final phase of the project will focus on attracting industry uptake by supporting:

i. CARA's field trials to grow barley and peas
ii. The scientific experiment / assessment of the solutions at our Tree Farmer Client
iii. Demonstrate the technology (greenhouse growth using the bio-solutions) at Farm Fair November 2017.

Unfortunately, the project is unable to quantify the contribution of microbial biomass to the nutrient profile.

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Year 2 April. 2016 to March 2017

I. *Trial various blends of phosphoric, nitric and sulphuric acids.*

II. *Install the dissolved oxygen control loop and investigate dissolved oxygen control strategies.*

III. *Investigate the culture of oyster mushrooms and vermiculture to utilize the screw press's residual cellulosic and lignin by-product. Successful use of this by-product would make the process waste-free.*

IV. *Upgrade the pH probes to meet temperature swings and abrasion due to the "feed grit" for gizzard health and oyster shell fragments for robust egg shells.*

V. *Install the antifoam control loops*

VI. *Continue process characterization and optimization while having a commercialization focus*

VII. *Try attaining the highest possible thermophilic temperature (target > 75°C) and experiment with the bioreactor as a continuous heat source for energy harvest.*

VIII. *Explore the use of co-fermenting waste streams from other industries specifically those containing soluble carbon – the BOD data to date suggests soluble carbon is the rate limiting nutrient*

11. Technology Transfer Plan ***(max. 1 page)***

a) Please indicate all completed and future activities relating to the Technology Transfer Plan for this project.

Tentative at the time of this report. The project may be demonstrating a greenhouse application (an informal request to present was received) at the Farm Fair, Northlands Edmonton Nov. 2017.

The project was featured in an online publication Green Business Canada, July 2017 https://greenbusiness.alchemyimageworks.com/

Bio-solutions were displayed at:

i. Green Industry Show & Conference, Shaw Center, Edmonton Nov. 2016
ii. Cultivating Connections Forum, Northlands Edmonton Feb. 2017
iii. The Festival of Big ideas, Research Park, Edmonton June 2017

The project was also presented at Cultivating Connections Forum, Northlands Edmonton Feb. 2017.

The project was featured in an internal AF webinar series Feb.2017; (the presentation had the highest attendance record).