Compost production for button mushroom

Contents

- Introduction
- Raw Materials and Formulations
- Long method of composting
- Short method of composting
- Indoor method of composting

Introduction

Agaricus bisporus, the white button mushroom is one of the most popular mushrooms in the world and contributes around thirty per cent of world production of mushrooms. It is cultivated on a specially prepared substrate known as compost, which is a product of fermentation by a number of thermophilic organisms that decompose plant residues and other organic and inorganic matters. The main purpose of composting is to release the nutrients in the straw and supplements and to transform them in such a way that they are suitable for the nutrition of this mushroom. During composting various chemical and biological processes help in achieving this. The nitrogen available in the ingredients is converted into proteins of the microorganisms and further a lignin humus complex is also formed during composting both of which later on are utilized by the mushroom mycelium as food. Compost if properly prepared is very selective in nature and only *A.bisporus* mycelium can grow successfully on it at the practical exclusion of other competing organisms.

Cultivation of this mushroom first originated in France around 1650, where melon growers observed spontaneous appearance of *A.bisporus* on used melon crop compost. Since then tremendous advancement has taken place in the cultivation technology of this mushroom particularly in the composting field. Today in our country white button mushroom is cultivated on the compost prepared by traditional method (long method of composting) as well as advanced methods like short method of composting or rapid composting method (Indoor compost).

Raw Materials and Formulations

White button mushroom requires a well-composted substrate for its growth. It is a saprophytic fungus and requires carbon compounds, which generally come through the agricultural waste materials. Besides carbon, it requires nitrogen and other essential elements, such as phosphorous, sulfur, potassium and iron, vitamins such as thiamine, biotin, etc. All the raw materials that contain these compounds are mixed in a fixed proportion and fermented in a set pattern to form a substrate, which is known as compost.

Raw Material and Ingredients Required for Composting

1. Base materials

Base materials are the bulk component of the compost. Various crop residues can be used for this purpose though the wheat straw is favoured all over the world. However, quality compost can be prepared using variety of other materials including paddy straw, hay, barley, oat, maize stalks and leaves, sugarcane bagasse, sugarcane trashes and leaves, soybean stalks, mustard stalks, etc. These materials should preferably be freshly harvested/procured and should be around 5-8 cm long. These base materials act as a reservoir of cellulose, hemi-cellulose and lignin which is utilized by *A.bisporus* during its growth as a carbon source. They also provide a little quantity of nitrogen. Besides acting as a nutrient source, they also add bulk to the compost and proper physical structure to the substrate and ensure adequate aeration during composting for the build up of microflora essential for the composting process and also for the nutrition of mushroom. Rice and barley straw are very soft and degrade quickly during composting. These materials also absorb more water as compared to wheat straw. While using these materials care must be taken on quantity of water used for wetting, schedule of turnings and adjustment to the rate and type of supplements.

2. Supplements

Above base materials do not have adequate amount of nitrogen and other nutrients required to start the fermentation process. The compounding mixture is supplemented with other materials having nitrogen and carbohydrate sources to achieve the proper CN ratio. These materials can be classified as follows.

a. Animal manure

Horse manure undoubtedly is the best material for compost preparation. However, due to difficulties encountered in procuring good quality horse manure, use of this material has been restricted to few farms only. More and more farms are switching over to easily accessible materials. Chicken manure has proved to be the best alternative to horse manure. Other manures viz., pig, cattle and sheep have also been tried for compost preparation but with limited success. All these manures provide nitrogen to the compounding mixture, little of carbohydrate is also provided. These materials are highly variable in composition and their N-content may vary from 1-4 percent and it is released slowly during composting process. In addition to providing nutrients, they greatly increase bulk of compost, which is very important factor under Indian conditions considering the high cost of wheat straw vis-à-vis chicken manure. If horse manure is used in composting then it should be used along with bedding and urine, as it may not require any further supplementation. If it is not having enough bedding and urine when collected from a clean stable, supplementation with inorganic nitrogen along with some wheat straw may prove useful. Chicken manure if used, should preferable be a deep litter chicken manure having nitrogen contents above 3%. If such manure is not available then the manure from cages can also be tried. Chicken manure is generally used under short method of composting. However, some of the growers are using this under long method and are getting fairly good yields, while some have met with failures. Chicken manure harbours heavy population of pathogenic nematodes and harmful fungi including *Sepedonium maheshwarianum, Stachybotrys atra, Papulaspora* sp. and *Verticillium* sp. Growers should therefore avoid the use of this material under long method of composting.

b. Carbohydrate sources

These materials are essentially required to hasten the composting process, to balance the C/N ratio and also for the establishment of the bacterial flora in the compost. Molasses, wet brewer's grains, malt sprouts, potato wastes, apple and grape pumice can be employed as carbohydrate source, since these materials provide readily available nutrients to microorganisms.

3. Nitrogen fertilizers

In this category of fertilizers, urea, calcium ammonium nitrate, ammonium sulfate can be kept. Nitrogen content of these fertilizers is very high (24-46%) which is released quickly, resulting in quick establishment of microflora.

4. Concentrate meals

Animal feeds are generally kept in this category, which include wheat or rice bran, dried brewer's grain, meal/cakes of soybean, cotton seed, castor, sunflower, etc. These materials supply both nitrogen and carbohydrates, which as in case of animal manures are released slowly. Nitrogen content may vary from 3-8% depending upon the source.

5. Supplements to rectify mineral deficiencies

In addition to carbon and nitrogen, *A. bisporus* also requires little quantities of potash, phosphorous, calcium and magnesium for its growth. Fertilizers viz., muriate of potash and superphosphate can be kept in this category. Besides above gypsum and calcium carbonate can also be kept here. Gypsum also has stabilizing effect on ammonium content. An increased ammonium concentration is obtained with gypsum, which is an indicator of productive compost. Furthermore, gypsum serves as a calcium source for the mushroom. It converts the oxalic acid produced by the mushroom mycelium into calcium oxalate. Requirement of phosphorous, potassium, and magnesium is generally met by chicken manure or horse manure when compost is produced by short or by indoor method. However, long method compost where chicken manure is not added addition of these materials may be required.

Table1: Moisture and nitrogen content (dry wt. basis) of compost raw materials

	% Moisture	% N
Wheat straw	15	0.6
Horse manure – light	30	0.8
Horse manure - Heavy	50	1.0
Deep litter chicken manure	30	3.0
Wheat bran	10	2.0
Brewer's grain	40	2.0
Soybean meal	10	6.5
Cotton seed meal	10	7.0

For making compost for *A.bisporus* above materials should judiciously be selected keeping in view the nutritional requirement of *A.bisporus*, cost and availability of raw materials (Table 1).

Formulations

A large number of formulations are available with the growers and these are based on cost and availability of raw materials in the particular region. To initiate a composting process and to minimize the loss of dry matter during composting 1.5-1.75 percent nitrogen is generally kept in the compounding mixture. The main objective of computing a formulation is to achieve a balance between carbon and nitrogen compounds. At stacking C:N ratio is adjusted to 25-30:1, which comes down to 16:1 after composting. N level in the compounding mixture at start should not be less than 1.5% as this will give improper compost with high CN ratio and such compost will be easily attacked by cellulose loving fungi. Further it should also not be higher than 1.75% as such compost will be easily attacked by yellow moulds and more time will be required to finish the composting process. Known and estimated values of nitrogen and water contents of different materials viz. straw, chicken manure, wheat bran and other chemical fertilizers can be used as guidelines in computing formulations having desired balance of nitrogen and C N ratio. These materials can be regularly tested for balancing the nitrogen in compounding mixture for productive compost preparation. Formulations for white button mushroom compost normally should have N-1.5-1.8%, P_2O_5-1.2-1.5%, K_2O-2.0-2.3%, CaO-1.5-3% and MgO-0.4-0.5% on dry weight basis.

Formulations having horse manure as one of the ingredients is termed as natural compost, while others are termed as synthetic composts. In addition to C and N, various other materials play an important role. Only in recent times importance of these minerals in mushroom cultivation has been realized. Chicken droppings have maximum amount of all the above elements and it should become an integral part of mushroom compost. An example as to how to arrive at standard formulation having desired N value is given in Table 2.

Table 2: Nitrogen computation guidelines

Ingredients	Fresh wt (kg)	Moisture (%)	Dry wt (kg)	% N	N (kg)
Wheat straw	300.0	10	270.0	0.4	1.08
Wheat bran	15.0	10	13.5	2.0	0.27
Chicken manure	125.0	10	112.5	2.6	2.93
Urea	5.5	-	5.5	46.0	2.53
Gypsum	20.0	-	20.0	-	-
Total weight	465.5		421.5		6.81

N % = (6.81/421.5) x 100=1.62

Different formulations

1. Natural compost

a. Horse manure 1000 kg
Wheat straw 350 kg
Urea 3 kg
Gypsum 30-40 kg

b. Horse manure 1000 kg
Wheat straw 350 kg
Chicken manure 300 kg
Brewer's grain 60 kg
Gypsum 30 kg

However, horse manure is not easily available and formulations using various types of straws and organic/inorganic supplements have been recommended by various workers. Some of the commonly recommended formulations are:

2. Synthetic compost formulation for long method

FORMULA – A		FORMULA- B		FORMULA- C	
Wheat or paddystraw	300 kg	**Wheat and paddy (1:1)**	300 kg	**Wheat straw**	300kg
CAN	9 kg	**CAN**	9kg	**Wheat bran**	21kg
Urea	3 kg	**Urea**	5 kg	**Cotton seed cake**	12 kg
Superphosphate	3 kg	**Wheat bran**	25kg	**Urea**	7 kg
Muriate of potash	3 kg	**Gypsum**	20kg	**Gypsum**	15kg
Wheatbran	15 kg				
Gypsum	30kg				

3. Synthetic compost for formulation short method

FORMULA – A		FORMULA- B		FORMULA- C	
Wheat straw	300 kg	Wheatstraw	300 kg	Wheat straw	1000kg
Chicken manure	60 kg	Chicken manure	210kg	Chicken manure	400kg
CAN	6 kg	Cotton seed cake	21 kg	Wheat bran	72 kg
Superphosphate	3 kg	Gypsum	15kg	Urea	14.5 kg
Wheatbran	15 kg			Gypsum	30kg
Gypsum	15 kg				

Wheat straw can be replaced with paddy straw. However the quantity of paddy straw may be 15-20 % more and special care may be taken to keep the moisture content of the compounding mixture on lower side. Wheat straw can also be replaced with sugarcane bagasse, mustard straw or all these base materials can be combined depending upon the availability. Sugarcane bagasse takes slightly longer time for degradation whereas paddy straw may require lesser composting time. Similarly brewer's grain can be replaced with 1.25 times wheat or rice bran.

Recently commercial units are using chicken manure up to 80% per ton of straw depending upon its N-content. The nitrogen content in the formulations is balanced by adding urea , CAN or ammonium sulphate. Gypsum is added at the rate of 3-5 % or even more. Some of the units mix gypsum and chicken manure to reduce the greasiness. However most of the units are adding gypsum at third turning. Under indoor composting all the ingredients including gypsum are mixed at the time of preweting only.

Long method of composting (LMC)

Preparation of compost by such method is very old concept and has been abandoned in most parts of the world excepting in few countries in Asia. Compost prepared by such method besides taking more time (around one month) gives low yield, as it is prone to attack by many pests and diseases. Yields obtained using such compost range between 10-15kg of mushrooms per 100 kg of compost. However, higher yields to the tune of 18-22 kg have also been reported by some seasonal growers who take single crop in the entire season and thereby extending the harvest period for three to four months depending upon the climatic conditions.

Compost by this method is prepared on clean cemented platform (Fig.1). If such facility is not available then a simple brick platform can be used. Most of the growers who are cultivating this mushroom seasonally do not have any of the above two facilities and are producing the compost in open fields. Composting yard should preferably by covered by G.I. or asbestos roofing. If such facilities do not exist then provision should be there to cover the heap during rains. For a medium size farm producing around 20 tons of compost in one operation, a platform of size 60'x40' (18 m x 12 m) is sufficient enough. As a thumb rule 1.5 tons of compost at start of composting occupies around one square meter of space. Besides composting yard, provision should also be there to store the base materials. In general around 4000 litres of water is required per ton of raw material for its proper wetting. The ingredients of compost are straw, wheat bran, urea etc. Any of the region specific synthetic formulation without chicken manure can be tried for compost production. Details of the formulation are given in the chapter entitled, "Raw material and formulations for white button mushroom cultivation". It is further mentioned that compost production should not be attempted with less than 300 kg of base materials, as required temperature may not be attained in piles made with lesser quantities.

Table 1: Processes of composting and their attributes

Attributes	Long method	Short method	Indoor method
Days required for compost preparation	28-30	16-20	10-12
Selectivity	Partial	Complete	Complete
Average yield (kg/100 kg compost)	10-15	18-22	20-25
Environment pollution	Moderate	Low	Negligible
Average compost production / ton of straw	1.75-2.0 tons	2.0-2.5 tons	3.0-3.5 tons
Average final N % in compost	1.75-2.0	2.0-2.2	2.2-2.5
Infrastructure required/ 20 tons out put compost	Out door composting yard (60 x 40 ft.)	Covered composting yard (60 x 40 ft) + 1 tunnel (36 x 9 x 12 ft)	Prewetting area (60 x 40 ft) + 2 Phase-I bunkers (45 x 10 x 10 ft) + one Phase - II tunnel (36 x 9 x 12 ft)
Man days required/ 20 tons compost out put	30-35	20-25	15-20
Power requirement/ 20 tons out put compost	Nil	Around 700-900 KW	800-1000 KW
Compost handling equipments required (Large farm) (> 500TPA)	Nil	Turner, filling line, hopper regulator, front end loader	Filling line, hopper regulator, front end loader

Requirement of base materials should also be judiciously worked out. In general one ton of raw material would yield around 1.75 to 2 tons of finally prepared compost having the required moisture level. When the compost is prepared with manual labours, use of a set of 3 wooden or iron boards (2 sides boards-180 x 150 cm; 1 end board-140 cm x 180 cm) is still in use.

1. Method

First important step in the production of compost is to thoroughly clean the area, spray 2% formaldehyde solution so that unwanted organisms are killed. On the following day, wheat straw or any other recommended base material is spread on the platform. Wheat straw is very hardy material and does not absorb water quickly, since it is coated with wax. This wax layer however, gets removed by the heat produced during composting or due to the physical actions like shredding, trampling, etc. and then, water is able to reach the inner portion of the straw easily. Water is sprinkled over the straw with a pipeline and straw is frequently turned till it absorbs sufficient moisture. Excess water escaping during wetting is collected in a goody pit and is recycled and used again for wetting the straw. Wetting of the straw may continue upto 24-48 hours till it attains 75% moisture. There should not be excessive wetting of the straw, as excess water fills the pores during composting resulting in anaerobic conditions in the pile, which is not a desirable trait of composting. On the contrary if the moisture is too less in the compost pile plenty of oxygen is available to the microorganisms but desired high temperature is not attained in the pile, which is again not a desirable trait for their growth. When the straw is fully wetted it is collected as a low heap on one side of the yard. Other composting ingredients viz., chicken manure, wheat bran and other fertilizers excepting gypsum and insecticides are mixed sprinkled with water and covered with a polythene sheet or wet gunny bags. Both wetted straw and these ingredients are kept as such for 24 hours. The day when wetting of these materials is completed is counted as (-) 1 day and the day when the two are mixed is treated as 0 day.

Fig.1: Composting yard

a. Day-0

On this day two lots of the ingredients (straw + other additives) are properly mixed. The main aim of mixing the ingredients is to obtain a homogeneous product. The mixed ingredients are then made into a high aerobic pile with the help of boards (mould) described earlier. While making the pile, materials are slightly pressed on the sides and kept loose in the centre. When the mould is completely filled, the sideboards are moved, lengthwise and again the space is filled with the ingredients. This process is repeated till a compost pile is formed with all the materials. Else the compost piles can also be made without these boards. Dimensions of the pile are important and depend upon the prevailing outside temperature. In the hills, where temperature may range between 7-20°C width of the stack should be kept between 130-150 cm and height of about 150cm, otherwise due to greater difference in temperature of compost and atmosphere proper temperature may not be attained inside the heap which may result in unproductive compost. In plains where the temperature is higher, slightly smaller heaps (100-120 cm width and around same height) are recommended since there is not much difference in temperature outside and inside the compost (Fig.2).

Fig.2: Turning the pile

b. Day 1-5

Pile is kept as such for 5 days. Temperature of heap starts rising and may go upto 70C in 24-48 hours. Maintaining a proper temperature inside the stack is an important parameter of compost preparation. High temperature besides favouring the growth of thermophilic micro-organisms, also removes wax from the straw which makes it more prone to the attack of micro-organisms. Higher temperature attainment is directly related with the activity of micro-organisms and is the result of their biological activities. However, role of higher temperature obtained during composting for the productive compost is still a matter of debate. Temperature above 80C is also not desirable in the central core of the pile as it may result in anaerobic conditions and loss of friendly thermophilic flora.

c. Day-6 (Ist turning)

To give compounding mixture an equal opportunity towards fermentation, compost pile is turned at different intervals. In LMC, 7-8, turnings are given to the compost pile. The correct method of turning is as follows. Remove about one feet of the compost from top and sides of the pile, shake it vigorously so that excess of free ammonia is released in the atmosphere and the mass is properly exposed to air, keep this portion on one side(lot A). Now central and bottom portion of the pile are removed, shaken properly and kept separately (lot B). A new pile is then made out of these portions keeping lot A in centreand lot B on the top and sides. During reconstruction of the pile water is added whenever required. In practice however, compost pile is turned inside out.

During the 1st turning itself the compounding mixture turns from golden yellow to dark yellow/light brown in colour and there is a slight shrinkage in its volume. Further production of ammonia and foul smell due to anaerobic fermentation within the central core of the pile could be noticed. Ammonia is produced under aerobic conditions by the breakdown of carbohydrates and proteins while other obnoxious gases due to anaerobiois. Besides ammonia large quantities of CO2 is also produced. After the 1st turning, temperature again starts rising and anaerobic conditions may still prevail, due to limited availability of oxygen in the central core of the pile. Oxygen penetration inside the compost mass depends upon several factors. It is less with more width of the pile, higher bulk density with higher outside temperature, low porosity and high moisture content than the recommended parameters. However, at any stage under LMC, 30-35% volume of the heap after eight hours of turning may be under semi-anaerobic or anaerobic conditions. Since this zone of the pile gets less than 5% oxygen, it becomes imperative to turn the compost again for maintaining proper aerobic conditions (Fig. 3).

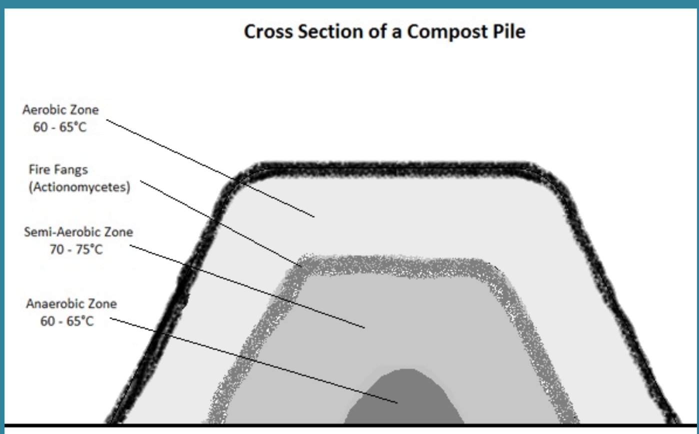

Fig.3: Different zones of the pile and turning

d. Day 10 (2nd turning)

Break open the pile and turn as described earlier. Pile will show further shrinkage and will exhibit higher temperature while colour of the ingredients will further darken. Ammonia production will be higher. Further, white flacks/powdery mass, which is known as fire fangs (Actinomycetes), will also be visible in the compost (indicator of a good compost).

e. Day 13 (3rd turning)

Again the pile is turned and the required quantity of gypsum is added. Role of gypsum in mushroom nutrition has already been narrated in previous chapter.

f. Day 16 (4th turning), Day 19 (5th turning), Day 22 (6th turning), Day 25 (7th turning).

The required quantity of insecticide is added during last turning. One may spray Melathion or Decis @ 0.01% for killing insects and pests.

g. Day 28 (filling day)

Break open the pile, check for the smell of ammonia. If no ammonia smell is there in the compost and instead a sweet smell is felt, the compost is ready for spawning. If ammonia smell persists then additional turnings are required to be given after 2-3 days. Normally ammonia concentration at spawning should not be more than 8-10 ppm. Correct amount of ammonia present in the compost can be measured with the help of dragger tubes available in the market. Simply smelling compost is fairly OK, as generally we cannot smell ammonia concentration below 10 ppm

2. Improvements in long method of composting

a. Chemical pasteurization

Compost prepared by LMC harbours a large number of organisms at spawning, many of which are strong competitors of *A.bisporus*. Such compost is invariably attacked by yellow moulds (*Myceliophthora lutea* and *Sepedonium chrysospermum*), green mould (*Trichoderma viride*) and brown plaster mould (*Papulospora bysinna*). Out of these, yellow moulds are the most dreaded competitors of white button mushroom mycelium and in severe cases complete crop failure has been reported. Best way to eliminate these organisms is to use compost prepared by short method (pasteurized compost). However, procurement/production of such compost is beyond the reach of many growers in India especially for those who are seasonal growers. To control yellow moulds and other diseases mentioned above, this Directorate came out with a novel chemical pasteurization technique of long method compost. The developed technique is as follows:

Prepare the long method compost as per schedule and on last day (turning) (27th day), break open the pile on a clean area. Now take 1.5 litres of formalin (formaldehyde 40%) and 50 g. of Bavistin (50% Carbendazim), dissolve these chemicals in 40 litres of water for one ton compost. Spray this solution thoroughly in the entire compost mass so that each and every portion of the compost gets the dose of this solution. Now make a heap out of this compost and cover it by a polythene sheet for two days. Remove the cover after 2 days and vigorously shake the compost and spawn. It may be noted that above chemical solution is for one tone of finally prepared compost only and growers should prepare the chemical solution as per the quantity of compost available with them. Quantity of water can be adjusted as per the moisture % of the compost but it should be sufficient enough to treat the entire compost. Growers are advised to procure standard make of chemicals only otherwise they may not get desired results. This technique works very well against the yellow moulds and also controls other competitors as well thereby increasing the yield (Table 2). Such chemical treatment of the compost is safe as there is no translocation of Carbendazim or formalin in the fruit bodies when used for the treatment of compost at spawning. Flow chart of long method composting is shown in the fig.4.

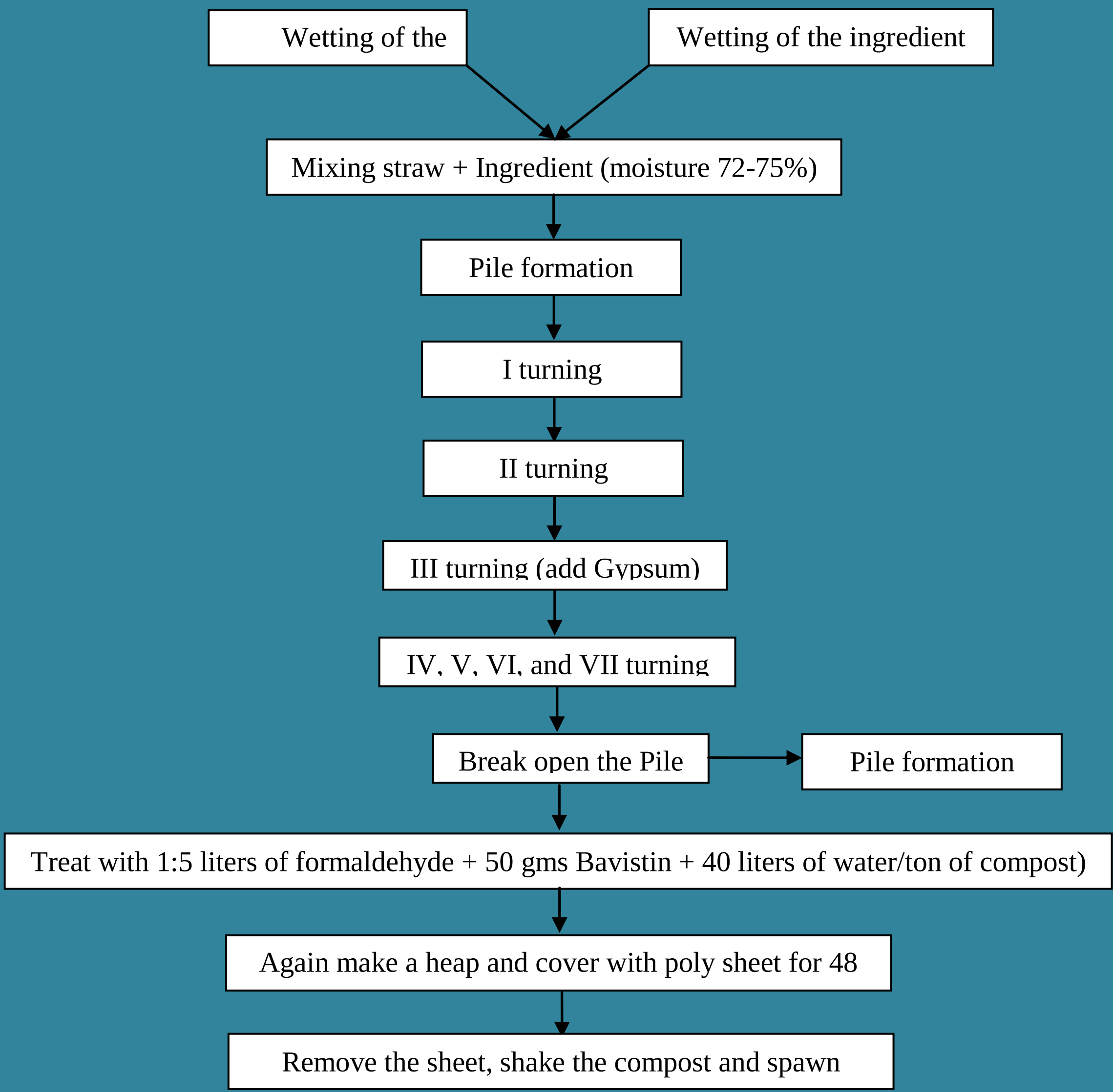

Fig.4: Flow chart LMC

3. Attributes of a good compost

A good compost should be dark brown in colour, should not be greasy or sticky; should have distinct sweet inoffensive smell, free from ammonia smell, should have 68-72% moisture and 7.2- 7.8 pH. There should not be visible growth of other undesirable organisms except for the fire fangs (Actinomycetes) and it should be free from insects and nematodes.

As indicated earlier composting is essentially a fermentation process brought about by the activity of various organisms. Their activity and growth determines the quality of the compost produced since these organisms convert ammonical nitrogen to microbial proteins, which are ultimately utilized by *A.bisporus* mycelium for its nutrition. Beside above, quality and composition of base materials, aeration and moisture also determine the quality of compost. Various factors, which govern the quality of compost, are as follows:

a. Nitrogen content

Nitrogen content of the composting pile in the mixture is very important. It should be 1.5 - 1.75% in the beginning (on dry matter basis). If the N content is kept below 1.5%, compost is not properly fermented and the temperature of the heap may not go beyond 55-60C due to lesser microbial activity. The compost so produced will be yellowish in colour and light in texture and will not be selective to mushroom mycelium. Moulds like *Stachybotrys atra, S.alternans, Stilbum nanum* and *Doratomyces stemonites* may inhabit such compost resulting in poor yields.

On the other hand if N content is kept above 1.75% level, C: N ratio will not be optimum and more of nitrogen will disappear from the pile in the form of ammonia resulting in the wastage of the nutrients. Such compost is invariably infested by *Sepedonium* spp. (yellow moulds), which may drastically reduce the yield. *Coprinus* spp. (Ink caps) and *Chaetomium olivaceum* (olive green mould) are also indicators of high nitrogen in the compost pile. N content of compost at the end of 28 days in long method compost is in the range of 1.75 to 2.0 %.

b. Carbohydrates content

During initial stage of composting free carbohydrates and nitrogen are utilized by the mesophilic flora and heat is generated in the process. Later on thermophilic flora takes over the mesophilic population. When the compost is cooled down, thermophilic flora can no longer grow due to low temperature while mesophilic flora also cannot grow since these organisms have already utilized most of the free carbohydrates. Normally there should not be any free or soluble carbohydrates present in the compost. Their presence is the indication of under composting and such composts are easily attacked by green mould (*Trichoderma viride*) or blackwishker mould (*D.stemonits*).

c. pH

This is an important parameter of *A.bisporus* compost. *A.bisporus* mycelium grows best at 7.2 - 7.8 otherwise growth of *A.bisporus* will be slow and white plaster mould (*Scopulariopsis fimicola, S.brevicaulis*) may invade such compost.

d. Moisture content

Optimum moisture content for the natural compost (i.e. compost made using horse manure) is about 65-67% while for synthetic compost it is 68-72%. If it is more than 72% at spawning there may not be proper aeration, as free space will be occupied by water. Under such circumstances anaerobic condition may prevail resulting in killing of *A.bisporus* mycelium. Further, moulds like brown plaster (*P. byssina*), white plaster (*S. fimicola*) may appear in the compost.

e. Quality of raw materials

If raw materials especially wheat or paddy straw used in compost making are of poor quality (old and exposed to rains) it may result in improper compost. On such compost *Sepedonium* spp., *Alternaria Alternata* and *Coprinus* spp. may appear resulting in low yield of mushrooms.

4. Shortcomings of LMC

Compost production by LMC is a very old concept and has been done away by advanced countries many years back. It is presently in vogue only India, China and Indonesia. LMC has the under mentioned shortcomings.

- Since compost is prepared over a period of 28-30 days dry matter loss of ingredients is more. We normally get 1.75 to 2.0 tons of final compost from one ton of dry straw.
- Compost is produced under out door conditions and hence invaded by many pests/competitors/diseases and hence not perfectly selective.
- Frequent sprays of insecticides and fungicides are required.
- Most of the ammonia is lost in the atmosphere resulting in low final N content of compost.
- Low yields
- Not environment friendly

Short method of composting (SMC)

Long method of composting has many shortcomings mentioned as above. Growers in the United States around 1915 found that if compost prepared for *A.bisprous* is kept in shelves in growing rooms and subjected to high temperature (around 60°C) for sometimes gives higher and consistent yield. This process was later termed as "sweating out" of compost and it laid down the foundation of pasteurization of compost. Based on the above principles/findings, American Scientist Sinden and Hauser in the year 1950, 1953 proposed a new method of composting, where pasteurization became its integral part, which was termed as the short method of composting (SMC)

This method of composting is being followed by most of the growers who are cultivating mushrooms round the year and has since revolutionized the mushroom industry. Short method of composting primarily consists of two phases:

- Phase-I: Outdoor composting for 10-12 days.
- Pasteurization and conditioning of the compost inside an insulated room by free circulation of air under definite set of conditions (Phase-II). The 2nd phase lasts for around seven days.

1. Purpose of pasteurization and conditioning

a. It reduces the time of composting.
b. It converts ammonia into microbial protein most of which otherwise goes waste in the atmosphere in LMC
c. It conditions or sweetens the compost under definite set of temperature and aeration, uniformly making compost more selective for the growth of *A.bisporus*.
d. It kills or inactivates insects/pests/diseases and competitors of *A.bisporus* which, if present hamper the growth of *A.bisporus* thereby reducing the yield.

e. Conditioning increases the biomass of thermophilic organisms specially that *Scytalidium thermophilum*, which later on is utilized by the mushroom mycelium as food
f. Through conditioning more compost per unit weight of ingredients is produced
g. Conditioning and pasteurization increases the yield of mushrooms.

During Phase-II steam pasteurization is done in a well insulated room constructed for the purpose. Boiler is required for the production of steam for proper maintenance of temperature inside the compost mass. Blower is required for the supply of fresh air and recirculation of ammonia and other gases for their conversion into microbial proteins. Details of pasteurization chamber are given elsewhere in the book.

2. Machinery required

Small farms would not require much mechanization owing to availability of cheap labour in the country. Also they have to handle little quantity of compost at a time which otherwise can easily be handled manually. However, for a large export oriented unit (around 2000-3000 TPA), which handles the compost in bulk (around 30-40 tons of straw/day), mechanization of the operations viz., prewetting, turning, filling, emptying, spawning and bagging becomes necessary to hasten the process and to get a quality compost. Such farms also employ computers, which monitor and control the process of pasteurization and conditioning inside the tunnels. Following machines will be required for an export oriented unit.

a. Prewetting machine or pre-wet heap turner

This machine is used to blend loose or baled material with other compost ingredients such as chicken manure and horse manure as well as wetting of the mixed ingredients. The primary function of this machine is to turn and restack prewetted materials formed into long and wide heaps by tractor and front loaders .

Fig.5: Prewetting machine

b. Compost turner

The compost turner comes in varying capacities from 30-70 tons of compost handling per hour. It is fitted with a round stainless steel pick up drum, one spinner and one forming bore. The turner is generally mounted on 4 wheels, two of which are castoring wheels and rest two are powered, large diameter pneumatic wheels. Turner is usually fitted with a full width water spray pipe mounted at the front of the machine with water outlets over the full input width.

Fig.6: Compost turner

c. Pile forming case

This machine is used when the pile is formed for the first time. This is usually supported on four castoring wheels and is attached to the front of the compost turner which is pushed by the turner during pile formation.

d. Front end loaders

Bucket type loaders are employed for various composting operations viz, prewetting, and transportation of the compost during pile formation in combination of compost turner and forming case. They are generally attached with a tractor. Else, Bob Cat can be employed for the purpose (Fig.7).

Fig.7: Front end loader

e. Oscillating head filling machine

This is made up of two conveyer units mounted upon a self propelled chasis. The two conveyers are so designed that one feeds directly into the other from above. Conveyer which is positioned above accepts the compost from the feed conveyers and transfer this compost to the conveyer positioned below. This is an oscillating type which fills the compost loosely in the tunnel over the entire width. The head filling machine comes in varying sizes suiting to the size of the tunnel.

f. Compost feed conveyers (2-3 units)

These are ordinary conveyer systems slightly elevated and can be coupled together to form a single conveyer system feeding one to the other during tunnel filling. The length and width of each conveyer is generally 7.5- 9 m and 0.6 m.(Fig.8)

Fig.8: Conveyor

Fig.9: Hopper regulator

g. Hopper regulator

This machine is required to feed the compost to the feed conveyers. It accepts the compost from the bucket of the front end loader and provides regulated output of the compost to the feed conveyer (Fig.9)

h. Tunnel emptying winch with combination of spawn dosing machine

This unit is employed for emptying the tunnel filled with pasteurized or spawn run compost by means of a polyethylene glide and pulling nets. The winch is equipped with one net reel for the pulling the nets, two spinners and a chain conveyer for the discharge of the compost.

Spawn discharging unit consists of twin spawn dispensers mounted over the full width of the compost flow on the discharge elevator.

i. Bag filling machine

This machine is used for filling the bags with spawned compost. The machine is equipped with a conveyer with two filling stations (Fig.10)

Fig.10. Bag filling machine

One or more of the above machines may be needed depending upon scale of operations, labour availability, type of raw materials used, etc.

Besides the above machineries, small instruments like multiprobes digital thermometers, oxygen meters, ammonia measuring equipments and computers are also required for a mushroom farm to maintain quality and high productivity of mushrooms.

One or more of the above machines may be needed depending upon scale of operation, labour availability, type of raw materials used, etc.. Front-end loaders, hopper, conveyers and oscillating head filling machines are useful for any commercial unit.

Besides the above machines, small instruments like multi probe digital thermometers, oxygen meters, ammonia measuring equipments and computers are also required for a mushroom farm to maintain quality and high productivity of mushrooms.

3. Methodology

Compost by short method can be prepared by any formulation given in the text earlier. However, a formulation based on wheat straw and chicken manure is widely used in the country. (Wheat straw 1000 kg, chicken manure 500 kg, urea 15 kg, wheat bran75 kg, gypsum 30 kg)

a. Phase I or outdoor composting

Like LMC, this phase of SMC also starts with the wetting of the ingredients. Wheat straw and chicken manure are wetted thoroughly till they absorb sufficient water (around 75%). Leached water is collected in a goody pit constructed for the purpose is regularly sprayed over the raw materials. After thorough wetting of the substrates an aerobic stack or a simple heap is made out of such materials. After 2 days the stack is broken, water is added to the dry portions and again a stack is made. Growers may provide artificial aeration to this heap and to the stack to be made later on for better results. They may pass up to 10 to 15 m^3 of air/ton of wet compost/hour through the stack. This will result in achieving high temperature and more homogenous compost. To have artificial ventilation in the stack, working floor of the composting yard is provided with under stack aeration ducts connected with the required capacity small blowers installed at one end of the yard. These blowers blow small quantities of air regularly or at fixed intervals through G.I. pipes, which have small holes running length wise of the yard. Stack is made on these pipes (Fig.11). The prewetting and mixing of ingredients is a must before starting actual composting procedure on 0 day and the stack made during this process are wide with low height of 3'-4'.

Fig.11. Under stack aeration ducts

0 Day

On this day the stack is again broken and the entire quantities of other raw materials like urea and wheat bran are added, water is also added if required and a high aerobic stack is made. Dimensions of the stack will be the same as mentioned for LMC. Turnings can be done manually or by compost turners built for the purpose. Similarly the compost is again turned after every 2 days and gypsum is added at third turning. In all three to four turnings are given. On 8^{th} – 10^{th} day the compost is ready for pasteurization to be affected in bulk chamber. This makes the end of Phase -I.

Characteristics of the compost after phase-I and before Phase-II

- Brownish throughout. Pieces of straw gleaming and wet.
- Straw rather long but can be broken with some force.
- Properly hydrated, around 72-75% moisture; when squeezed drops of water appear between the fingers.
- Very heavy smell of ammonia. pH approximately around 8.2 - 8.5.
- Still sticky and slimy, hands get dirty and wet.
- Actinomycetes (fire fangs) not so apparent.

- Nitrogen content between 1.5 - 2.0%; ammonia concentration around 800-1000 ppm.

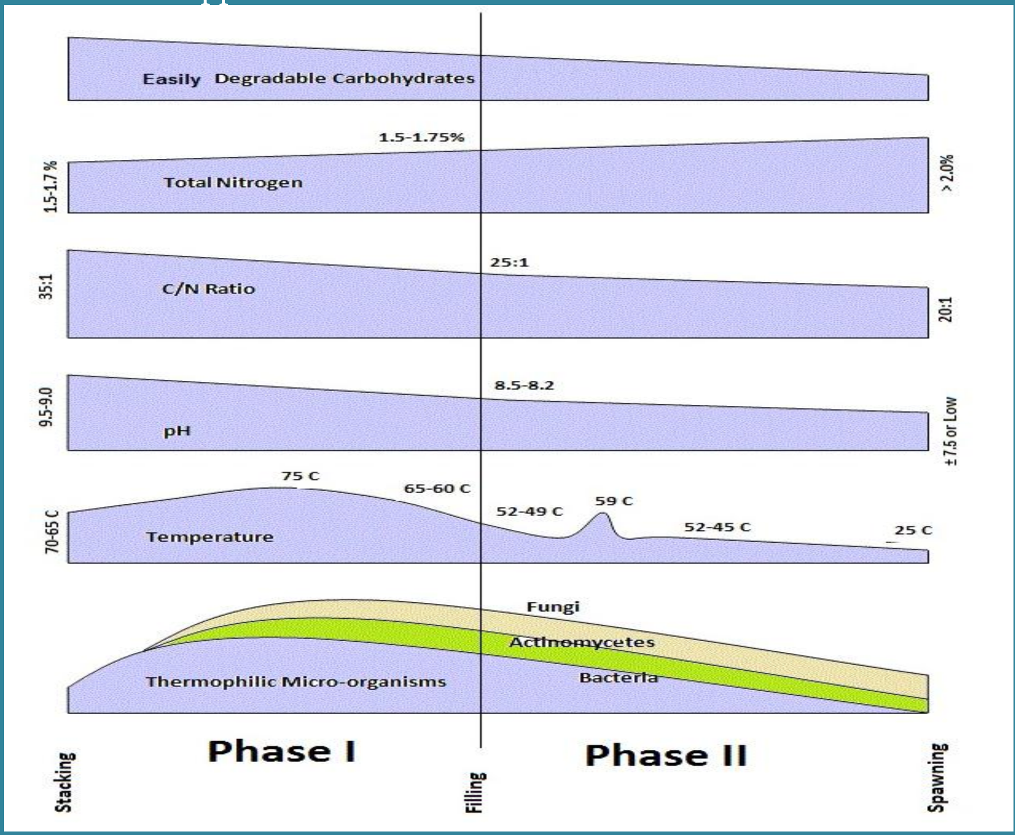

Fig.12: Showing changes during composting (Phase-I &Phase-II)

b. Phase-II:

This phase of composting is generally performed in pasteurization tunnel in bulk. Phase-II process can be divided into two stages namely pasteurization and conditioning.

i. Conditioning

It can be divided into pre-pasteurization conditioning (PPC) and post pasteurization conditioning (POPC). During this phase of composting, whole of the compost mass is brought to a temperature range optimum for the growth of thermophilic flora (45-52°C). During this phase major part of NH_3 gets fixed in lignin-humus complex and excess of ammonia is released into the atmosphere. POPC again regenerates the lost thermophilic organisms during pasteurization. It has also been found that maximum ammonia generation takes place at 45-50°C, which corresponds well with optimum temperature range of majority of thermophilic flora. Compost should not be conditioned below 40°C, as some mesophilic fungi may set in at this temperature rendering compost unsuitable for mushroom growth specially *A.bitorquis*. Besides keeping compost at a particular range of temperatures (45-52°C), during this phase enough of oxygen is supplied (O_2 concentration above 10%) to the compost mass to maintain fully aerobic conditions. Both pasteurization and conditioning make the compost most selective for the growth of white button mushroom at the expense of other harmful competing organisms.

ii. Pasteurization

Main purpose of pasteurization is to kill or inactivate harmful organisms. They are eliminated when the compost is subjected to a temperature above 55°C for certain period when humidity in the compost and surroundings is high. Therefore use of live steam to heat up the room and compost sometimes become essential. It has been found that compost is pasteurized properly if it is kept at 57°C for 6-8 hours. Temperature above 60C is harmful as this temperature may kill all kinds of organisms including thermophilic fungi very essential for governing the phase-II of composting. Activity status of the compost is also very important to achieve pasteurization temperature. If it is an active compost, its temperature starts rising immediately after filling and may rise by 1°C per hour and the required temperature of pasteurization can be achieved in few hours only by self-generation of heat. Pasteurization of the compost can either be done soon after room/tunnel filling or after few days.

iii. Phase-II in tunnel (Bulk pasteurization)

In this process the compost is treated in bulk inside a specially built chamber known as the tunnel (Fig.14&Fig.15). The compost is filled in the bulk chamber upto the height of 2- 2.2 meters in such a way that one square meter of space occupies approximately 900-1000 kg of compost. Several temperature sensors are placed at different points of the tunnel to measure the temperature. One sensor is placed below the plenum in the ventilation duct below the grated floor, two or three are placed inside the compost mass and two above the compost for air temperature. Immediately after filling, all the doors are closed and the blower is switched on to bring the compost, plenum (air below and compost) air above the compost at a uniform temperature (around 45-48°C). There will be a little difference in temperature at all the three places and this difference may be 1-3°C. Levelling may take 4-5 hours and at this stage no fresh air is introduced in the tunnel and air introduced through the leakage of the dampers and ducting would suffice the purpose. After leveling that is to say after 4-5 hours (more in case of bigger tunnels >15 tons) of filling the tunnel, we will start PPC.

We have to increase the population of thermophilic fungi at this stage, which will demand more oxygen for their growth and multiplication and this may reach above 15% of the total gaseous volume inside the tunnel. Fresh air is therefore introduced in the tunnel through the dampers (10% opening). Now the compost is kept between 45-52°C for two days. Two days after conditioning the compost is now ready for pasteurization. Now opening of the damper is narrowed down which will gradually increase the temperature of the compost by approximately 1°C/hr. Required temperature (58-59°C) of compost needed for pasteurization may reach in 10-12 h by self-generation of heat (Fig.13) In no case difference in the temperature above the compost (air temperature) and inside the compost should be less than 1°C, if it is more than that (> 1°C, maximum) than it is all the more better. Some quantity of steam can also be used for the purpose if temperature is not rising. This process is called pasteurization or kill. Duration of the pasteurization is normally 4-6 hours. It will eliminate harmful insects, nematodes and competitor moulds from the compost and at the same time will preserve the nutrients in the compost, which can effectively be utilized by *A.bisporus* mycelium. Temperature variation with respect to time in Phase-II operation is given in the Fig.12.

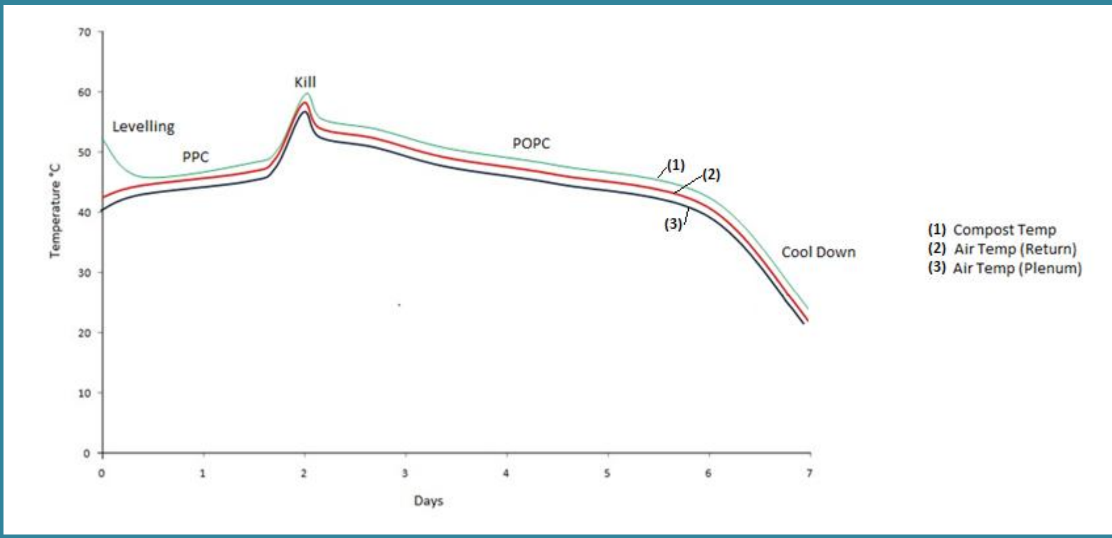

Fig.13: Temperature variation with respect to time in Phase-II

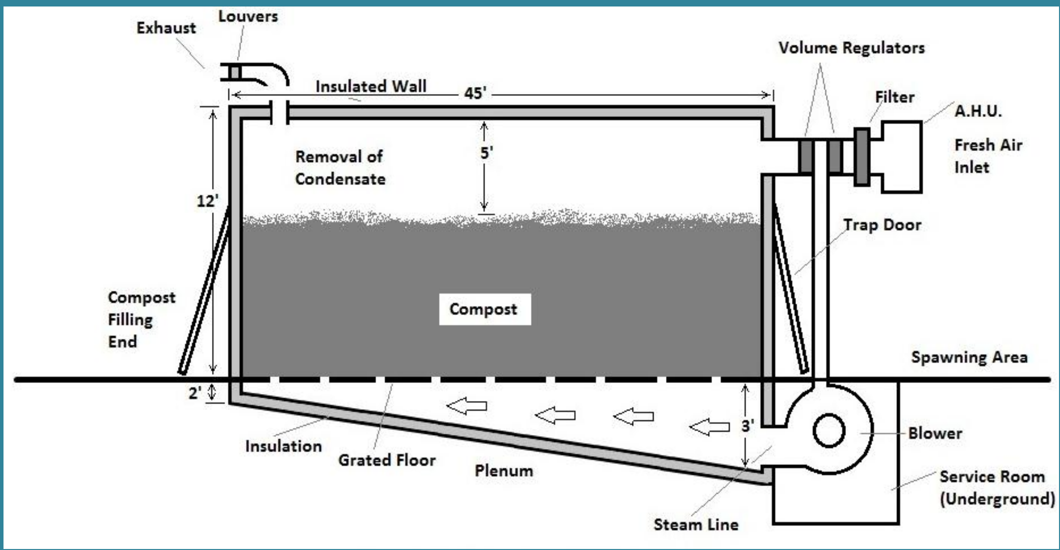

Fig.14: Schematic diagram of phase-II bulk Chamber (45' x 9' x13')

After kill fresh air is again introduced in the tunnel and temperature of the compost is brought down @ 1.5°C/hour and finally maintained between 48-45°C till there is no detectable smell of ammonia (less than 10 ppm) in the compost. This phase is known as post pasteurization conditioning (POPC) of the compost, which is normally accomplished in 3-4 days. Temperature of the compost is gradually brought down to 25-30°C after conditioning by introduction of fresh air in the tunnel and when this temperature reaches, the compost is ready for spawning.

Above method of pasteurization is recommended for the commercial tunnels having more than 15 tons output of the compost. Smaller tunnels while adopting above procedure may require frequent injection of steam during PPC and especially when pasteurization is affected. This increases the cost of production of compost. Such tunnels may resort to traditional pasteurization wherein levelling is done at higher temperature (around 50°C) and after that opening of the damper is so adjusted that compost temperature starts rising and it attains pasteurization temperature mentioned as above. Usual conditioning is done afterwards for 4-5 days or till the period when compost is free from ammonia and spawning done as usual. At the end of conditioning (at spawning) compost should be dark brown in colour with a full coating of white powdery mass due to abundant growth of actinomycetes.

This is a sign that Phase-II was performed in a perfect manner with abundant supply of fresh air.

Fig.15 Bulk chamber

Line flow chart and composting (SMC) at glace is given in the Fig.16 and Fig.17 respectively

Fig.16. Flow chart SMC

Fig.17: Pictorial flow chart SMC

Phase-II process is almost biological oxidation (90%) and hence here O_2 and temperature play very important role. It is advisable to connect temperature probes with a computer or data logger for round the clock changes/monitoring of the temperature. Further, gadgets are available in the market to monitor ammonia concentration and oxygen level inside the tunnels. These can also be installed in the tunnel to monitor above gases round the clock. The fresh air inlets are fitted with 2 micron washable HDPE filters.

As the composting proceeds there is loss in biomass. In phase –I there is about 30% loss in weight and in phase –II, 20-25 % loss in weight takes place. As a result from the standard formula of one ton wheat straw and 0.5 ton chicken manure, we can get about 2.5 tons of final compost.

Characteristics of the compost after Phase-II

- Dark brown in colour, full of thermophilic fungi and actinomycetes.
- It is soft, straw breaks rather easily.
- Moisture around 64-66%. No liquid oozes when squeezed firmly
- Pleasant sweet smell
- No stickiness. Hands stay clean and dry
- N content > 2%
- Ammonia below 10 ppm

Advantages of bulk pasteurization

- More compost per unit size of the room can be treated at a time.
- The cost of pasteurization in tunnel is less.
- Same tunnel can be utilized for spawn run in bulk, which gives effective use of the space.
- Yield per unit weight of compost is generally higher.

A. Indoor Composting

Compost prepared either by LMC or SMC involves traditional outdoor composting, which causes environmental pollution. Large amount of malodourous gases viz., ammonia, methane, hydrogen sulfide and other methylated sulphur compounds are emitted in the atmosphere creating nuisance. This foul smell is more when the compost is fermented at high temperature under anaerobic conditions. Laws governing pollution are becoming stringent day by day in India and many mushroom units producing compost by LMC or by SMC are threatened to close down their operation or to shift their operations away from the municipal limits. Need is therefore felt to control the composting process in such a manner so that there is a least possibility of environmental pollution and at the same time to produce high yielding compost in shortest possible time. Work on such composting procedure started in France way back in the year 1967 but only very recently put to use by commercial units abroad. In this case whole composting process is carried out indoors in specially built tunnels and hence the name indoor composting. Since such compost is produced under total environmental controlled conditions. Sometimes it is also called environmentally controlled composting (ECC) or rapid indoor composting (REC), or aerated rapid composting (ARC). In India work on this line was started at our Centre few year back and technology to produce such compost in 12 days time perfected. Facilities required and methodology for the production of such compost is presented below:

Most important aspect of indoor composting is that besides being environment friendly, it takes less time and gives more compost biomass (around 25-30% more) per unit weight of the ingredients taken and hence over all yield of mushrooms in such compost is higher.

1. Facilities required

a. Composting Yard

In indoor composting Phase-I is performed indoors and hence requirement of composting yard is greatly reduced. A small composting platform is required for prewetting and mixing of the ingredients, which is mainly performed either by front-end loaders or by preheap turners by big commercial units. A platform of the size 60x60x14 ft (h) would suffice the purpose for a medium size farm (250 TPA).

b. Phase-I tunnels or bunkers

These are specially built non-insulated tunnels having full width opening at the front. Dimension of the bunkers would depend upon the output of the compost required. Generally the bunkers are 1.5 times more the size of the phase-II tunnels. It has a plenum (ventilation duct). A perforated concrete floor is constructed above the plenum, which is serviced by a centrifugal fan having ¼ the capacity of phase -II blower which means that a ventilator having air displacement of 50 m^3/hour/ton of compost at 50mm WG water pressure would suffice the purpose. Alternatively the bunkers have no plenum and several pipes are buried in the floor along the full length of the bunkers having small holes (5-8 mm dia). These pipes are converged into a manifold, which in turn is connected to a high-speed blower fan (around 1000 pascals). A timer is usually attached to the blower, which pulsates the air in the bunker periodically as per the setting of the timer. A minimum of 2 such phase-I tunnels (bunkers) are required (Fig.18).

Fig.18: Bunkers and ventilation systems

c. Phase-II tunnels

Structure and design of these tunnels are the same as required in case of short method of composting.

2. Selection and mixing of ingredients

Selection of the raw materials for indoor composting is very critical and should have the following qualities:

- High bulk density,
- Good structure and texture,
- Perfectly mixed raw materials,
- Well balanced chemical composition and
- High level of nutrients

3. Procedural requirements

Two methods, INRA method (double phase high temperature process) and Anglo Dutch method (single phase, low temperature process) are prevalent in most parts of the world giving almost equal yields. This Centre has developed a method combining the two methods as mentioned above. Methodology developed is presented below:

For preparing compost by this improved method of composting, ingredients say – wheat straw 1000 kg, poultry manure 500 kg, wheat bran 70 kg, cotton seed cake 20 kg, and gypsum 40 kg are first thoroughly mixed in dry form. They are then thoroughly wetted so as to achieve around 75% moisture percentage. Run off water should regularly be collected and sprinkled over the wetted straw. On the following day these wetted ingredients are then spread over the composting yard (around 8-10" height) and trampled hard by running Bobcat several times over the wetted ingredients or by other means so as to increase the bulk density of the ingredients and also to shred the straw. Wetted straw together with other ingredients is than made up into heap and left as such for 48 hours. Temperature in the heap may rise up to 55-60C. On the following day material is again flipped to bring the uniformity and proper mixing and transferred to phase-I bunker, for phase-I operation. This material will weigh around 4 tons and height of the compost in the bunker is kept up to 1.8-2 meters. Temperature sensors are installed on the top and in the Centre of the pile in the bunker and blower fan switched on @ 5 min/h with the help of a timer installed for the purpose. Temperature will rise to 60-65C after 24 hours in the centre and 48-52C at the bottom, sides and on top of the compost. After 24 hours air flow inside the tunnel is increased to 10 min/hour. This will further increase the temperature in the centre of the compost between 72-75°C while it will remain same in other parts of the compost mentioned as above. No foul smell will be noticed while performing phase-I operation in the bunker, however little bit ammonia smell will be there. After 3 days of partial fermentation in phase-I tunnel, entire compost mass is taken out and a complementary turning is given, more water can be added if required and is transferred to another tunnel or to the same tunnel at the same sets of conditions mentioned as above for 3-4 days. Total period of phase-I operation in the bunker should normally last for 6-8 days. Afterwards compost is transferred to phase-II tunnel for usual phase-II operations to be completed in 6-7 days.

a. Composting Schedule

-4 day:	Mixing and wetting and of the ingredients out doors
-3 day:	Turning, trampling by Bobcat and thorough mixing of the ingredients, addition of water.
-2 day:	High aerobic heap
0 day:	Filling in the phase-I tunnel
+ 3 day:	Emptying the tunnel, turning and mixing of the compounding mixture and re-filling the compost in another phase-I tunnel
+6 day	Phase-I operation over and compost transferred to phase-II tunnel
+ 12 day:	Phase-II operation over

b. Advantages of indoor composting

- Requirement of composting yard is reduced to 1/3
- No emission of foul smell
- Number of labourers and cost of production reduced
- Duration of composting greatly reduced
- Reduced effects of weather and seasonal variations
- More compost per unit weight of the ingredients
- Higher yields
- Compost turner is not required

c. Disadvantages of indoor composting

- Low bulk density of compost
- Aesthetic look of the compost is not good (brown in colour)
- Since turnings are less, initial superior blend of raw materials is critical