sometimes it creates much heating ...

3. Management of the compost during composting

The compost is to be prepared on a cleaned preferably cemented floor. It should be done in the open or under shed having open sides. If composting is performed outsides, heap must be protected from rains by covering plastic sheet. If it is inside the room, the room should be well ventilated.

Composting Process

The composting process is divided into two stages, commonly called Phase I and Phase II. Each stage is designed to accomplish specific ends, these being:

Phase I: It is termed as outdoor composting. This stage involves the mixing and primary decomposition of the raw materials.

Phase II: It is carried out indoors in specially designed rooms. Here, the compost is pasteurized and conditioned within strict temperature zones.

Phase-I composting: In this phase the raw materials (organic matter) are mixed and wetted. The degradable metabolic activities of the microorganisms (which are already present in those materials) starts. Firstly, the cellulose and hemicellulose of the substrate convert into sugar along with other nitrogenous substances. This supports to increase the further growth, if many fungi and bacteria enhance the amount of protein in the compost. In the later stage of phase-I composting, thermophilic actinomycetes will grow and become dominant, having also an important role in phase-II composting. In this process, the raw materials are made into heaps and wetted then turned to narrow stacks where the composting process will be taken place. The stacks are made up in open or under the protection of open sided compost sheds. 7-10 days are required for phase-I process. The temperature of the centre of a compost stack generally reaches 76°C which destroys most of the pests and pathogen which are naturally present. But the peripheral layers of the stacks do not have such temperature, so that phase-I compost having the probability of contaminating later stages of production.

Basic Raw Materials

The basic raw material used for composting is cereal straw from wheat, rye, oat, barley and rye grass. Of these, wheat straw is preferred due to its more resilient nature. This characteristic helps to provide structure to the compost. Straw provides a compost with carbohydrates, the basic food stuffs of mushroom nutrition. Wheat straw consists of 36% cellulose, 25% pentosan and 1.6% lignin. Cellulose and pentosan are carbohydrates which upon break down yield simple sugars. These

sugars supply the energy for microbial growth. Lignin is changed during composting to a "Nitrogen-
rich-lignin-humus-complex, a source of protein. When cereal straw is gathered from horse stables, it
is called "horse manure". Although cultivators call it by this name, the material is actually 90% straw
and 10% manure. This "horse manure" includes the droppings, urine and straw. The quality of this
material depends on the proportions of urine and droppings present and the essential elements like
nitrogen, phosphorus and potassium being contained therein. When horse manure is used as the basic
starting ingredient, the compost is considered a "horse manure compost" whereas "synthetic compost"
refers to a compost using no horse manure. Straw, sometimes mixed with hay, is the base ingredient
in synthetic composts. Because straw is low in potassium and phosphorus. These elements must be
provided by supplementation and for this reason chicken manure is the standard additive for synthetic
composts. Horse manure or straw are insufficient for producing a nutritious compost by themselves.
Nor do they decompose rapidly. They must be fortified by specific materials called supplements.

Supplements

To stimulate microbial activity and enhance their growth, nutrient supplements are added to the bulk starting materials. These supplements are designed to provide protein (nitrogen) and carbohydrates to feed the ever increasing microbial populations.

Different formulations of composting ingredients or supplements based on nitrogen content are given below.

Formula I: High nitrogen, no organic matter

Ammonium sulfate-21% N

Ammonium nitrate-26% N

Urea-46% N

Maximum rate-25 lbs/dry ton of starting materials

These are inorganic compounds that supply a rapid burst of ammonia. They are frequently used for initial straw softening in synthetic composts. When used, care should be taken that they are applied evenly. If ammonium sulfate is used, calcium carbonate must also be added at a rate of 3 parts $CaCO_3$ to 1, to neutralize sulfuric acid groups. These supplements are not recommended for horse manure composts.

Formula II: 10-14% N

Blood Meal-13.5% N

Fish Meal-10.5% N

These materials consist mainly of proteins but because of their high cost are rarely used.

Formula III: 3-7% N

Malt sprouts-4% N

Brewers' grains-3-5% N

Cottonseed meal-6.5% N

Peanut meal-6.5% N

Chicken manure-3-6% N

This group contains the materials most widely used by commercial growers and is characterized by a favorable Carbon:Nitrogen balance. Dried chicken manure from broilers mixed with saw dust is commonly used and easy to handle.

Formula IV: Low nitrogen, high carbohydrate

Grape pomace-1.5% N
Sugar beet pulp-1.5% N
Potato pulp-1% N
Apple pomace-0.7% N
Molasses - 0.5% N
Cottonseed hulls-1% N

These materials are excellent temperature boosters and for this reason are a recommended additive to all composts. They can be added to any compost formula at a rate of 250 lbs per dry to of ingredients. Cottonseed hulls are an excellent structural additive.

Minerals Supplement

Gypsum—Calcium sulfate

Gypsum is an essential element for all composts. Its action, largely chemical in nature, facilitates proper composting. Its effects are:

1. To improve the physical structure of the compost by causing aggregation of colloidal particles. This produces a more granular, open structure which results in larger air spaces and improved aeration.
2. To increase the water holding capacity, while decreasing the danger of over-wetting. Loose water is bound to the straw by colloidal particles.
3. To counteract harmfully high concentrations of the elements K, Mg, P and Na and thereby preventing a greasy condition in the compost.
4. To supply the calcium necessary for mushroom metabolism. Gypsum should be added at a rate of 50-100 lbs per dry ton of ingredients. When supplementing with chicken manure, it is advisable to use at high rate.

Limestone flour— Calcium carbonate

Limestone is used when one or more supplements are very acidic and need to be buffered. A good example of this is grape pomace, which has a pH of 4. Because it is added in large quantities, grape pomace could affect the composting process which normally occurs under alkaline conditions.

Some of the popular compost formula:

The primary aim of the development of suitable compost formulation is to achieve a nitrogen content of 1.5%-1.7% at the initial makeup of the compost pile. Starting materials used for compost formulation is horse manure (0.9-1.21 N), or straw (0.5-0.71 N). This staring materials amends with different supplements to achieve the required amount of Nitrogen in compost pile. Some important compost formulations developed by different scientists are given below:

Formulae of manures

Formula 1: Horse manure compost (Van her et al. 1994)

- Horse manure: 800 kg
- Chicken (broiler) manure: 80 kg
- Gypsum: 20 kg
- Water: 240 l

Formula 2: Horse manure compost (Beyer 1999)

- Horse manure: 80 ton (wet wt.)/50 ton (dry wt.)
- Poultry manure: 7.5 ton (wet wt. /6.0 ton (dry wt.)
- Brewers grain: 2.5 ton
- Gypsum: 1.25 ton

Formula 3: Natural compost (IARI, in Vijay and Gupta 1995)

- Horse manure: 1000 kg
- Wheat straw: 500 kg
- Chicken manure: 300 kg
- Urea: 7 kg
- Brewer's grain: 60 kg
- Gypsum: 30 kg

Formula 4: Synthetic compost (Seth and Sandilya 1975)

- Wheat straw: 300 kg
- Calcium ammonium nitrate: 6 kg
- Urea: 2.4 kg
- Super phosphate: 2.5-7.5 kg
- Sulphate of potash: 3 kg
- Brewer's grain: 15 kg
- Gypsum: 30 kg

Formula 5: Synthetic compost for standard long method of composting (Mushroom Research Laboratory, Solan)

- Wheat straw: 300 kg
- Wheat bran: 30 kg
- Gypsum: 30 kg
- CAN: 9 kg
- Urea: 3.8 kg
- Muriate of potash: 2.5 kg
- Super phosphate: 3 kg
- Molasses: 5 kg
- Carbofuran (Furadan 3G): 183 g
- Benzene Hexachloride (BHC) or Gamaxene (10%): 250 g or lindane dust (10%)

Formula 6: Synthetic compost (IIHR, Bangalore, in Vijay and Gupta 1995)

- Paddy straw: 3 tons
- Chicken manure: 1.5 tons
- Wheat bran: 125 kg
- Gypsum: 90 kg

Formula 7: Synthetic compost for organic mushroom extended (Phase-I) short method of composting (in NRCM, Dhar & al. 2007)

- Wheat straw: 1000 kg
- Poultry manure: 800 kg
- Brewer's grain (wet): 400 kg
- Wheat bran: 150 kg
- Cotton seed cake: 60 kg
- Gypsum: 35 kg
- Water: 3500-4000 l

Building the Pile

Building the compost pile is called stacking, ricking or "make up". At this time the pre wetted starting materials and the nitrogenous supplements are evenly mixed, watered and assembled into a pile. The size, shape and specific physical properties of this pile are very important for optimum composting. These are:

1. Pile dimensions should be 5-6 feet wide by 4-6 feet high. The shape should be rectangular or square.
2. The side of the pile should be vertical and compressed from the outside by 3-6 inches. The internal section should be less dense than the outer section.
3. The pile is such that any further increase in size would result in an anaerobic core.

Turning

A well-built compost pile runs out of oxygen in 48 to 96 hours and then enters an anaerobic state. To prevent this, the pile should be disassembled and then reassembled. The purposes of this turning procedure are:

1. To aerate the pile, preventing anaerobic composting.
2. To add water lost through evaporation.
3. To mix in supplements as required.
4. To fully mix the compost, preventing uneven decomposition.

Type I composting is again subdivided into two categories according to the time span utilized for this process. One is long composting and another is short composting procedure.

Long Composting

Long composting is designed to carry out the complete composting process outdoors excluding pasteurization. The method is characterized by the avoidance of high temperature chemical decomposition and a reliance on purely microbial action. Specifically, this procedure is designed to promote the growth of actinomycetes and rid the compost of all ammonia by the time of filling. An outline of the Long Composting procedure follows (Table 11).

Table-11: An outline of the Long Composting procedure

DAY	LONG COMPOSTING PROCEDURE
-10	**For synthetic composts:** Break the straw bales and water them thoroughly. Mix in group 1,4 or 5 supplements or chicken manure. Windrow. Start at day -5 if straw is short or has been chopped.
-5	**For synthetic composts:** Turn and add more water. Break up any concentrations of supplements.
-2	**For horse manure or synthetic composts:** Thoroughly wet and mix raw materials and supplements (except gypsum). Windrow.
0	**Make up the pile.** Dimensions should be 6 feet wide and 4 feet high. The vertical sides should be tightly compressed with the middle of the pile remaining loose. Use the pile formers to make the stack and stomp the sides from the top to achieve ample compression. Water dry areas.
6	**First turn:** Water as needed. Move the center anaerobic zone to the outside of the new pile and the outside zone to the center. Keep the pile height and length constant by reducing the width as decomposition proceeds.
10-12	**Second turn:** Add the gypsum and water as needed. Distribute the zone of actinomycetes evenly throughout.
13-15	**Third turn:** The actinomycete zone should be evident throughout. Strong actinomycete growth may cause excessive drying, so be sure to check moisture content and water as needed. The smell of ammonia should be slight. Build the new pile only 24 inches high and 4-5 feet wide. Distribute the actinomycetes evenly throughout.
15-17	**Fourth turn:** The compost should now appear dark brown and well flecked with actinomycetes. All traces of ammonia should be gone. Moisture content should be approximately 67-70% and the pH 7.0-7.5. If this is not the case. continue the process turning at 2 day intervals until this condition is reached. The pile height may vary between 16-24 inches and is designed solely to promote optimum conditions for the growth of the actinomycetes—temperatures of 120-135°F.

Once finished, this compost is normally pasteurized at 135°F for four hours. If pasteurization is impossible, discard the cool outer shell and utilize the areas showing strong actinomycete activity. Although these areas will not be free from all pests and competitors, they should provide a reasonably productive substrate.

Short Composting

Commercial *Agaricus* growers uniformly base their composting procedures on the methodology developed by Dr. James Sinden, who called his technique "Short Composting" in reference to the short period of time involved. Dr. Sinden's process is centered around the fast acting chemical reactions. Besides the shorter preparation time, this process also results in a greater preservation of dry matter, thus retaining valuable nutrients. Without commercial composting equipment, approximating the temperature conditions of Short Composting is very difficult. However, it does provide a model for optimum composting and can be approached by adhering to the basic principles. The short composting procedure is outlined below (Table 12).

Table-12: An outline of the Short Composting procedure

DAY	SHORT COMPOSTING PROCEDURE
-1	**Formula for horse manure:** Wet the starting materials thoroughly. Windrow.
0	**Make up the pile.** Add all supplements except gypsum. Mix and water thoroughly. Pile should be 6 feet wide by 5-6 feet high. The sides should be vertical and compressed tightly.
2, 3	**First turn:** Add gypsum and water as needed. Keep the pile height constant and vary the width only in relation to the amount of anaerobic material.
5	**Second turn:** Add water as needed.
7	**Third turn:** Add water as needed. Compost should be ready to fill.

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 to 8.5.
- Still sticky and slimy, hands get dirty and wet.
- Actinomycetes (fire fangs) not so apparent.
- Nitrogen content between 1.5 to 2.0%; ammonia concentration around 800-1000 ppm.

Phase-II composting :

Phase-II composting is a pasteurization process. This process is also referred as peak-heating sweat out process. Through this process insects and contaminating microorganisms are eradicated but decomposition of substrates by thermophilic organisms is actively continued which is favourable for selective substrate of mushroom growth. This process is basically the controlling of environment which distinguishes phase-II from phase-I composting. While Phase I is a combination of biological and chemical processes, Phase II is purely biological, in fact, Phase II can be considered a process of microbial husbandry. By bringing the compost indoors into specially designed rooms, the environmental factors of temperature, humidity and fresh air can be controlled to such a degree that conditions for growth of select microbial groups can be maximized. The conditioning of compost starts at nearly 52°C (125°F) which is the optimal temperature allowing biological activity of microflora that renders the compost suitable for mycelial growth.

Of course, there is no such sharp point at which phase-I is translated to phase-II. However, if one phase having more activity the another phase needs less activity. The point of shifting of process of phase-I to phase-II depends on the complex issues of management and available facilities. Generally, it is more economical of phase-II and lasts less than 1 week.

Phase II can be separated into two distinct parts, each serving a specific function. These are:

1. **PASTEURIZATION:** The air and compost temperature are held at 135-140°F for 2-6 hours. The purpose of pasteurization is to kill or neutralize all harmful organisms in the compost, compost container and the room. These are mainly nematodes, eggs and larvae of flies, mites, harmful fungi and their spores. The length of time needed generally depends on the depth of fill. Deeper compost layers require more time than shallow ones. In general, two hours at 140°F is sufficient. Compost temperatures above 140°F must be avoided because they inactivate fungi and actinomycetes while at the same time stimulating the ammonifying bacteria. If temperatures do go above 140°F, be sure there is a generous supply of fresh air.
2. **CONDITIONING:** The compost temperature is held at 118-130°F. Once the pasteurization is completed, the compost temperature should be lowered gradually over 24 hours to the temperature zone favoured by actinomycetes and fungi. The exact temperature varies according to the depth of the fill. At depths up to 8 inches, 122°F as measured in the centre of the compost is most frequently used. At depths over 8 inches, temperature stratification becomes more pronounced, making a higher core temperature of 128°F advantageous. A common procedure is to bring the compost temperature down in steps, dropping the core temperature 2° per day, from 130°F to 122°F. This temperature is then held until all traces of ammonia are gone.

Room Design for Phase II Composting

The Phase II room can be a special room set aside solely for this purpose (the norm on Tray farms) or it can be in the same room where cropping occurs. Design features are critical for its success and should be strictly adhered to. These features are:

1. Adequate insulation: Insulate to a R value of 19 for walls and a minimum of 30 for the ceiling. A vapour barrier is needed to protect the insulation. (A layer of polyethylene is cheap and effective.)
2. The room must be functionally airtight. The door should form a tight seal. Any cracks or openings allow the passage of flies.
3. The ventilation system uses a backward-curved centrifugal fan driven by pulleys and belts, and whose speed can be varied. The fan should be capable of moving air at 1 cubic foot per minute (CFM) per square foot of compost surface area. A perforated polythene duct runs the length of the room and directs the air either straight down the center aisle or across the ceiling to the side

walls. High velocity airflow is necessary to maintain even temperatures throughout as well as to keep the room under positive pressure.

4. A fresh air vent is located before the fan. This damper also regulates recirculated air.
5. Filters are placed before the fresh air inlet. These filters are important as protection against flies, dust and spores. High efficiency spore filters are commonly used for the incoming fresh air. A pre filter placed upstream of the main filter will increase its life. Recirculated air should never be filtered during Phase II because of its high moisture content.
6. At the opposite end of the room from the fresh air vent are exhaust louvers operating on air pressure. This exhaust air outlet must be screened from the inside.
7. If steam is used for boosting temperature, pipes can be run the length of the floor along the side walls discharging outwards. Steam can also be discharged directly into the air duct after the fan. High output electric space heaters can also be used.