Increasing production and promoting adoption of organic king oyster mushrooms

Final Report for FNE06-584

Project Type: Farmer
Funds awarded in 2006: $8,644.00
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Region: Northeast
State: New York
Project Leader:

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Flower City Mushrooms, LLC

Project Information

Summary:

Note to readers, attached is the complete final report for FNE06-584

Executive Summary

A benchmark for the success of this project was to be able to economically produce a pound or more of King Oyster mushrooms per six pounds of substrate (i.e. the material upon which the mushrooms are grown) within a five-week period. The strategy employed to accomplish this goal was to explore the efficacy of a variety of substrate formulations, using locally produced agricultural products and by-products containing constituents previously demonstrated by others to be effective in growing these mushrooms.

Using an analysis of fiber and protein content in a successful control formulation developed and published by Royse and Sanchez-Vazquez (1), six additional mixtures of ground corncobs, hardwood sawdust, wheat straw, wheat bran, soy meal, millet spent brewery grain, grape pomace and other supplements, were formulated to duplicate, and in two cases enhance, constituent content. Two complete mushroom crop cycles were conducted using these formulations. A third crop cycle was run with the most successful formulation, R7, and with modified versions of the three next best formulations, R2, R3 & R4.

While all ten formulations were productive, R7 clearly met and, in fact, surpassed the established benchmark by producing 1.3 pounds of mushrooms per five-pound block in just over four weeks. Beyond this measure of success, were evaluations of quality, compatibility with the ongoing farm operations, availability of local resources, and cost.

Quality was evaluated quantitatively as the "sellable" percentage of the harvested crop after removing deformities and other debris. With only one exception, quality measured greater than 90% and for the R7 formulation, 91.7%. Even with this approximately 8% reduction in overall harvest quantity, the sellable portion of R7 still exceeded the production and timeframe benchmarks for success. Additionally, the chefs of four top Rochester restaurants and the produce buyer for a large, local

natural food store, performed qualitative evaluations. Evaluators were asked to assess the quality of the mushrooms based on size, weight, shape, texture, flavor, ease of preparation and culinary versatility. In every case, assessments were positive with several indicating the highest rating in every category.

Flower City Mushrooms LLC (FCM) began and continues to operate principally as a grower of Shiitake mushrooms. Compatibility with current operations was thus evaluated on the bases of synergetic and competitive relationships regarding materials, procedures, equipment, labor, and space. The similarity of needs in each of these categories led to a favorable evaluation in this regard and considerations regarding competition were easily outweighed by gains associated with a shorter production cycle for the King Oysters and the benefits of offering an expanded crop variety.

FCM was successful in identifying and establishing satisfying working relationships with additional local resources for substrate materials, including a microbrewery, primary log mill, organic seed producer, organic wheat straw farmer, and winery. Additionally, FCM's customers were pleased with the expanded selection and most have indicated a commitment to continue to purchase King Oyster mushrooms. FCM believes that development of strong local relationships and exchange of by-products is key to sustainability and is especially pleased to have succeeded in this regard.

The result of a benefit-cost evaluation for growing King Oyster mushrooms as an FCM crop yielded a favorable 1.53 benefit-to-cost ratio. FCM now plans to run a batch of King Oyster blocks every four weeks thus comprising one twelfth of its overall production potential. This is anticipated to generate approximately $5,700 in revenue annually above total production costs (at standard labor rates).

Statement of the Problem Being Addressed

Of all the oyster mushroom varieties, the King Oyster mushroom (Pleurotus Eryngii) is often characterized as the best tasting and the best textured (2). It is very popular in Europe and Japan and is in increasing demand by top chefs in the U.S. However, attempts to grow King Oysters commercially in the US have largely been unsuccessful as, up until recently, evidenced by their absence in super markets and natural food stores.

While a variety of standard substrate formulations exist for the most common oyster mushroom varieties, standard substrate formulations that produce comparable quantities of the King Oyster mushroom (Pleurotus Eryngii) have not yet been established. A benchmark for success is to be able to produce more than a pound of oyster mushrooms per six pounds of substrate (i.e., the material upon which the mushrooms are grown) over a four to five week period. This corresponds to the quantity and growth rate of the most common oyster mushroom, Pleurotus Ostreatus (3). By comparison, productivity of the King Oyster ranges only from 0.66 to 0.99 pound of mushrooms per six pounds of substrate and taking up to twice as long to produce them (4,5). Since the production effort and market value for all oyster varieties are similar, the farmer must decide which to grow based on other factors and while there appears to be growing interest in the King Oyster mushroom, unfortunately, the biological efficiency of King Oyster production (i.e., the fresh weight of mushrooms produced per dry weight pound of substrate) is less than that for the more common varieties (6,7) and the production time is longer (28 to 30 days for incubation as compared to 18 days for the common oyster). Unless the King Oyster mushroom can be more competitively produced, it is unlikely to become a commercially viable organic crop.

Interestingly, since the time that this research was first proposed, King Oyster mushrooms have begun showing up hi some supermarkets, challenging the assumption proffered by the researchers that they would not. However, these mushrooms are being offered at prices 50% higher than Shiitake of comparable quality. This will be a good situation for mushroom farmers if the market will bear it, however, the work reported upon herein may help keep the cost down while increasing profitability for farmers.

Research and Feasibility Study Design

A benchmark for the success of this project was to be able to economically produce a pound or more of King Oyster mushrooms per six pounds of substrate (i.e., the material upon which the mushrooms are grown) within a five-week period. This benchmark was established as comparable to production of other commercially produced oyster mushroom species. The strategy employed to accomplish this goal was to explore the efficacy of a variety of substrate formulations, using locally produced agricultural products and by-products containing constituents previously demonstrated by others to be effective in growing these mushrooms.

The Research and Feasibility Study Design task involved the review of published works focused on production of King Oyster mushrooms. These included works by Stamets, Royse & Sanchez-Vazquez, Luo & Hsu, and the Edible Fungi Institute. Each piece included a discussion of various substrate materials used during King Oyster mushroom production. Substrate is defined as straw, sawdust, compost, soil, or any organic material on which mushroom mycelium (the collection of filament cells that grow into the mushroom body) will grow (8). Often, mushroom growers will use different substrate "formulas" for different species of mushroom. For example, mushroom growers often prefer a sawdust-based substrate formula for shiitake mushrooms, while a straw-based one is used in oyster mushroom production. These formulas usually include a combination of other materials, such as wheat bran or corn powder, for nutrient supplementation.

The technical advisor for this project, Dr. Robert King, suggested that FCM choose one control formulation for our experiment. The formulation ultimately selected was developed by Royse and Sanchez-Vazquez, as published in their article "Effect of Brewer's Grain and Delayed Release Nutrient Supplementation on Yield and Size of Pleurotus Eryngii". This formula was selected as an experimental control because:

--It reported biological efficiencies ranging from 30% to 54% (9), with 40% representing one pound of mushroom growth per six-pound substrate block on a wet-weight basis

--A detailed breakdown of formulation content was available

--The same strain of Pleurotus Eryngii spawn was available and would be used in FCM's research project

--All control formula materials were locally available to FCM.

FCM selected a quasi-experiment research design to measure and evaluate the feasibility of the various King Oyster production methods employed for this project. (Appendix A – Quasi-
Experimental Design provides a more complete discussion of the research design and feasibility analysis.) Ultimately, economic feasibility is dependent upon production/quality, time to market, and production costs.

Process Design

Formulation Development:

Because oyster mushrooms are degraders of cellulose and lignin, as well as users of protein, each substrate component in the control formulation was characterized by these elements and an overall formula characterization of percentage fiber and protein content was developed. A methodology was then developed, allowing overall fiber and protein percentage content to be varied by selection of various substrate material components. Using this methodology, six experimental formulations plus the one control formulation were developed and used in the first stage ("Stage One) of this project. After evaluating the production results of the Stage One formulas, four experimental formulas that appeared to exhibit the most promising results hi terms of mushroom growth were selected for a second round of production ("Stage Two"). The discussion below provides a more detailed explanation of these project stages.

"Stage One": Formula Rl was designated as the control formula, replicating the experiments of Royse and Sanchez-Vasquez. Formula R2 uses a sawdust-based bulk substrate (supplemented with wheat bran, soybean meal and calcium carbonate) to duplicate the overall fiber and protein content of the control formula. Formula R3 uses a corncob-based bulk substrate (supplemented by sawdust, millet, grape pomace and calcium carbonate) to duplicate the overall fiber and protein content of the control formula. Formula R4 uses a wheat straw-based bulk substrate (supplemented by sawdust, corncob, beet pulp, brewer's gram, grape pomace and calcium carbonate) to duplicate the overall fiber and protein content of the control formula. For the remaining formulas, the strategy was to vary specific substrate component percentages to correspond with reported successes. Formula R5 uses a sawdust-based substrate to increase overall lignin content, relative to the control formula, by 50%. Formula R6 also uses a sawdust-based substrate to increase overall lignin content by 35% and hemi-cellulose by 25%. Formula R7 essentially reproduces the control formula, but with the addition of 1% sucrose. The R2, R3 and R4 formulations attempted to duplicate the lignin, cellulose, hemicellulose, and protein content in the Rl control. The R5 and R6 variations are described above. (All formulations are described in Appendix B: Formulation Development.)

"Stage Two": Due to their relative success in terms of mushroom growth (both quality and quantity), formulas R2, R3, R4 and R7 were selected to perform another sample set of experimental production. However, it was surmised that perhaps the presence of sucrose in the R7 formula was a significant factor in the success of the first sample set of King Oyster production, and therefore sucrose was added to formulas R2, R3, and R4 in the third sample set (i.e. Stage Two).

Production Design:

Moisture determination. In order to determine biological efficiency (i.e., the ratio percentage of the wet weight of harvested mushrooms to the dry weight of the substrate from which they were harvested) the moisture content of all substrate materials was determined using the microwave oven drying method, which involved repeated 2 to 5 minute cooking intervals and weighing of substrate samples until successive measurements were within 0.001 Ib. (see Appendix C: Moisture Determination).

Depending upon the size of the substrate blocks, FCM's sterilizer is capable of holding between 60 and 120 blocks. In order to ensure identical environmental conditions for each formulation throughout the research, all formulations needed to be mixed, sterilized, inoculated and incubated during the same tune intervals. During Stage One of the project, the first sample set was mixed and inoculated during the week of 7/10 and the second sample set during the week of 7/24. During Stage Two of the project, the third sample set (consisting only of formula R7 and the sucrose-enhanced formulas R2, R3, and R4) was mixed and inoculated during the week of 9/4 and 9/11.

Substrate, Supplement and Spawn:

Basal substrate materials were procured for this work included (10):

--Organic corn cobs (Source: seed company in Ithaca, NY)

--Hardwood sawdust (maple/oak) (Source: log mill in Caledonia, NY)

--Organic red wheat straw (Source: organic farm in Albion, NY)

Supplement materials included:

--Brewer's grain (Source: brewery in Honeoye Falls, NY)

--Grape pomace (Source: vineyard in Hammondsport, NY)

--Wheat bran

--Soybean meal

--Millet

--Calcium Carbonate

--Beet pulp

--Sucrose (table sugar)

Spawn:

--9 blocks, Pleurotus eryngii (King Oyster) - Strain 515 spawn from Northwest Mycological Consultants

Substrate Preparation:

"Stage One": Substrate preparation took place over two 1-week periods, "Run A" and "Run B" respectively. Basal substrate materials (corn cob, sawdust and wheat straw) were soaked overnight prior to substrate preparation. Batch One consisted of fifteen 5-pound blocks of substrate per formula, totaling 75 Ib. wet substrate weight per formula. Batch Two consisted of sixteen 5-pound blocks of substrate per formula, totaling 80 Ibs wet weight per formula. In order to eliminate suspicion of spawn as a source of contamination, should it occur, one block from each formula in Batch Two was used as a 'control' block and was not inoculated with spawn. The microwave method was used to determine formula dry weight prior to sterilization. This was later used to determine biological efficiency. Each block was inoculated with V* cup of strain 515 Pleurotus Eryngii spawn. Batch number and unit number were recorded for future reference, if necessary. Each block was labeled by formula and date of inoculation. (See Appendix D: Production Worksheet 1 for more details on substrate preparation.)

"Stage Two": Substrate preparation took place over two 1-week periods, comprising "Run C". Main substrate materials (corn cob, sawdust and wheat straw) were soaked overnight prior to substrate preparation. Sixteen 5-pound blocks of substrate per formula were prepared for formulas R2, R3, and R4. In order to eliminate suspicion of spawn as a source of contamination, should it occur, one block from each of these formulas was used as a 'control' block and was not inoculated with spawn. Sixty 5-pound blocks of substrate were prepared for formula R7. All sixty blocks were inoculated with spawn. Each block was inoculated with Vz cup of strain 515 Pleurotus eryngii spawn. Batch number and unit number were recorded for future reference, if necessary. Each block was labeled by formula and date of inoculation. (See Appendix D: Production Worksheet 1 for more details on substrate preparation.)

Production Results

Production involved:

--Spawn run (i.e., the vegetative growth phase) of the inoculated blocks. The room temperature is maintained at 68 degrees and 12 hours of overhead fluorescent light. Weekly photographs were taken of spawn run blocks.

--Fruiting, harvesting, weighing and qualitative assessment. Production quantities and initial quality assessments (i.e. "sellable" quantity) are presented in Appendix E: Production Worksheet 2. Production data are linked to photos of harvested mushrooms.

The productivity results (i.e. cumulative "sellable" weight harvested as a function of time) are depicted for Run A, Run B and Run C, respectively, in Figures 1, 2 & 3 below. Summary data is reported in Tables 1,2 & 3. Complete productivity tables for each run are presented in Appendix F: Productivity Results. The total experimental crop yielded 213 lbs of mushrooms, 197 lbs of which were considered "sellable".

As already mentioned, the benchmark for success was to be able to grow one or more pounds of King Oyster mushrooms on a six-pound block of substrate. A concept known as Biological Efficiency (BE), i.e., the ratio of the wet weight of harvested mushrooms divided by the dry weight of the substrate upon which they were grown, expressed as a percentage, is useful to more precisely measure this productivity for the sake of comparison. The moisture content of the control formulation used in the Royce experiment (11) was 59%. By comparison, the moisture content of the experimental formulations ranged from 54% to 61%. At 59% moisture, the six-pound substrate block formulation used in the Royce experiment contained 2.46 pounds of dry substrate. By comparison, the dry material in the five-pound substrate blocks used in these experiments ranged from 1.95 to 2.3 pounds.

Run A

The Royce experiments produced between 0.738 abd 1.328 pounds of mushrooms per six-pound block of substrate, yielding BE values ranging from 30% to 54%. The first run of the FCM experiments (i.e. Run A) prudced between 0.33 and 1.48 pounds of mushrooms per five-pound block of substrate, yielding BE values ranging from 7% to 73%. FCM further refined its analysis to consider that not all harvested mushrooms were sellable. Considering only the sellable portion of each formulation, quantities ranged from 0.29 and 1.35 lb per block and BE, from 7% to 67% (see Table 1).

Consistent with the quasi-experimental research design proposed for this project, Run A production was evaluated on a time basis as well as a quantity basis. FCM's time benchmark for success was to produce one or more pounds of mushrooms per block in five weeks or less. Of these seven formulations used in Run A, only one, R7, met this criterion, producing 1.12 lb. within five weeks (see Fig. 1).

Run B

FCM replicated the Run A formulations beginning approximately 2 weeks after the initial run but encountered HVAC malfunctions that very likely compromised the integrity of the second run. Run B production ranged from only 0.08 to 0.73 pounds per five-town block, with BE values ranging from 2% to 35% (See Table 2).

Evaluation of the crop timing was unnecessary, since production quantity never reached the benchmark for success.

Run C

The final run was conducted when the results of Run A were obvious, as was the failure of Run B. Four formulations were used, representing those most successful in the initial run. R7c duplicated the original R7 formulation, except 60 blocks were prepared instead of the 16 originally used. R3c, R4c & R5c were similar formulations to their original counterparts but each was amended with an addition of 1% sucrose. Formulation R2c production achieved the quantity benchmark for success, growing over 14 pounds of mushrooms with a BE of 40% to 42%. Had six-pound blocks been prepared instead of five-pound blocks, this formulation clearly would have exceeded a production rate of 1 pound per block Formulation R7c again exceeded the production quantity benchmark, by growing an average 1 pound of mushrooms using only a 5 pound block. (See Table 3.).

Both formulations R4c and R7c took over six weeks from the point of inoculation until final harvest. While this length of time did not meet the five-week benchmark, both formulations were yet determined viable for continued production. Environmental conditions were difficult to match identically among all the runs. Additionally, while FCM attempted to precisely replicate the formulations by using substrate components collected at the same time, from the same batch, some variation could not be avoided. That which stands in the forefront of concern in this regard is spent brewery grain. For example, spent brewery grain tends to sour if not used right away, so a new batch was acquired for each run. It was not until after the experiments had been conducted that FCM considered that it was likely that different beers were being brewed and consequently the spent grains had different component percentages. This variation has been identified for an area of follow-up research and, in fact, the R7 King Oyster formulation being incubated at the time of this writing is now identified as the English Pale Ale-R7 formulation. FCM will continue to keep track of and monitor production using spent grain from different brews in order to keep BEs high. (See Fig. 3).

Product Assessment

Quality was evaluated quantitatively as the "sellable" percentage of the harvested crop after removing deformities and other debris. With only one exception, quality measured greater than 90%.

Additionally, the chefs of four top Rochester restaurants and the produce buyer for a large, local natural food store performed qualitative evaluations. Evaluators were asked to assess the quality of the mushrooms based on size, weight, shape, texture, flavor, ease of preparation and culinary versatility, hi every case, assessments were positive with several indicating the highest rating in every category.

Economic Analysis & Enterprise Budget

Actual costs and projected revenues were used as a basis for an enterprise budget analysis to help determine viability and sustainability. Determining the cost of formulation ingredients (e.g., spent brewery grain, wheat bran supplements, calcium sulfate, and calcium carbonate), classified as production materials, was fairly straightforward. Costs for full-scale operations were extrapolated from actual data collected. Labor costs for production using the experimental substrate material were equivalent to those associated with the current production schedule using traditional substrates. Non-substrate material, energy and supply costs, classified as facility overhead, were equivalent to those using traditional practices.

All costs associated with this project were extrapolated to full-scale and compared with those using current materials and methods to determine an overall benefit/cost ratio. The results of this analysis are provided in the chart below.

Business Plan

The result of the benefit-cost evaluation for growing King Oyster mushrooms as an FCM crop yielded a favorable 1.53 benefit-to-cost ratio. FCM now plans to run a batch of King Oyster blocks every four weeks, thus comprising one twelfth of its overall production potential.

Evaluation of spent substrate

The researchers met with Frank Ricotta, Regional Engineer, NYSDEC Region 8, and staff to assess the applicability of environmental regulations governing the composting of organic agricultural by-products. After reviewing FCM's activities, DEC determined that environmental regulations did not apply to the operation's composting activities associated with its spent substrate. FCM was also advised by Dr. Robert King, then Agricultural Specialist for Cornell Cooperative Extension that the Cooperative Extension holds a statewide permit for composting agricultural by productions and that anyone could use it. He advised that our composted substrate could be used and/or sold as an organic soil amendment.

Information Dissemination

--The researchers presented the findings of this project at the 9th Annual Organic Production and Marketing Program Work Team Meeting held at Cornell University on December 4th, 2006. To extend the reach of this conference beyond farmers and educators in Ithaca, this was convened as a videoconference to include farmers, researchers and Cornell Cooperative Extension agents from Monroe, Rensselaer, and Suffolk counties in New York State.

--A third-party assessment of product quality for the King Oyster mushrooms grown during the course of this project was conducted by the chefs of four top Rochester restaurants and the produce buyer for a large, local natural food store. Evaluators were asked to assess the quality of the mushrooms based on size, weight, shape, texture, flavor, ease of preparation and culinary versatility. In every case, assessments were positive, with several indicating the highest rating in every category.

--The researchers have eagerly shared the results of this project with Joe & Angela Evans, owners of Oley Valley Mushrooms, a small, organic mushroom farm growing Oyster and Shiitake mushrooms in Pennsylvania. The Evans are currently attempting to duplicate the results of this project, as they share an interest in increasing production and promoting the adoption of organic King Oyster mushrooms in their region.

--These findings will be submitted for publication in mushroom grower publications including The Mushroom Growers Newsletter.

--Farm tours have been available on an ongoing basis by request.

- FNE06-584 Final Report
- Outreach Publication

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Research

Participation Summary