A substrate is provided for growing basidiomycete mycelium comprised of nutritional and one of non-nutritional particles and fiber characterized in that the substrate promotes the growth and differentiation of basidiomycete mycelium without supporting the production of a basidiocarp. The method of growing the basidiomycete mycelium includes inoculating the substrate with a vegetative mycelium and incubating in a first incubation period at controlled temperature, humidity and carbon dioxide levels followed by a finishing incubation period.
SUBSTRATE COMPOSITION AND METHOD FOR GROWING MYCOLOGICAL MATERIALS

[0001] This application claims the benefit of Provisional Patent Application 61/494,477.


[0003] This invention relates to a substrate composition and method for mycological materials.

[0004] As is known from published United States Patent Application 2008/0145577, use can be made of a fungus to form composite materials by mixing an inoculum including a preselected fungus with discrete particles and a nutrient material capable of being digested by the fungus. It is also known from U.S. Patent No. 8,001,719 to enclose and grow a fungal primordium in a mold to obtain a mass of fungal tissue in the form of low density chitin material.

[0005] Briefly, this invention provides an engineered substrate for the production of mycological materials as well as an improvement on the method described in published US Patent Application 2008/0145577 for the production of mycological materials. In this regard, the method also provides for an optimal incubation environment to promote various types of mycological physiology on the substrate.

[0006] In accordance with the invention, the substrate is comprised of both nutritional and non-nutritional particles or fiber, which promote the growth and differentiation of basidiomycete mycelium but does not support the production of a basidiocarp (fruiting body or mushroom). A nutritional particle or fiber is defined as providing an easily accessible carbon source for the fungal mycelium; this includes simple sugars (dextrose, cellulose, maltose), carbohydrates (maltodextrin, starch), and lignin. These nutritional carbon sources can be used either in their raw form, as in a reagent grade chemical, or as the prevailing plant matter component. A prevalent carbon source is defined as comprising more than 20% of dry mass, and a nutritional particle must contain at least one dominate carbon source.

[0007] The summation of carbon source composition, such as a combination of a starch and lignin, does not meet the criteria since basidiomycetes can alone breakdown one carbon source at a time and enzymatic repression has been found to promote singular carbon source selection.

Nutritional Particle Example:

[0008] Softwood sawdust, such as Scot Pine or Birch, range in cellulosic composition by greater than 40% by dry weight. Hemicelluloses are also prevalent, which serve as a secondary carbon source for the fungal mycelium, and typically compose more than 20% of the tree biomass. Cottonseed hulls, which are byproduct from cottonseed extraction, have an average lignin content in excess of 21% and a starch content of 1.7%.

[0009] A non-nutritional particle or fiber either offers a carbon source accessible by the fungal mycelium but is less than 20% of the material's total dry mass, or the material offers no nutritional value. This particle or fiber could be carbon deficient, such as the silicon dioxide found in rice hulls, or offer a carbon source that is not accessible by most basidiomycete species.

Non-Nutritional Particle Example:

[0010] Oat hulls have low starch content and a naturally high lignin content of 14.8% and 5.4% by dry weight respectively. Rice hulls represent a carbon deficient particle, since 67.3% of the material’s composition is silicon dioxide. Similarly buckwheat hulls do not offer starch content and the remaining fiber does not offer the lignin necessary to maintain growths.

Substrate Composition Examples:

[0011] Each of the following substrate compositions composes 5 L volume of dry substrate

<table>
<thead>
<tr>
<th>Non-nutritional Particle or Fiber (g)</th>
<th>Nutritional Particle or Fiber (g)</th>
<th>Trace Nutrient (g)</th>
<th>Water (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>335 g Rice Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>432 g Cottonseed Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>450 g Buckwheat Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>700 mL</td>
</tr>
<tr>
<td>335 g Soybean Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>432 g Cottonseed Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>335 g Soybean Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>432 g Cottonseed Hulls</td>
<td>8 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1000 mL</td>
</tr>
<tr>
<td>521 g Cotton Fiber</td>
<td>32 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>1100 mL</td>
</tr>
<tr>
<td>480 g Cotton Burs</td>
<td>32 g Maltodextrin</td>
<td>10 g Calcium</td>
<td>800 mL</td>
</tr>
</tbody>
</table>

[0012] Of note, oat hulls are density equivalent and interchangeable with rice hulls and kenaf fiber, hemp pith, sorghum fiber and flax shive are density equivalent and interchangeable with cotton fiber.

[0013] Blending substrate, either through stratification or intermixing, can also enhance mycological material characteristics. For example, a low density and elastic modulus substrate (cotton moos) can be applied to external features of a tool while a high density and elastic modulus substrate can be internalized within the material to stiffen the core. An elongated fiber, such as coconut coir, can be positioned along the exterior of a substrate to create a tensile skin to increase surface energy and bolster flexural strength.

Incubation Conditions For Mycological Materials

[0014] The incubation environment for the production of mycological materials promotes the continuous production of vegetative tissue (mycelium, “mycelium run”) and inhibits primordial formation or fruiting (the production of a basidiocarp or mushroom). Fungal tissue differentiation, physiology and morphology, is dictated through tropisms, which stimulate various growth characteristics based on the surrounding environment. The proposed is two-phase approach that can be implemented in either batch or continuous processing.

[0015] In accordance with the method for the production of mycological materials, the engineered substrate is inoculated with a vegetative mycelium as described in the parent patent application and subjected to a two step incubation treatment.
The initial incubation environment at the point of substrate inoculation with the vegetative mycelium is designed to accelerate mycelium run. Full colonization of the substrate can be achieved in as little as four days, and the mycelium can inhibit competitive organisms (mold and bacteria) with metabolic standstill exudates. The environment has an operating relative humidity (RH) of 80-100%, carbon dioxide (CO2) levels that build over the course of the incubation period to be in excess of 5000 ppm, and a temperature between 24 and 30°C. The heightened temperatures support the production of generative hyphae, which achieves rapid colonization but does not offer ideal strength characteristics.

Furthermore, minimizing light exposure or a direct view factor is crucial as light cycling can trigger the fungal circadian rhythm to produce a fruiting body. Reducing the direct light exposure to the mycelium can be achieved with part nestling configurations or ensuring that the light used is outside of the 380 to 500 nm range. Once full colonization is established secondary incubation can be initiated as a finishing step.

The secondary environment can modify any of the following individual growth conditions or a combination thereof depending on the mycelium species and strain:

1. Reducing or maintaining the temperature between 15 and 25°C. This promotes the formation of binding hyphae, which is a different mycelium physiology that offers the optimal strength characteristics for a mycological material. These hyphae are finely branched and non-septate. Basidiocarp formation typically occurs for poly pores in temperatures in excess of 21°C, thus fruiting is inhibited and tissue differentiation is predominately within vegetative hyphae.

2. The carbon dioxide levels can be elevated between 10,000 and 60,000 ppm, which is within range for mycelium run and primordial formation, but not for the formation of a fruiting body. The induction of a primordial surface finish (20,000 to 40,000 ppm), which offers a smooth, homogenous surface finish, and superior surface tension strength. The commercial cultivation of mushrooms requires constant air exchanges to maintain an environment containing less than 2000 ppm of CO2.

3. Relative humidity should be elevated to greater than 90%, since the surface area to volume ratio of the nested, pre-colonized materials can be prone desiccation. Moisture and surges pressure accelerate mycelium growth and ambient humidity can ensure growth is not hampered. The relative humidity can be passively retained using an open filtered water source or actively with misting through distributed nozzles. This is not an issue with substrate prepared for mushroom production since the trays or bags that house the mycelium culture are either fully enclosed or minimize the surface area to total volume. Furthermore, the relative humidity for mushroom production is typically less than 95% since moisture can activate spores found in mushrooms and result in autolysis. 4. The mycological materials should remain nested in a configuration or environment that offers low or no light exposure.

What is claimed is:

1. A substrate for growing basidiomycete mycelium comprising nutritional and one of non-nutritional particles and fiber characterized in that said substrate promotes the growth and differentiation of basidiomycete mycelium without supporting the production of a basidiocarp.

2. A substrate for growing basidiomycete mycelium comprising non-nutritional material, nutritional particles and nutrient

3. A substrate as set forth in claim 2 where said non-nutritional material is selected from the group consisting of rice hulls, oat hulls, cottonseed hulls, buckwheat hulls, soybean hulls, perlite, cotton fiber and cotton burs.

4. A substrate as set forth in claim 2 where said nutritional particles are maltodextrin.

5. A substrate as set forth in claim 2 where said nutrient is calcium sulphate.

6. A substrate as set forth in claim 2 comprising 335 g Rice Hulls, 432 g Cottonseed Hulls and 8 g Maltodextrin.

7. A substrate as set forth in claim 2 comprising 450 g Buckwheat Hulls, 432 g Cottonseed Hulls and 8 g Maltodextrin.

8. A substrate as set forth in claim 2 comprising 335 g Soybean Hulls, 432 g Cottonseed Hulls and 8 g Maltodextrin.

9. A substrate as set forth in claim 2 comprising 300 g Perlite, 432 g Cottonseed Hulls and 8 g Maltodextrin.

10. A substrate as set forth in claim 2 comprising 520 g Cotton Fiber and 32 g Maltodextrin.

11. A substrate as set forth in claim 2 comprising 480 g Cotton Burs, 40 g Cottonseed Hulls and 52 g Maltodextrin.

12. A method of growing basidiomycete mycelium comprising the steps of:

a. providing a substrate comprised of non-nutritional material, nutritional particles and nutrient capable of promoting the growth and differentiation of basidiomycete mycelium without supporting the production of a basidiocarp;

b. adding water to said substrate;

c. inoculating the substrate with a vegetative mycelium; and

d. thereafter incubating the inoculated substrate in a first incubation period at a temperature between 24 and 30°C and an operating relative humidity of 80 to 100% while allowing carbon dioxide levels to build over the course of incubation to in excess of 5000 ppm.

13. A method as set forth in claim 12 further comprising the step of subjecting the incubated substrate to a secondary incubation period wherein said temperature is maintained between 15 and 25°C.

14. A method as set forth in claim 12 further comprising the step of subjecting the incubated substrate to a secondary incubation period wherein said carbon dioxide level is elevated to between 10,000 and 60,000 ppm.

15. A method as set forth in claim 12 further comprising the step of subjecting the incubated substrate to a secondary incubation period wherein said relative humidity is greater than 90%.

16. A method as set forth in claim 12 further comprising the step of subjecting the incubated substrate to a secondary incubation period wherein the incubated substrate is nested in a configuration that offers no light exposure.