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Productivity Improvement in Mushroom Plants

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Abstract

Consumption of mushrooms has been on rise over the past several years in North America because of awareness in public regarding the positive impact of mushrooms on overall health. However, the number of mushroom plants has gone down by 34% since 1991/92. Many of these farms are being confronted by objections raised by local governments, environmental groups and local people. The objective of this research is to develop a new automated system in which three phases will be done inside a growing container. Total growing cycle will be reduced to 69 days compared to 109 days in old system. The raw material requirement for phase I will be reduced by at least 10 to 15%. In addition, the oxygen level will be controlled over the time which will eliminate the volatile sulphur compounds and volatile fatty acids odor emissions leading to an environment friendly system

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Abstract

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Keywords: Mushroom growing, Productivity improvement, Automation, environment friendly.

1. Introduction

Mushrooms have aroused our interest since time unmemorable, not just because of their different forms and color but also because of their properties from poisonous to beneficial and their edibility. During 2001/02 seasons the farm value of all mushroom production reached a record of $912 million. Mushroom were the fourth leading vegetable commodity in terms of farm cash receipts- exceeded only by potatoes, tomatoes and lettuce. Typically used as a vegetable, per capita consumption of this carefully cultivated fungus crop has quadrupled since 1965 (United Sates Department of Agriculture (USDA)). Economic Research services per capita use of all the fresh mushrooms totaled about 3.94 pounds in 2002 as compared to 0.69 pounds in 1965. In 2001 U.S.A alone, consumption was 1.13 Billion pounds, which is 21% higher than in 1991. The common white button mushroom (Agaricus Bisporus) accounted for 87% all the domestic sales in 2001. In 2001/02, mushrooms were grown on 262 farms in U.S.A, which is down 14% from 1999/2000 and 34% below 1991/92. U.S. fresh market production is 83 percent of total sales volume with processed production making up the remaining 17 percent. In Canada and United

States the demand of fresh mushrooms are going up but the number of mushroom farms are going down each year. For Canada it is even worse than United States as shown in figure 1.

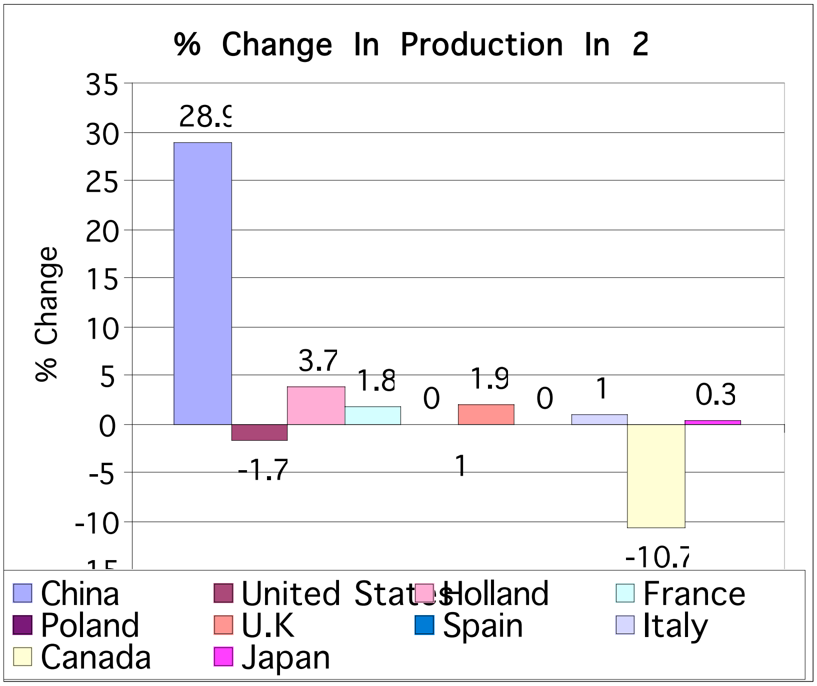


Figure 1 Percentage Change in Production of Mushrooms in 2001/02

The objective of this research is to develop a new system with high productivity as compared to traditional system. The new system will be less labor intensive and highly environment friendly. The procedures and problems associated with the traditional systems were presented in section 2. Section 3 was devoted for describing the stages, and production steps involved in the new proposed system. Section 4 is exhibiting a comparison between the traditional system and the new proposed system.

2. Present Mushroom Growing System

Mushroom cultivation requires the manufacturing of compost and the control of growing environment. Present systems have many problems associated with mushroom growing in both areas. These problems and procedures will be discussed in this section. Mushroom production consists of Phase I (Compost Preparation), Phase II (Pasteurization & Conditioning), Phase III (Spawn Run), Case Run, Flush run, Harvesting and cook out.

In Phase I composting lasts from 28 to 36 days, depending on the composition of the material at the start and its characteristics at each turn. Next is phase II which lasts for 10 to 12 day. There are two major purposes to Phase II composting. First is pasteurization which is necessary to kill any insects, nematodes, pest fungi, or other pests that may be present in the compost. And second, it is necessary to remove the ammonia, which formed during Phase I composting. Next is phase III that lasts for approximately 14 days in which the spawn (mushroom seed) has been mixed throughout the phase II compost and the relative humidity is kept high to minimize drying of the compost surface or the spawn. The next step is casing in which a top-dressing applied to the spawn-run compost on which the mushrooms eventually form. A mixture of peat moss with ground limestone, or reclaimed weathered, spent compost can be used as casing and it is kept there for 8 to 10 days. Then after case run carbon dioxide content of room air is lowered to 0.08 percent. Once an initial quadruples in size, the structure is a pin. Pins continue to expand and grow larger through the button stage, and ultimately a button enlarges to a mushroom. Harvestable mushrooms appear 11 days after lowering the CO2. Then picking is done for 22 to 24 days maintaining at 60 to 64F air temperature. After all the three or four breaks of mushrooms are taken the rooms are cooked at 160F for 10 to 12 hours to sterilize of used material.

In the present system the inventory cost is very high. Usually two months of the material is kept in the stock due to uncertain growing processes and total time for one growing cycle could be as long as 109 days.

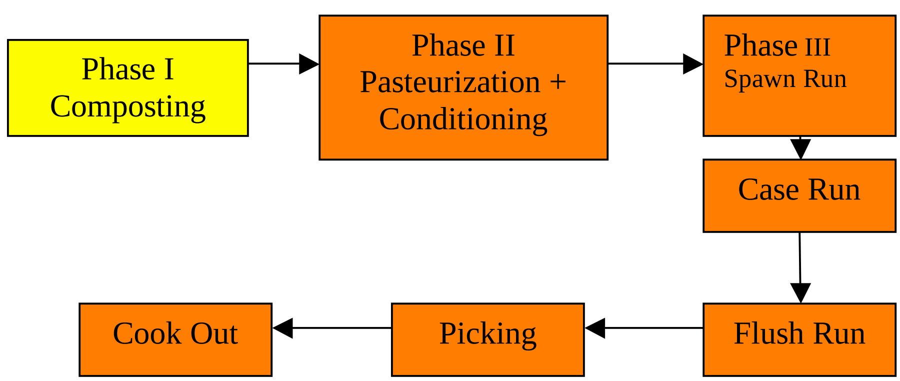


Figure: 2 Material Flow Diagram for Traditional System

Mixing of ingredients, such as chicken manure, gypsum and ammonium sulphate was often carried out in a very simple manner, using front loader and turner and the application of water at best by poorly placed sprinklers or manually. Therefore, it is obvious that time-to-time these farms suffer from the headache of “inconsistent compost quality”. This means that the compost is not a highly homogeneous mixture, which causes problems at a later stage of cultivation.

Compost is the major supply of food for the mushroom. The overall aim of composting is to produce a growing medium which will support the mushroom but unfavorable for its competitors. To do this the microorganism (microbes) in the compost use up the readily available nutrients leaving behind the tougher materials like lignin the mushroom mycelium is well equipped to use these materials. One of the most important effects of the activity of the microorganisms in the compost heaps the production of heat the more microorganism are there the more heat they produce they grow faster in turn they will soften the straw and broken down into shorter lengths. The microorganisms mainly responsible for the composting process need oxygen supply so any thing, which reduces the supply slow down their activity also. The weather during manufacturing compost is highly influential to compost quality. There are however, quite a number of farms in Canada, Northern Europe, Russia, the Middle East and other countries with extreme climates, which causes great composting difficulties generally makes compost anaerobic (Anaerobic means lack of oxygen). They have huge loss in yields, every year, when the climate becomes unfavorable.

Compost in traditional systems is made in stacks. The compost is piled into large bulk pyramid and are moved everyday or day after because in conventional piles or stacks only 50% of its mass in high temperature range. The stack if not turned creates gradients of temperature, gaseous environments and moisture. The three zones have been defined as an outer cooler zone where mesophillic (Biological) microorganisms are dominant, a large inner region where majority is true thermopiles (Chemical) and a core wherein traditional composting an aerobic condition occurs due to lack of oxygen is very acidic in nature as shown in figure3. Consequently to get all of the material in the chemical break down range piles are turned every alternate day it is turned in an attempt to switch the material that is outside of the desired range into the center where it has the opportunity to reach high temperature(different temperature range is shown in figure 4). After four or more turns it is assumed that the compost is fully converted is filled directly into Phase II. This compost is not very selective to the mushrooms because of temperature variations.

Heat evolution causes water loss so water is added from time to time. These gradients of gas and temperature are destroyed on mixing and also compost loses its texture when handled too many times. Traditionally compost is scheduled for 28 days which causes dry matter loss due to cellulose and hemi cellulose degradation during composting. In microbial population number of species come which are mesophillic bacteria, thermophillic bacteria, actinomycetes and fungi.

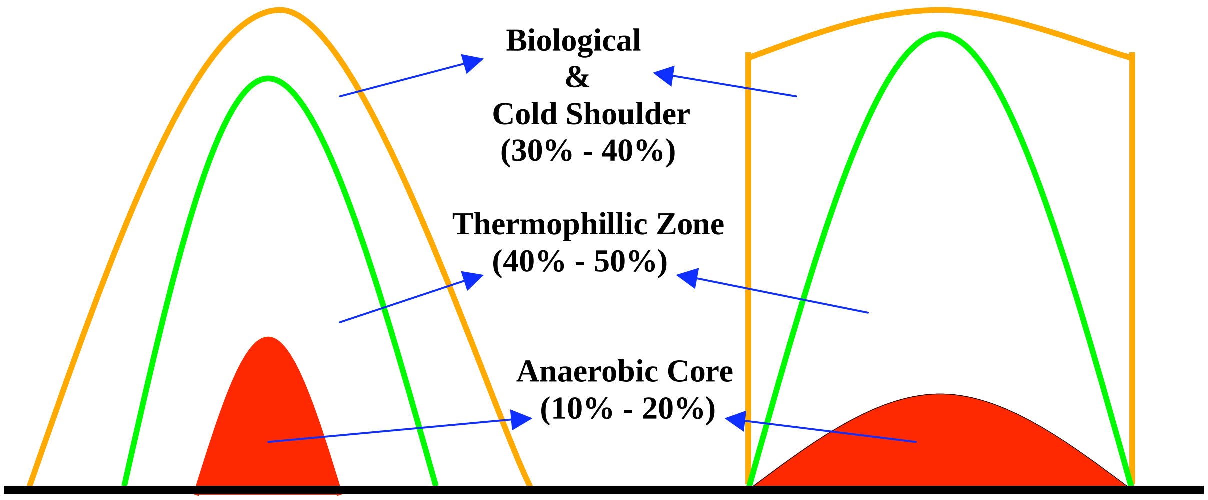


Figure 3: Different zones in Compost Piles due to Temperature Difference in Traditional Systems

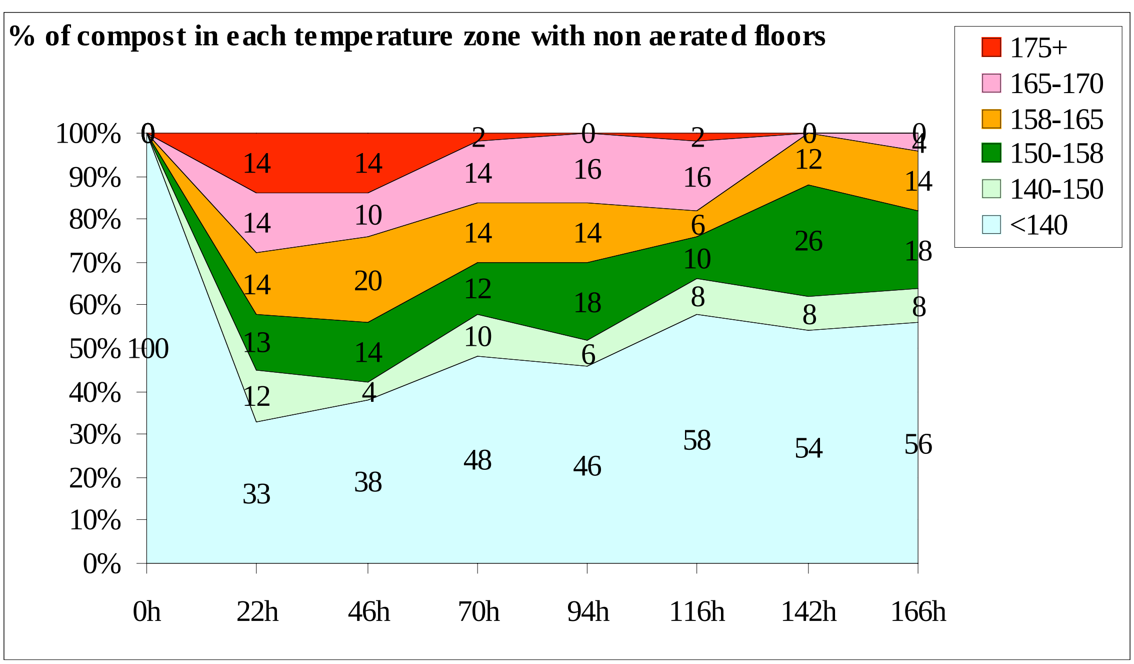


Figure 4: % of compost in each temperature zone with non aerated floors in Traditional Systems

Many mushroom farms around the world are, and will continue to be, located near villages and small town in order to be close to their markets. Nowadays, in Western Europe and in North America, many of these farms are being confronted by objection posed by local government, environmental groups and local people. These increasingly restrictive, environmental pressures not only touch their current activities, but also seriously endanger any planned expansion of their compost yards. Many of these are already searching for new locations for their compost yards and, more recently, for alternative compost manufacturing system.

In traditional outdoor compost process the large amount of ammonia and odorous compounds are emitted and control is very difficult. Volatile sulphur compounds like sulphide, carbon disulphide and metenamine mainly cause the ordure as shown in figure 5. Results of Concentration of various volatile sulphur compounds are shown in the table 1 when tests are performed within a sealed container given by H.J.M.Op den Camp, A.Pol, C.van der Drift (Deptt of Evolution Biology University of Nijmegen, Netherlands).

Value	Hydrogen Sulphide	Carbonyl Sulphide	Methanethiol	Di Methyl Sulphide	Carbon Di Sulphide	Dimethyl Di Sulphide	Dimethyl Tri Sulphide
PPM	6.7	0.32	1.01	1.67	0.39	1.29	0.19
Gm S/ Ton	4.47	0.21	0.67	1.12	0.52	1.72	0.37

Table 1: Concentration of Different Sulphur Compounds during Phase I Composting.

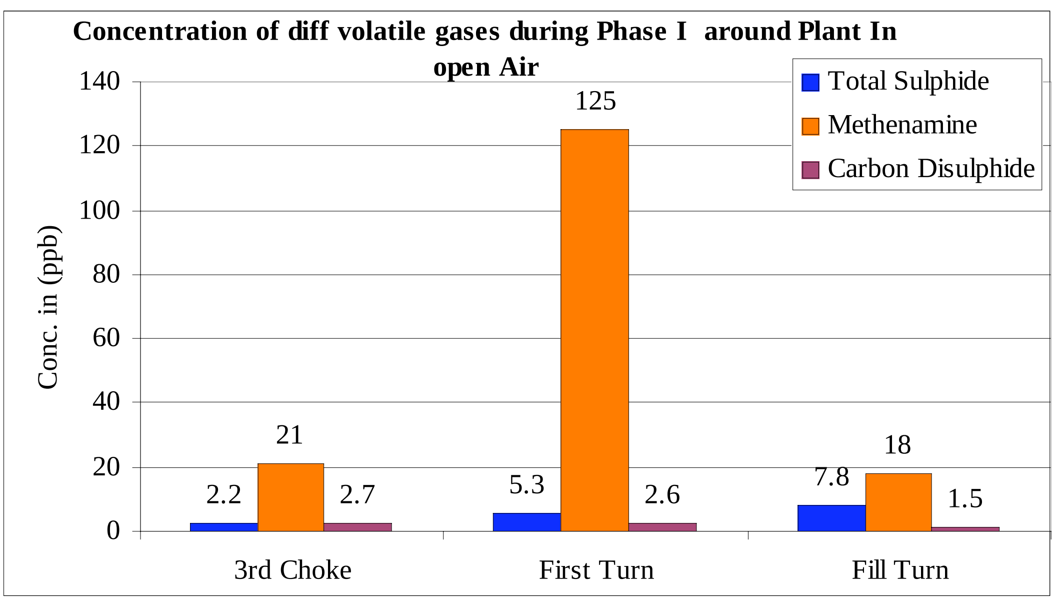


Figure 5: Concentration of diff volatile gases during Phase I when samples taken around Plant In open air.

Phase I take place completely outside. In phase II the compost is then filled manually into the concrete tunnels or straight into growing rooms. Pasteurization and conditioning are usually manually controlled process. Filling bed is highly unhygienic process and the doors of pasteurization tunnels and growing room open into same corridor. At this time compost is very sensitive and easily prone to decease. Mostly Spawn (mushroom seed) is spread by hand. It creates uneven spawning. Also the wastage of material is very much. Spawning is done in the same room as where the mushroom grows. It is not exactly the ideal condition to prevent the moulds.

The air distribution ducts are not well designed and constructed; it creates uneven air distribution in the rooms. There can be too little or too much air movement in the room. The effects can be seen in uneven growth of the mushrooms. In present systems, the bottom shelves normally get too much air, while the middle ones get too little. Excessive air movement is always seen at the bottom shelves and the edges of the shelves under the air ducts.

Figure 6 shows the temperature distribution in the traditional bed system during Phase II and spawn run i.e. Phase III, which is highly unacceptable during conditioning and spawn run. (From Griensven Holland).

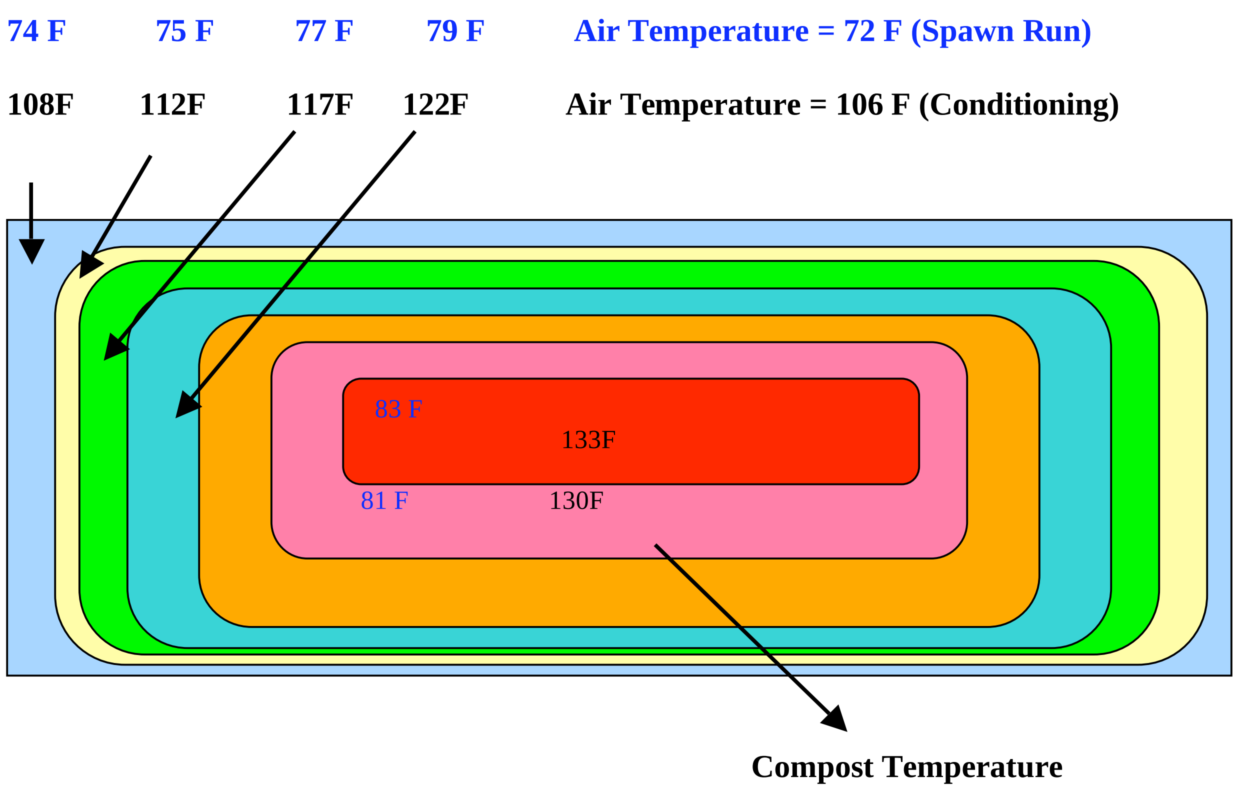


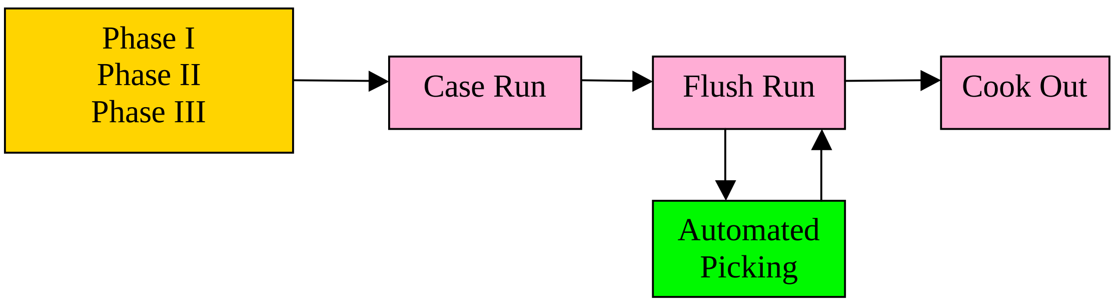
Figure 6: Temperature Distribution of Compost in Trays or Beds in Traditional Systems

In present system mushroom picking is very labor intensive and is hard on the backbone so the picking as well as work compensation cost goes high. Average picking rate is very low. Presently mushrooms are picked at a speed of 40 lbs/ hr. Poor picking practice often results in severe downgrading of mushrooms quality. Present picking process has increased the risk to damage the crop by spread disease to other growing room by spores in air, by flies, dirty equipments, hands, clothing and the like. Because during picking doors are open several time and pickers travel one room to another room. Once mushrooms are picked these are stored for little longer so plants can meet demand in coming days particularly if the production is low which will shrink the mushrooms and some weight and quality will be lost also. Usually by storing the mushrooms almost 10 to 15% of these mushrooms will be a waste after 3 days because of quality issues. Delivery of mushrooms to various distant cities ruins the quality and is very expensive when shipped every day or every other day.

With the present system every week it’s about 200 ton of compost by an average size farm needs to be disposed off in the fields which is an environment issue. And also during the operations the wastage of compost is high. In U.S the spent mushroom substrate is estimated to be in the excess of 1.2 billion cubic feet. In recent years industry has faced increasing challenges from regulating agencies demanding environmental friendly.

3. Automated System Schedule

Mushroom production in the new system will consists of 3 phases (Phase I, II and III all the phases will be done in same container), Case Run, Flush run, Harvesting and cook out. In Phase I composting will be of 8 days for biological and chemical breakdown. Phase II will last for 4 days just for conditioning. Phase III will be of same number of days as traditional system i.e.14 days. The next step casing which will be a mixture of peat moss with ground limestone and it is kept there for 6 days. Harvestable mushrooms appear 11 days after lowering the CO_2 i.e. after case run. Then picking is scheduled for 22 to 27 days maintaining at 60 to 64F air temperature. After all the three or four breaks of mushrooms are taken the containers will be cooked at 160F for 10 to 12 hours to sterilize of used material.



Change of color means change of locations

Figure 7: Material Flow Diagram for Automated System

3.1. Overview of new system

The new system is the improved version of present system and will be practically implemented in 2007. The straw will be placed on the NH_3 floor. When the straw has absorbed sufficient amount of NH_3 and gets dewaxed, it is pushed out of the roller floor and passes through new pre wet machine. The moisture content of the bales must be raised to the saturation point during the presoak The sprinkles are set in side hydrating unit to soak the bales with pit water by vacuum technique. The aim is to maintain complete coverage of bales while soaking. Which will help recharges straw with intense hydration, leaving it deeply moisturized (75%). Automatic string removal and mixing setup install next to hydrating unit. The moisturized straw will de-string by automated string removal and bales break by bale breaker shaft. There will be hopper install to regulate the horse/chicken manure. Mixture will pass through the blender. To add gypsum, dispenser will be used and mixture passing through a drum provided with V-shaped teeth picks up the compost and places it in an output elevator. This process produces a good homogeneous mix.

AUTOMATED PHASE I & PHASE II

#Day	**Operation**	**Temperature Zone F**
0	Break bales and Raise Moisture By Vacuum Technique	90
1	Mix Straw + Chicken Litter + Express R + Water	122
2	Mixing + Water	122
3	Mixing + Water	122
4	Mixing + Water	175
5	Rest	180
6	Mixing + Water	180
7	Rest	180
8	Mixing + Water	180
9	Mixing + Water + Scytalidium Thermophile	122
10	Rest	122
11	Mixing	122
12	Rest	118

Table 2: Automated Phase I & Phase II

After that compost is transferred to controlled environment room called tunnel container for pasteurization, mixing and spawn run. A special turner machine is used to mix and water the ingredients. Compost will stayed in tunnel for 26 days for processing. On 9th day a special bacteria will be mixed into the compost because until now the compost temperature is in sterilized zone as shown in table 2. No human interaction with compost for these days. All the tests are performed by the machine in tunnel container and accessed by computer. On 27th day hallway is opened and tray packer machine is used to pack the tray with fully grown compost and move the ingredients to the growing container which can be shipped to any location in North America. The special trailers have been designed for growing mushrooms. In these containers the trays will be stacked automatically with the help of conveyors and stacking machine. When mushrooms are ready for picking, trays will be shifted to picking rooms. Watering as well air supply in the container will be done automatically.

Picking room is designed in a special way where pickers can sit on the chairs and pick mushrooms while trays pass through conveyors in front of them. In this system we have two picking station with controlled environment chamber called buffers to avoid the bottleneck as shown in picking station diagram. Picking speed will be approx 100 lbs/hr to 120 lbs /hr. Once mushrooms are picked these will be packed automatically according to the sizes of the mushroom i.e. small, medium, and large.

The Process objective is to gain high temperature as rapidly as possible by supplying oxygen at the rate that it is used and to then maintain those temperatures with minimum air volume. Due to chemical reaction at high temperatures the oxygen requirement is very little. In our system material will be filled into the container and doors closed to give complete control of the process. Compost temperature will rise to 122F over 24 hours will keep it for next 2 days. Compost will be mixed every day to get the even mixing and more density. After 2 turnings the temperature will let rise to 175F in next 24 hours and then to 180F for next 2 days. After two days it will be again turned to chop the straw and to get the density in the material within the container.

During these last 5 days the temperature will not drop below180F. Air supply will be controlled to ensure an oxygen level minimum at 10%. After five days the air temperature will be dropped to 110F and compost temperature will be dropped to 140Fduring a period of 5 hours. Once it hit 140 the required inoculum will be spread over the compost and it will be thoroughly mixed into the compost. The temperature will be kept at 122F for another 3 days and then 118F until ammonia level comes to 5 ppm. In our system we will manage the air supply according to the oxygen levels in the compost. The oxygen level will not let go below 6% and high more than 12%. This has been defined by P. S Perrin & B.J. Macauley, School Of microbiology Vic, Australia.

Mushroom compost must be inoculated with mushroom spawn. Also in our system it is possible to store the spawned compost for one month so to match with the demand of the market because at a temperature of 34 F the spawned compost becomes doormat and can be shipped to any location by keeping at a temperature at 34 F. This way the quality of freshly picked mushrooms at a particular location is very high. At temperatures below 74F, spawn growth is slowed and the time interval between spawning and harvesting is extended to meet the demand and supply ratio during Christmas or on other occasions.

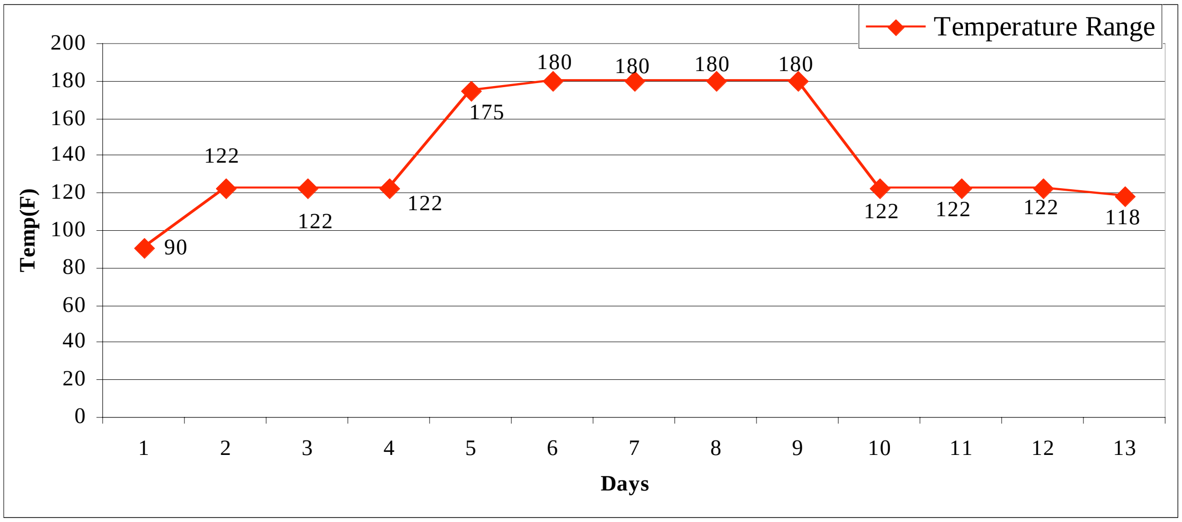


Figure 8: Graph for Temperature Distribution for Automated Phase I & II

4. Advantages of the New System

The area required with newer system will be far less than a conventional system. This could be high as 80%. Because in our system we are going to use containers instead of big growing rooms therefore area to heat or to cool is less as compared to traditional big growing rooms and also the insulation can be done in better way in containers. All these factors contribute in lowering the energy cost.

The process can be controlled and manipulated 24 hours a day with little impact from Mother Nature. With the facility totally enclosed rainwater will not be the issue. Due to short and controlled process the actual run off from compost is less. This will reduce the need for large and expensive water collection and treatment systems which will reduce the energy cost. In the new system the material required for phase I will be reduced by 15 to 20% because of reduction in number of days for phase I. Therefore it will save 10 to 20% of the cost for phase I required raw material.

Since system is better controlled with more homogeneous mixes and better conditions therefore the amount of time required to produce high quality compost is less. In this case Phase I composting will be reduced from 36 days to only 9 days and Conditioning for only 3 days from 14 days. In new system the total growing cycle will be reduced from 109 days to almost 65 days. Research done by R.B. Beelman Dep't of Food Science, The Pennsylvania State University, Pa, U.S.A has confirmed that the with increase in Cu the yield goes down and Cu increases with the stages so it is always better if number of days can be reduced for growing cycle as shown in figure 9 .

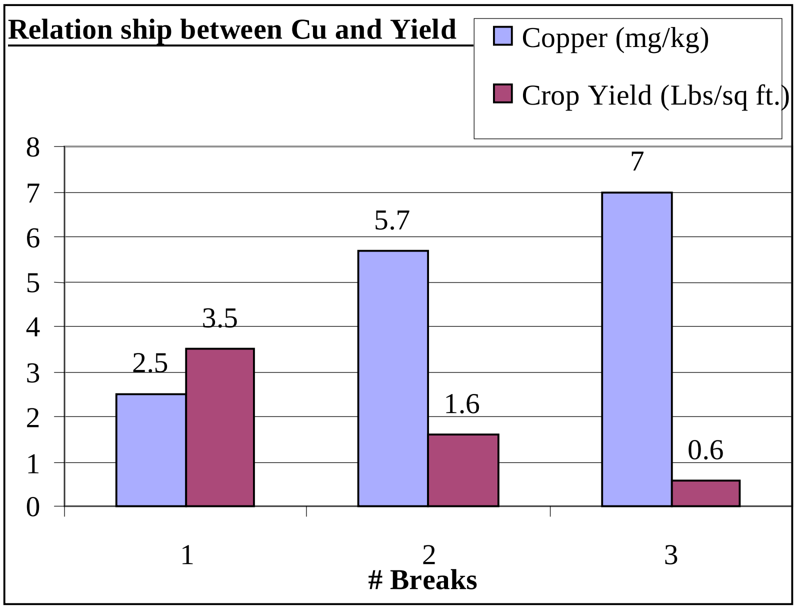


Figure 9: With Increase in Cu at Different Stages the Yield Goes Down

Since the entire process is shortened and the material is handled less there is significant reduction in labor. Picking cost in traditional farms varies from 25 to 40 % depending upon the location of the plant. Picking cost for plant running on traditional method in Canada is 30 cents per pound (average speed of picking is 27 lbs/hr) and little automated plant like A.B.C in U.S.A it is 17.90 cents which is less 12 cents (average picking speed is 40 lbs /hr). In new system the picking speed will be 100 lbs / hr. so this way companies can save lots of money in picking which is highest labor consumption area.

Shipping cost will be reduced also because instead of shipping mushrooms every day compost will be shipped which has ready to pick mushrooms to particular locations once a week or once in two weeks. Quality will be very high because of less time needed between the mushroom picked and consumer and also the picking dimensions and shape will be improved with semi automated picking like in our system. Quality standards as set by the Griensven (1988) in Holland and USDA (1966) in United States includes the following

- Taste
- Color, shape, Dimensions
- Shelf Life

- Improved Nutritional Value (how old are mushrooms)
- Health Factors

With new system it is possible to have some degree of flexibility to decide when and what kind of mushrooms are required for market at a particular time i.e. Brown mushrooms are needed or white and their respective size which was almost impossible with traditional system. Also the compost which is ready to pick mushrooms can be stored for one month to meet the demand in future instead of storing the picked mushrooms (shelf life of picked mushrooms is only 5 days)

With his new system it is possible to ship the compost, ready to pick mushrooms to a location where the demands for fresh mushrooms are more and quality is highly needed. It will be done in special containers, which can be shipped, to any part of North America. Those empty containers can be reused to grow mushrooms

In newer system the air is continuously monitored and oxygen level is set at same value all the time. Therefore almost no odor to the atmosphere is liberated so this system is totally environmental friendly. The elimination of the anaerobic core and therefore production of volatile sulphur compounds and volatile fatty acids can reduce odor emissions by up to 96 %.(P. S Perrin & B.J. Macauley, School Of microbiology Vic, Australia.)

With new system temperature distribution will be better because temperature will be monitored very closely and automated mixing of air, oxygen, water and supplement will make the compost perfect for mushrooms. With new system because every part of the plant is sealed from each other therefore it is very less likely that disease can travel from one part to another and also due to more automation & very limited human involvement therefore very less chances of contamination. Presently some plants have been closed down because of some diseases in the crops like laf ronse viruses but in new system the chance of getting any diseases is almost nil because of more automation at each operation and less human interaction.

Due to more controls set during growing process it is possible to monitor all the aspects which can cause damage later on and can be detected early and necessary actions can be taken. Another big advantage is that operators do not have to work and operate equipment in steam laden odorous conditions. Push buttons control the operations of Load/Unload/Packaging. Operators can be trained to be fully schooled in a matter of days.

The shrinkage after harvesting and before sales is approximately 9 %. But in the new system the shrinkage will be very less as compared to the traditional system because of tremendous reduction in travel time between the time mushrooms picked and the mushrooms sold. In new system the mushrooms are picked near to the market instead of being picked at a large distance.

Spent compost amount is equal to the amount filled in container. These spent mushroom substrate has K+, Na+, Ca+, Mg+2, Cl-, So4, and No3 all of which are essential for the optimal plant growth and development. (Mushroom news 2001) In new automated system because mushrooms will be picked at different locations therefore the material to be disposed off is very limited as compared to traditional plants and it's easy for the Nurseries to buy and use this small amount at each location.

5. Conclusions

The main emphasis of this research was to develop a perfectly automated system for mushroom growing. Presently the mushroom techniques used are developed by Dr. Shinden in 1950. With the passage of time this industry has gained little automation but at very high cost at poor utilization rates and almost no environment friendly. The new proposed system will be totally automated with high utilization rates at less cost and fully environmental friendly. In future we will be working towards making the system more efficient by designing the machines with even higher utilization rates and implementing these theories practically. Another area of future research would be to find the different ways to reduce the growing cycle time and prediction of yield more accurately at different stages of growing.

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