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Agaricus bisporus Casing Layer V: Water-Holding Increased by Adding Gels to Clay Chips

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ABSTRACT: Previous work has shown that, although casing is an important source of water for mushrooms, inert casing materials with poor water-holding capacity can support good mushroom yields. Three non-ionic gels were tested to determine if increased water would increase yields. Gels of 1% agarose, 10% agarose, 1% acrylamide-starch, 10% acrylamide-starch or 1% methylcellulose were added to calcined clay chips with limestone. The gels differed from one another in both chemical and physical properties, but all casings with gels gave lower mushroom yields than the control casing made only of calcined clay chips and limestone. Yield seemed to be inversely proportional to the swollen volume of the gel. The data strongly supports the importance of gas-holding capacity of casing.

1 INTRODUCTION

It is often believed that water in casing is of great importance. It was believed that if the water held in the casing could be increased that yields would increase. With the advent of disposable diapers, there was a need for greater retention of water. Acrylamide-starch coplymers were developed and found very effective in providing long-term "dry" diapers. The acrylamide-starch was able to hold large volumes of water.

If acrylamide-starch could hold extra water in a diaper it might do the same in casing and increase mushroom yields. So a few years back, a number of companies sold acrylamide-starch copolymers, under various trade names, to mushroom growers, to increase water-holding capacity and thereby increase yields. The only thing that was apparently wrong with the idea was that peat moss itself holds very large amounts of water and allows quite easy release of that water; could the acrylamide-starch do more?

While there was no research directly showing that the acrylamide-starch was not of value, research was done which put its value in question. The work of Kalberer (1991) established that the water needed for growth of basidiocarps could come from the compost. More recently, Kurtzman (1995a, 1995b) showed that casing made of nearly inert materials were capable of supporting mushroom production that was only slightly less than peat moss. The materials he used held very little water and he kept them well watered to assure that the basidiocarps would have the water that was required.

In other work Kurtzman (1996) showed that ion-exchange materials added to his inert casings, caused some increase in mushroom yield. Some of his ion-exchange materials were gels which held water. Were those materials beneficial because of their ion-exchange characteristics or because they held water? The current research examines that question by using various gels, including acrylamide-starch, which lack ionic chemical groups.

2 MATERIAL AND METHODS

Compost was supplied by Sunrise Mushroom Co., Watsonville, California and Mills Mushroom Co., Healdsburg, California. Spawn was obtained from the same growers and used in their compost. Sunrise supplied their own S-281 spawn and Mills supplied Amycel U3.

Turface, a product of Applied Industrial Materials Corp., Deerfield, Illinois consists of flakes of calcined montmorillonite clay. The Turface casing was prepared by mixing two parts of the Turface with one part of ground limestone by weight.

Agarose was SeaKem LE from FMC, the acrylamide-starch was Agricultural-Gel brand, and the methyl cellulose was from Aldrich Chemical.

The agarose casings were made by combining agarose equal to 1.0% or 10.0% of the weight of the Turface with water equal to the weight of the Turface. The water was stirred as it was brought to a boil. Boiling continued until all agarose was dissolved. The hot liquid was mixed with dry Turface and limestone casing. The mixture was stirred immediately and after it cooled.

The acrylamide-starch casings and the methyl cellulose casings were prepared by mixing acrylamide-starch or methylcellulose equal to 1.0% or 10.0% of the weight of the Turface with the dry Turface and limestone casing. Then water equal to the weight of the Turface was added and the mixture was well stirred.

Compost was placed in high density polyethylene trays 28 X 17 cm X 13 cm deep. The trays were packed to the top with 3.7 kg of compost. Casing was an additional 3 to 4 cm on top.

Spawned trays were placed in a growth chamber at 22C and mushroom mycelium was allowed to grow through the compost for one week, before the casing was applied. The trays were wrapped in polyethylene during that time and they were not watered. Casings were applied wet. Watering was begun on the second day after the casing was applied. While the spawn was growing into the casing, they were watered approximately every second day, depending on appearance. Water was applied daily when pinning was first expected and during the remainder of the experimental period. All watering was done with a fogging type nozzle to avoid splash and reduce the spread of disease. All water was deionized.

While the spawn was growing through the compost and casing, the temperature was maintained at 22C. When mushroom primordia (pinning) were expected the temperature was lowered to 10C for several days. It was then brought to 15C for the remainder of the experiments.

All data are based on two experiments. Mushroom yield experiments included five replicates of each casing in each experiment. However, the figures were drawn from only one experiment. The least standard difference (lsd) values were calculated for each day. The largest lsd values or both largest and smallest lsd values are shown in the legends.

3 RESULTS AND DISCUSSION

The cumulative yield of mushrooms grown with casings containing agarose is shown in shown in Fig. 1. The yield from the experiments with 1.0% agarose was sightly greater than the Turface control for two days at the end of the second flush at all other times it was less. The yield from experiments with the 10.0% agarose casing was always much less.

The cumulative yield of mushrooms grown with casings containing acrylamide-starch and methylcellulose are shown in Fig. 2. All three experiments with gel containing casings in Fig. 2 gave lower yields than the Turface control at all times. Trays with 1.0% acrylamide-starch showed lower yields than the 1.0% agarose experiment. The 1.0% methyl-cellulose yields were lower than the 1.0% acrylamide-starch and the lowest yields were on casing with 10.0% acrylamide-starch.

Gels are colloidal substances, all colloidal particles have an electrical charge (Gortner and Gortner 1949). For that reason it is not possible to find a gel which can not exchange ions with its surroundings. However, agarose is prepared from agar by removing the polymers that contain

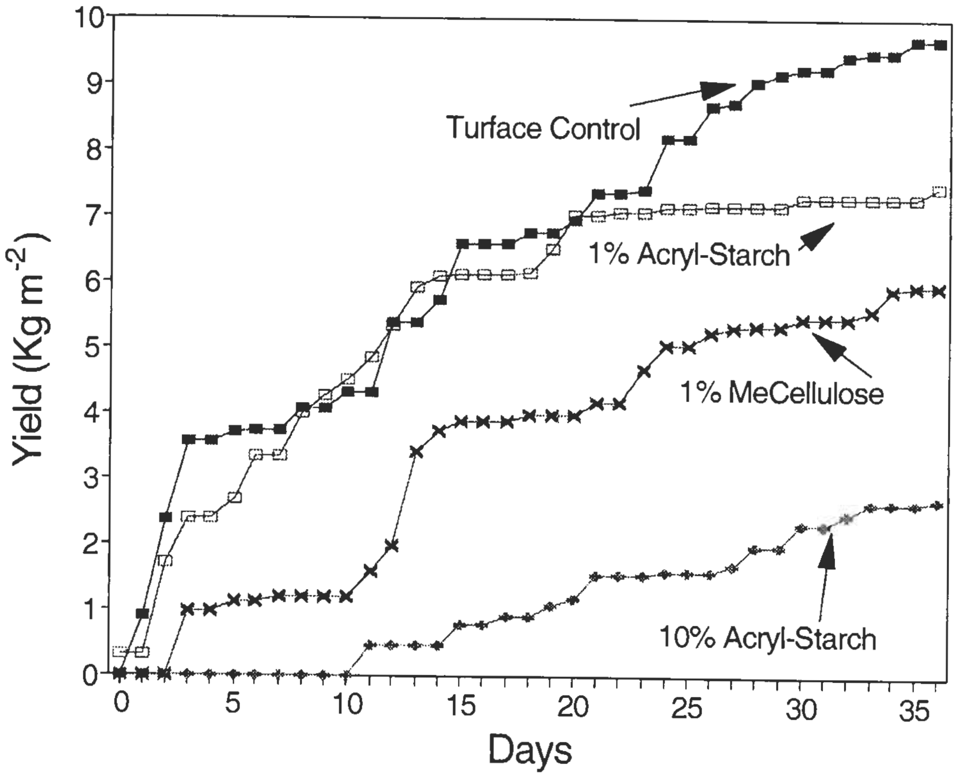

Fig. 1. Cumulative yields of mushrooms grown on Turface, and Turface with agarose. Day 0 is the day before the first harvest. The largest lsd values for any day during the entire experiment were (.05)=0.3 and (.01)=0.4 kg/m^2.

ionic chemical groups. The monomers of acrylamide-starch have no ionic groups. Methylcellulose is prepared by methylating pure cellulose. Pure cellulose has no ionic groups. Thus, the materials used are as free of ion-exchange properties as anything that could be used.

The gels all have a soft structure. The Turface has a rigid structure. Casing must have a reservoir of gas (Kurtzman 1965a, 1995b). Any gel mixed with Turface will tend to decrease the gas-containing space between the Turface particles. Of the three gels, agarose is the most rigid. When an agarose gel is mechanically broken, as was in preparation, there will be some gas-containing spaces. Once agarose cools it continues to loses water to evaporation, but even when water is poured on it it tends to imbibe very little. Water loss tends to cause shrinkage, added water generally causes little expansion. So natural evaporation will tend to leave gas-containing areas that may not refill with water.

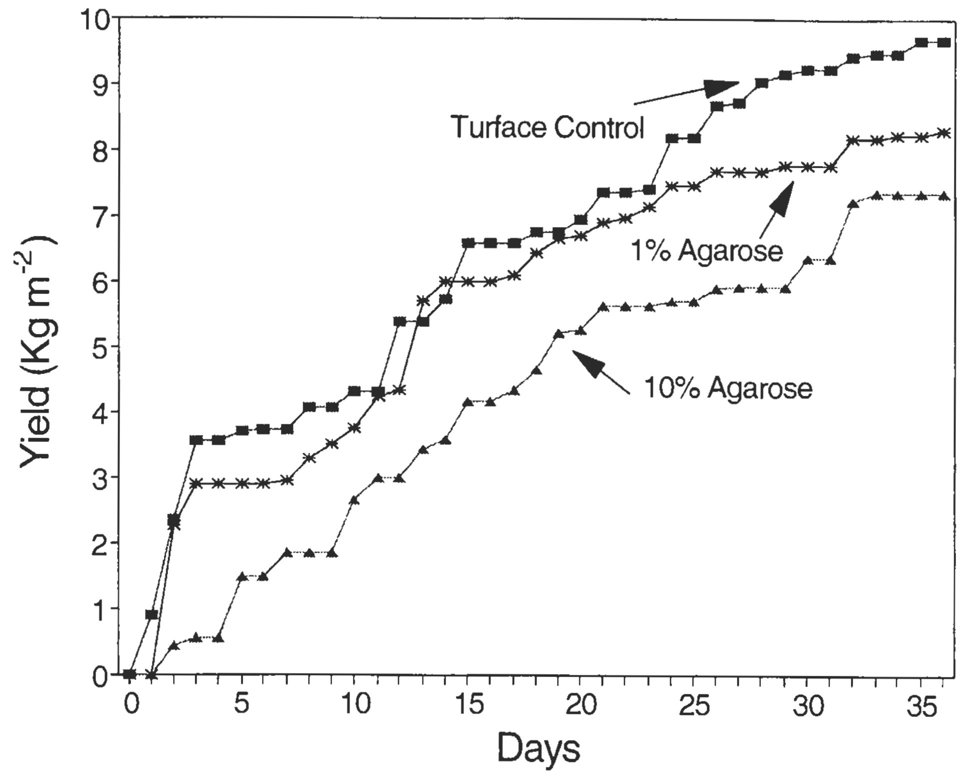

Fig. 2. Cumulative yields of mushrooms grown on Turface, and Turface with acrylamide-starch or methylcellulose. Day 0 is the day before the first harvest. The largest lsd values for any day during the entire experiment were (.05)=0.3 and (.01)=0.4 kg/m^2.

Acrylamide-starch expands when cold water is added and shrinks when it dries, but expands again when it is watered again. It holds water well because of its ability to expand in cold water. The behavior of methylcellulose in water is similar to the behavior of acrylamide-starch. However, methylcellulose is more "soluble," so that when it receives large quantities of water, it may wash away. Also, it will hold considerably less water than acrylamide-starch.

From the foregoing analysis we would expect that all gels would decrease yields. We would also expect that agarose would cause a smaller decrease than acrylamide-starch and methylcellulose. Further, we would expect that a higher concentration of acrylamide-starch would cause a greater loss in yield than a lower concentration. The greater concentration could swell to a greater volume and exclude gas to a greater degree. It is somewhat more difficult to explain why 1.0% methylcellulose causes a greater decrease in yield than 1.0% acrylamide-starch and why 10.0%

agarose caused a greater decrease than 1.0% agarose. If the agarose is semirigid and does not expand with greater water, the greater concentration should increase the rigidity and allow more gas-space. One possible explanation is that the Turface was glued together during the preparation and was not as well broken up as intended. The methylcellulose may have migrated to the bottom of the casing or the top of the compost and the gas-space in that area might be more critical.

The results show that the gels tested are all detrimental to yields. The data supports the conclusion of Kurtzman (1995a, 1995b) that gas porosity is the most important characteristic of casing. They also show that the increased yields reported by Kurtzman (1996) from ion-exchange gels were due to the ionic character of the gel and not to their water-holding capacity.

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