Ceres Solutions Ltd.
Non-confidential
Final Outcomes Report

Submission Date: June 25, 2024

1.0 Title Page

Project Title: Using local forestry and ag by-products to grow high value mushrooms.
Agreement Number: B01060953

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Project Start Date: June 15th, 2021.
Project End Date: January 15th, 2024
TRL at Project Start: **7**
TRL at Project End: **9**

Project Budget: **1,332,571.00**
Total ERA Funding received: **$468,264.17**
Total Project Costs: **$1,351,217.44**

Project Description:

This project covers the first commercial demonstration of Ceres' sustainable specialty mushroom cultivation system in a 6,000 sq. ft. facility near Calgary, Alberta. This facility demonstrates the mushroom cultivation system at scale, using industry leading process automation, data collection, climate control systems, and food safety certification. The facility demonstrated tech which converts a variety of local biomass byproducts into a substrate to produce gourmet mushrooms for the Alberta regional market. Infrastructure is now in place at the farm to produce between 5,400 and 6,000 lbs. of fresh mushrooms per week. At project completion, Ceres was producing 4,000lbs per week.

The project demonstrated new tech which adds value to local biomass byproducts while producing high quality and affordable food for Albertans. The project creates a new industry within Alberta, generates value for clients and reduces GHG emissions in each step of its production process.

Ceres has plans to increase its mushroom production footprint in Crossfield and to further scale the substrate processing tech within Alberta.

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3.0 Executive Summary

Ceres was successful in the demonstration of its first sustainable specialty mushroom cultivation system in a 6,000 sq. ft. facility near Calgary, Alberta. This facility demonstrates the mushroom cultivation system at scale, using industry leading process automation, data collection, climate control systems, and food safety certification. The facility demonstrated tech which converted local biomass byproducts into a substrate to produce gourmet mushrooms for the Alberta regional market. Once production is maximized in late 2024, the farm can produce between 5,400 and 6,000 lbs. of fresh mushrooms per week. At project completion, Ceres was cultivating 4,000 lbs per week.

The project demonstrated new tech which adds value to local biomass byproducts, produces high quality and affordable food for Albertans. The project creates a new industry within Alberta, generates value for clients and reduces GHG emissions.

The project directly offsets mushrooms which were previously brought into the province via air freight.

Ceres has plans to increase its mushroom production footprint in Crossfield and to further scale the substrate processing tech within Alberta.

4.0 Project Description

Introduction

This project covers the first commercial demonstration of Ceres' sustainable specialty mushroom cultivation system in a 6,000 sq. ft. farm near Calgary, Alberta. This facility demonstrates the cultivation system at scale, using industry leading process automation, data collection, climate control systems, and food safety certification.

Background

Ceres began in a dorm room at Olds College with the founder, Alex, having the idea that spent brewers' grain could be used as a medium to grow specialty mushrooms. The theory was tested and proven on a small scale before being grown, in many small steps, to the commercial facility discussed in this project. In the years since incorporation, Ceres developed an improved substrate production and inoculation process as well as several alternative uses for the spent mushroom substrate created as a byproduct of the mushroom growing process. Existing specialty mushroom farms in Alberta lacked size and food safety certification to service the wholesale market. This meant that product was shipped or flown in from BC, Ontario, and oftentimes as far away as China and Korea.

Project Objectives (Planned vs Achieved)

1) Automate incubation, pinning and fruiting cycles within climate systems without human input. 24 containerized units and 2 automated processing vessels will be deployed during the project.

Only 16 climate-controlled containers were required to meet the production targets, this reduced project expenditures. 2 mixing vessels, with automation and sensor package, were installed during the project and operate as anticipated.

2) Demonstrate congruent data collection, artificial intelligence, analytics, process refinement and climate condition alteration with AI partner. Use computer vision platform to correlate variables in processing parameters with yields. Use mushroom "ripeness" classifier to alter crop development to meet inputted harvest dates.

During the project, Ceres demonstrated the viability of computer vision based mushroom classification system, data collection, and process refinement. External factors and cost prevented the commercialization of the vision system. Infrastructure to support a computer vision-based systems is installed in each of the climates and may be revisited when feasible. Data from sensors, yield records, and other sources are being used to continuously improve the process. Staff and management have been trained to interpret this data and manage crops with settings on each climate container.

3) Implement refined processing vessels, reducing utility usage, improving turnaround times and improve product quality.

Ceres successfully completed this objective with the more advanced processing system installed at the Crossfield farm. Data collected from the sensor package was used to set automated production parameters which reduced utility usage, decreased turnaround times, and improved quality of the substrate. Timeline improvements from 18h to as little as 2 hours were achieved during the project.

4) Localize regional supply chains by offsetting imported mushroom products with Ceres' sustainably produced product.

Ceres discovered during the project that many of the mushrooms available in Alberta are imported via air freight. Often, mushrooms were flown from Ontario to BC where they would be repackaged and then driven back to final sales locations across the prairies. We are proud to offer locally grown mushrooms with minimal logistics.

5) Divert spent beer brewer's grain from compost and landfill.

Efficiencies were discovered when using a denser substrate that the originally used spent grain and wheat straw. This efficiency, along with organic and food safety complications found when using a spent grain and straw substrate, shifted the project away from spent grain as a growing medium.

6) Bring GHG reducing Mycopro feed product to market.

The CFIA required Mycopro to be dried before being fed to cattle. During commercial tests of this drying step, we found the cost and emissions generation far outweighed its benefit for use as a cattle feed. It was decided that the spent mushroom substrate (Mycopro) would be more beneficial if used in its undried state. This also allowed for the shift to more efficient substrate ingredients as previously mentioned.

7) Bring high quality and affordable specialty mushrooms to the AB market.

Ceres' Crossfield facility can produce 5,400 - 6,000 lbs of specialty mushrooms per week. This output is higher on a per container basis than originally planned. We will further increase production capacity in Alberta to meet demand with the addition of more warehouse space.

Performance/Success Metrics

As the project progressed, several factors, which were discussed with and approved by ERA, affected the project's success metrics initially outlined in the application. Ultimately, Ceres was able to demonstrate its tech at the intended scale and created a viable business that will grow to service a much larger market and reduce more emissions than originally anticipated in the coming years.

<u>Decrease in substrate processing time</u> - improvements of up to 9-fold were achieved during the project.

<u>Fresh mushroom production cost</u> – Initial cost of production metrics were optimistic given new market conditions. Current production costs are still below market average, and we have a clear path to achieving initially projected metrics with additional scale.

<u>Mushroom production capacity</u> –The farm has a capacity to produce between 5400-6000lb per week as required by existing orders and customer demands. Ceres currently grows 4,000 lb per week and is scaling up to max capacity in late 2024.

<u>Farm implementation timeline</u> – Implementation timelines for the Crossfield farm were affected by supplier delays and a variety of other factors. The complexity of each climate system was reduced significantly while installing the 16 climates in the ERA project. This will allow for greater installation speed in the future.

<u>HACCP certified</u> – Ceres achieved HACCP certification for the Crossfield facility in July 2022 and passed an SQF audit in September 2023. SQF is an internationally recognized program and is a higher level of food safety certification.

<u>Single use plastic</u> – Ceres investigated several degradable plastic options during the project offering varying degrees of success.

Project Scope Changes

- Switching Mycopro from being used as a cattle feed for non-dried use in other applications.
- The modification of the project budget to exclude 8 climate containers and 1 processing vessel.
- The removal of our original computer vision partner.
- Switching biomass inputs to wood and bran as opposed to spent grain and straw.

- The addition of SQF food safety certification
- The design and installation of more advanced climate control panels in house.

Technology Risks

- Substrate processing systems designed to decrease production timelines, manual labor, and the footprint necessary to produce specialty mushroom substrate were developed during the project. The automated substrate processing system cut down production times from 18h to 2h. A technological risk that arose late in the project was the introduction of internationally manufactured substrate in North America. Countries overseas can produce mass quantities of substrate blocks and ship them to North America for a lower cost than they can be manufactured locally. This was not a threat to the project initially due to lack of market reach from international competitors but became apparent as time went on. Ceres made improvements to its batch production process and, when the demonstrated tech is scaled to a larger facility, will be able produce substrate at an internationally competitive cost. Additional investment will be required to achieve this.
- Part of the project's objective was to get our new Mycopro cattle feed product CFIA approved and supply it to local ranchers. The CFIA mandated that the Mycopro be dried prior to being fed to animals. We conducted commercial drying and laboratory safety tests to have the product approved in its dried state. The drying process cost around $7,000 an hour and produced large amounts of unnecessary emissions which offset the project goals. We determined it was more efficient to use the spent mushroom substrate in its undried state. This change in end use, combined with efficiency found when using a denser wood-based substrate and compounded by Organic and food safety requirements prompted us to switch from spent brewer's grain to other agricultural and forestry by-products as a growing medium. This change created greater emission reductions by improving output while using roughly the same amount of input energy.
- Other risks to the project were identified and effectively remedied. These risks included changes to cost, timelines, and market requirements.

5.0 Project Work Scope

This project's work scope was to scale specialty mushroom production to a commercial sized facility that in the most recent contribution agreement would produce at least 4,000lbs per week of fresh mushrooms.

At project completion, the Crossfield facility had the capacity to produce 5,400 – 6,000lbs of specialty mushrooms per week. Our farm supplies the market with local products and offsets emissions from imported mushrooms. Substrate processing times were reduced significantly, and cost of production was lowered, Ceres achieved SQF, HACCP and Organic certification which were the final requirements to begin selling at the project volume goals.

Ceres began the project after receiving funding from investors, a loan organization, and gaining final approval from ERA. Since the technology had been tested during the prototype phase at Olds College, the project started at the point of scaling to a commercial level. A building in Crossfield, AB was secured, equipment was ordered, and installation began. Climate-controlled containers were brought online in two phases, allowing for more substrate to be produced and fruited in each phase. During this time, batch formulas were experimented with, and data was collected to determine the best process for substrate fruiting success. Once mushrooms were grown successfully and in large volumes, sales efforts began. Small distributors servicing the Calgary area and restaurants that didn't require food safety certifications were brought onboard and their capacity was quickly met. Ceres began focusing on larger customers and secured orders which were contingent on Ceres achieving more advanced food safety certification.

Ceres successfully increased production to 4,000lbs per week while focusing on reducing production costs. Most of the large customers Ceres supplies previously sourced mushrooms from outside of the province and brought them in via refrigerated air freight.

6.0 Commercialization

The fresh mushrooms grown at the Crossfield location have been able to service much of the demand in Alberta. We see the market for fresh mushrooms growing in AB and sales increasing as our fresher and more economical product has become available on a larger scale. While market adoption is difficult to accurately measure, Ceres is now the largest grower of specialty mushrooms in the Canadian prairies in terms of total output. We have plans to further scale our mushroom cultivation in Crossfield in late 2024 and early 2025.

During the project, Ceres created a commercially viable business and commercially viable technology while creating jobs for Albertans.

Additional investment will be made to further increase the scale and reach of the technology developed during the project to national and international markets.

Performance and success metrics were updated during the project to reflect changes made to the project. Some of the original metrics were optimistic given changes to the market, the pandemic, and lessons learned during our first commercial installation. The project has been successfully completed and key metrics have been met.

Ceres TRL, at project completion, is 9.

7.0 Lessons Learned

There have been many lessons learned and several major changes in the industry while completing this project which Ceres has adapted to.

Delays in materials, contracted labor, and computer hardware were experienced because of the pandemic. This affected the originally planned project completion timelines. Ceres was able to complete much of the work in-house, which offset the cost of these delays.

Partway through the project, the cost and emissions associated with drying Ceres' Mycopro cattle feed product were found to be far higher than anticipated. Ceres had to find an alternative solution to use the Mycopro in its undried state.

Several customers changed their supplier food safety certification requirements. We originally anticipated operating with a less advanced food safety program based on initial conversations with customers. Once this certification was achieved, customer requirements were increased creating a delay in our ability to supply on a large scale.

Other lessons were learned around the installation process of the climate and processing systems. Great improvements were made to the simplicity of the systems as we iteratively designed and installed them on site. This learning process will expedite future installations.

8.0 Emissions Reduction impact

8.1 GHG Emissions Reduction

Baseline description

A Canadian mushroom farm in Ontario who previously supplied western Canada with mushrooms via air freight has been used as the baseline. For simplicity, we have assumed that their production system operates with the same inputs, energy usage, and output management as Ceres. For the purposes of this calculation, we are demonstrating the emissions reduction from localized supply chains only. Often, the mushrooms would be transported via air from Ontario to BC where they would be re-packed and then would be shipped overland for sale in Alberta and the rest of the prairies. We have completed the calculations based on the air freight distance between YYZ and YYC airports only.

Emissions Reduction Direct

The table below summarizes the metrics reported to Emissions Reduction Alberta between Milestones 2 and 5. This period was largely spent constructing the facility, running tests, obtaining certifications, increasing sales, and refining the production process.

Reporting period: 15-Sep-2021 to 30-Nov-2023 (803 days)

Project Summary Tables

Total tonnes of Mushroom production during project	35.79

Table 1: Project Emissions Analysis

[tCO2e/project]	Proponent Assertion
B1 - Elimination of sawdust or soybean use as input substrate	0.4
B2 -Diversion of input biomass from compost, landfill or incineration	0.0
B3 - Diversion of output biomass from compost, landfill, or incineration	0.0
B4 - Processing Efficiencies	348.8
B5 - Impact of local supply chains	10.6
B6 - Impact of local distribution	102.7
B7 - Methane reduction from mycopro consumption by cattle	0.7
B8 - Indirect benefits – methane reduction from feed production	2.1
B9 - Methane reduction as a result of food waste reduction	0.0
Total	465.4
P1 - Elimination of sawdust or soybean use as input substrate	0.2
P2 -Diversion of input biomass from compost, landfill or incineration	0.0
P3 - Diversion of output biomass from compost, landfill, or incineration	0.0
P4 - Processing Efficiencies	190.6
P5 - Impact of local supply chains	1.8
P6 - Impact of local distribution	0.0
P7 - Methane reduction from mycopro consumption by cattle	0.0
P8 - Indirect benefits – methane reduction from feed production	0.4
P9 - Methane reduction as a result of food waste reduction	0.0
Total	193.1

Reduction [tCO2e/project]	**273.0**

Table 2: Emissions Intensity Emission Factors

Scenario	Proponent Assertion
Baseline Emissions per tonne of product [tonne CO2e/tonne mushrooms]	13.004
Project Emissions per tonne of product [tonne CO2e/tonne mushrooms]	5.396
Emission Reductions per tone product [tonne CO2e/tonne mushrooms]	7.608

Emissions Reduction Projected

With the project being completed, the table below represent our emission reductions potential later this year when production is maximized, at 5,400 lbs per week, which is at the lower end of our production scale. These production metrics will be achieved in Q3 2024.

Projected Emissions Summary Tables

Total annual tonnes of Mushroom production 127.00 [tonnes product / year]

Table 1: Project Emissions Analysis

[tCO2e/Year]	Proponent Assertion
B1 - Elimination of sawdust or soybean use as input substrate	1.2
B2 -Diversion of input biomass from compost, landfill or incineration	0.0
B3 - Diversion of output biomass from compost, landfill, or incineration	0.0
B4 - Facility energy consumption	112.6
B5 - Impact of local supply chains	7.4
B6 - Impact of local distribution	426.7
B7 - Impact of local supply chains, downstream	0.0
B8 - Impact of local distribution, downstream	2.4
B9 - Diversion of output biomass from compost	0.0
Total	550.3
P1 - Elimination of sawdust or soybean use as input substrate	1.2
P2 -Diversion of input biomass from compost, landfill or incineration	0.0
P3 - Diversion of output biomass from compost, landfill, or incineration	0.0
P4 - Facility energy consumption	112.6
P5 - Impact of local supply chains	7.4
P6 - Impact of local distribution	0.0
B7 - Impact of local supply chains, downstream	0.0

P8 - Impact of local distribution, downstream	2.4
P9 - Emissions from worm digestion	0.0
Total	123.6
Reduction [tCO2e/ year]	**427.0**

Table 2: Emissions Intensity Emission Factors

Scenario	Proponent Assertion
Baseline Emissions per tonne of product [tonne CO2e/tonne mushrooms]	4.333
Project Emissions per tonne of product [tonne CO2e/tonne mushrooms]	0.973
Emission Reductions per tone product [tonne CO2e/tonne mushrooms]	3.360

Market-Level Emission Reductions

10,000 lbs per week of specialty mushrooms are consumed in AB every week. We believe that we will be able to produce and sell 10,000 lbs per week which will be consumed in Alberta and the rest of Western Canada. The plan is to increase capacity with additional warehouse space in Crossfield.

Once scaled up, we will be able to provide accurate emissions reduction for the expanded substrate production side of Ceres' business which will have a significantly larger direct and associated impact.

Our daily production in the substrate facility is forecasted to process 14,400 shiitake logs, or 17,040 oyster logs, yielding 27 tons of substrate per day. This will produce approximately 15,840 lbs of mushrooms when fruited by customer farms. However, it is unlikely that other farm in the province will adopt our production method. The market in Western Canada is quite small and our production can meet demand. Substrate production will be for our own farm and for export. It is likely that only farms in other provinces and states will adopt the substrate products produced in our processing system.

Project Impact for a Low-Carbon Economy and Alberta's Success in a GHG-Constrained Future

The benefits from the project completed by Ceres are clear and will help facilitate a low-carbon economy in Alberta and secure Alberta's success in a GHG-constrained future. Ceres production model creates large amounts of high quality, affordable food for Albertans within a very small production footprint, with minimal utility use and minimal waste. When we have further scaled the technology demonstrated in the project, we will be able to significantly increase the value of waste streams from local farming and forestry industries. This will further improve the efficiency of our farm and develop an export market. Mushrooms are some of the most efficient converters of waste to protein and other valuable nutrients. No photosynthesis occurs and no external gases are needed to supplement their respiration or growth. These factors make regional mushroom cultivation, and especially Ceres method of mushroom cultivation, highly efficient in a low carbon future.

8.2 Other Environmental Impacts

Immediate environmental benefits

Air Contaminants: Ceres' fresh mushroom production directly offsets mushrooms that were previously transported to Alberta, and the rest of western Canada, via air freight. This offsets logistical emissions and reduces product loss in transit.

Land use: Ceres' Crossfield mushroom farm is highly efficient and uses very little land and warehouse space.

Soil: No soil is used in Ceres' operation, but our spent mushroom substrate is often used in soil enriching activities.

Water consumption: Compared to other types of conventional and indoor agriculture, Ceres uses very little water to produce its mushroom crops. Minimal wastewater is created in the operation.

Potential future environmental benefits

Air Contaminants: Ceres will expand its mushroom production business in Crossfield, AB further offsetting mushrooms brought into western Canada by air freight. Ceres plans to expand its substrate production facilities.

Land use: As above, Ceres' expanded operations will remain highly efficient per square foot. This will produce a large amount of food and mushrooms in relatively small industrial spaces.

Soil: No soil will be used in the future for Ceres mushroom or substrate production and spent substrate will continue to be upcycled.

Water consumption: Ceres' expanded operations will remain highly efficient in their use of water.

9.0 Economic and Social Impacts

9.1 Projected economic impacts in Alberta based on the outcomes of the Project

This project's completion has led to and will continue to support positive economic and social impacts within the province of Alberta.

The Crossfield farm now creates a very significant amount of taxable revenue, taxes remitted will outweigh all public funding received in the coming years. Ceres currently employs 7 full-time staff and will add 4 additional full-time staff to help manage the upcoming increases in production. We will employ 11 FTE when production is maximized in late 2024.

Since the project has concluded, Ceres is pursuing the next steps in expanding parts of its business and tech to become internationally competitive. Private investment, from new and existing stakeholders, will be used to undertake this project.

9.2 Project impact in increased innovation capacity in the province

Ceres has supported several research projects at Alberta institutions. Including research projects at The University Lethbridge, Red Deer Polytechnic, and The University of Alberta. Along with regular hires, Ceres has made a special effort to employ local youth and at-risk individuals.

Ceres, and project partners, created new knowledge during the computer vision crop monitoring project which has benefited other startup companies.

9.3 Project impact on local communities, underserved communities, and/or indigenous groups

Ceres' Crossfield farm offers employment opportunities to residents which are traditionally limited in the area. The company has been able to hire and give work experience to multiple high school students and other residents who would be unable to commute to other cities for employment. Ceres often hires at-risk or otherwise disadvantaged individuals.

10.0 Overall Conclusions

Ceres Solutions successfully completed all the project's updated milestones. The company scaled up production and demonstrated processing technology to supply the Alberta market with specialty mushrooms. This has reduced the number of imported fresh mushroom products from out of province and out of country. The project tested and improved the substrate production process, cemented sales channels with major distributors, and had positive environmental benefits. Ceres is in the early stages of further commercializing the systems to be internationally competitive.

11.0 Next Steps

Ceres has a clear path to expand its production of fresh and value-added specialty mushroom products. Additional space will be added in Crossfield to increase weekly output to approximately 10,000 lbs per week as needed in 2024 and 2025.

A project involving the formulation and processing of a new line of value-added mushroom products will take place in 2024. This will include chips, sauces, jerky and other ready to eat products.

There is an emerging opportunity for Ceres to expand production of substrate for internal use as well as national and international export. This will increase the reach of the tech Ceres demonstrated during the project. We are in the early stages of addressing this opportunity in a new central AB facility.

Future benefits through the technology developed in the project will reduce significantly more GHG emissions than originally anticipated and will create more jobs in the province. We are excited that the technology developed will have far wider reaching implications than planned!

12.0 Communications Plan

Ceres has undertaken non-proprietary knowledge sharing during the project with post-secondary institutions, during international mushroom conferences, facility tours, and video calls. Further communications about the project will take place in a similar manner. Our primary audience is post-secondary institutions and the broader mushroom industry.

13.0 Literature Reviewed

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