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China Agricultural University

Method and Practical Skills for the Composting Fermentation of Straw and Manure

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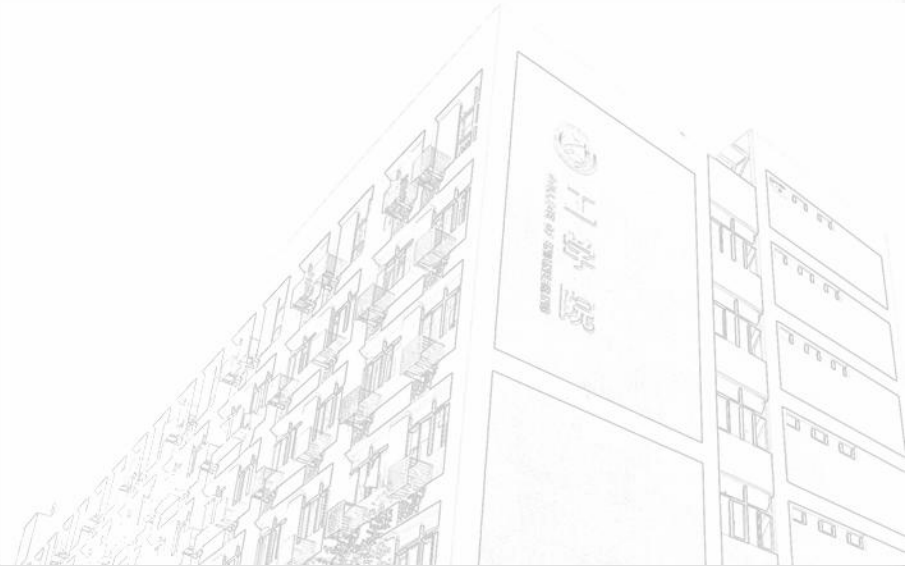
Outline

- Physical-chemical characteristics of Straws
- Physical-chemical characteristics of Livestock Manure
- Definition and Function of Organic Fertilizer
- Composting Fermentation Type of Straw and Livestock Manure
- Method and Practical Skills for Composting Fermentation
- Factors affecting fermentation process
- Evaluation of Composting Fermentation
- Application Skills of Organic Fertilizer

Physical-chemical characteristics of Straws



Physical-chemical characteristics of Straws

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Straw Resource for composting

Wheat Rice Maize Cotton Rape

Physical-chemical characteristics of Straws

The physical-chemical properties of straw are the foundation for fermentation

1 Shape and Particle Size

- The Particle Size and distribution of straw is uneven, and the shape is very irregular.
- Pretreatment is necessary.
- Cutting, Crushing, screening and even compression molding are required to achieve appropriate utilization shape and relatively uniform particle size.

Physical-chemical characteristics of Straws

1 Shape and Particle Size

Cutting off

Crushing to pieces

Straw pellet

Baling of wheat straw

Straw Pretreatment

Physical-chemical characteristics of Straws

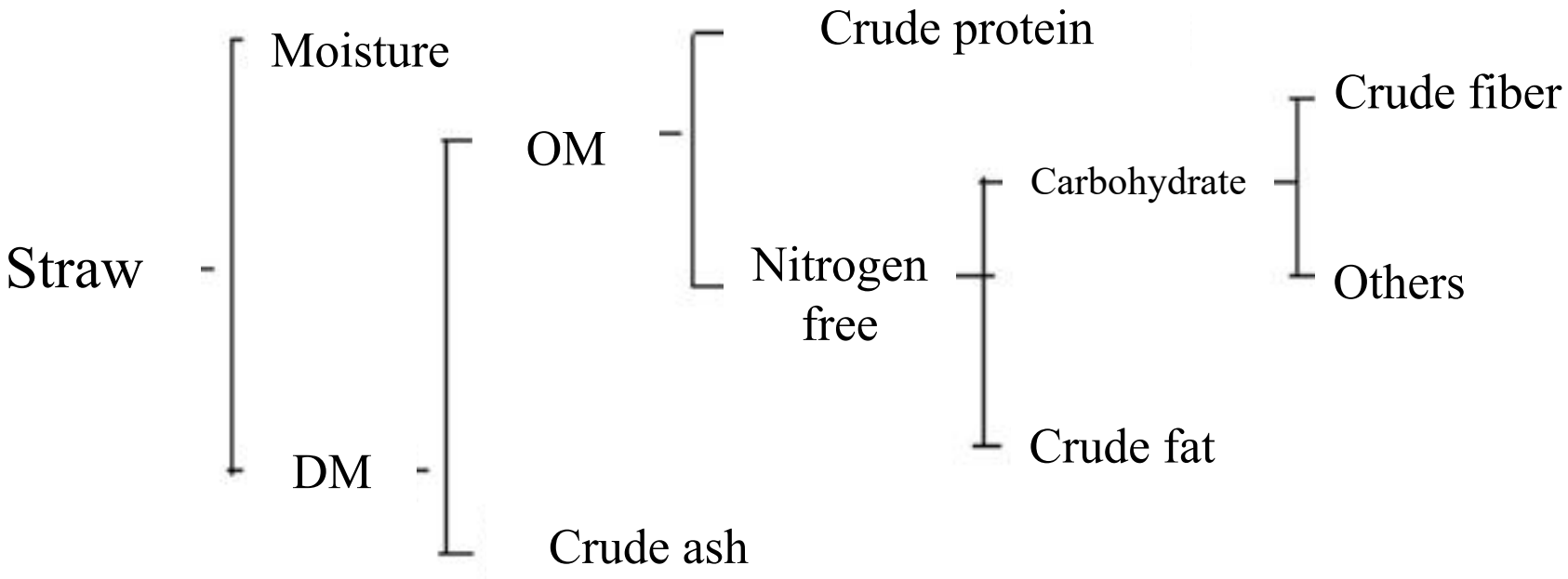
2 Density and Bulk Density

- Density and bulk density of Straw raw material is relatively low and different.

Category	Bulk density（kg/m³）
Loose	20～40
Chopped	20～80
Packaged	110～200
Molding blocks	320～670
Pellet	560～710
Corncob	260
Cotton straw	200

Physical-chemical characteristics of Straws

- Straw is a complex organic compounds.

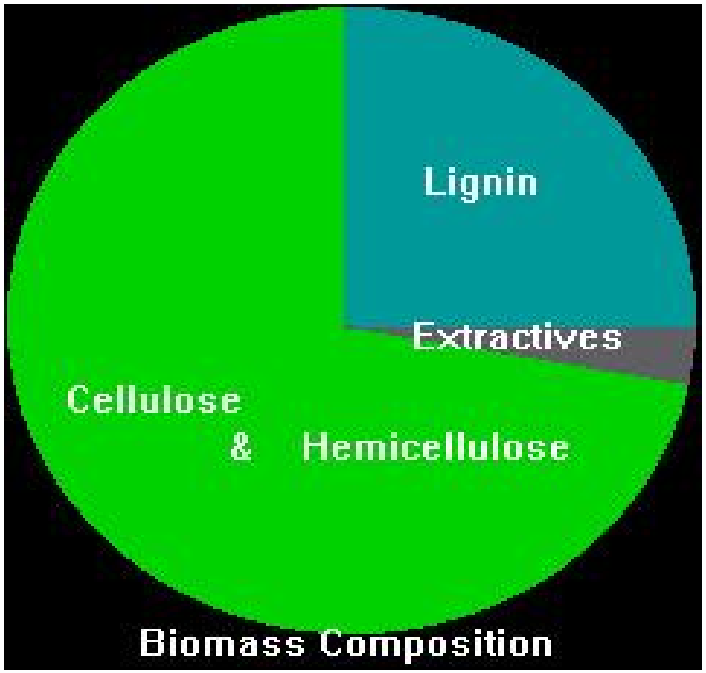


Chemical compositions of straw

Physical-chemical characteristics of Straws

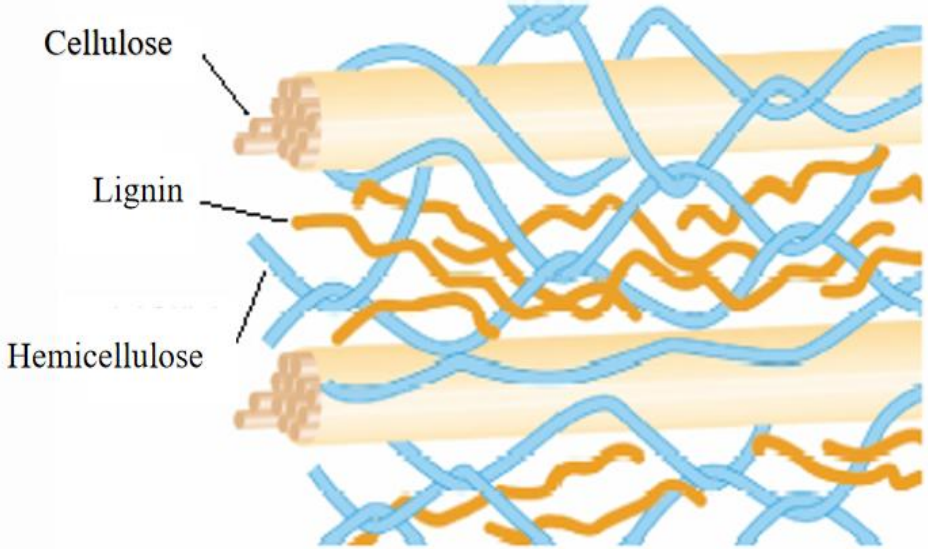
3 The chemical compositions of straw

- Chemical composition basically includes cellulose, hemicellulose and lignin.



Crude Fiber components

Smashing can partly break the connections and promote the fermentation.



Structure of straw lignocellulose

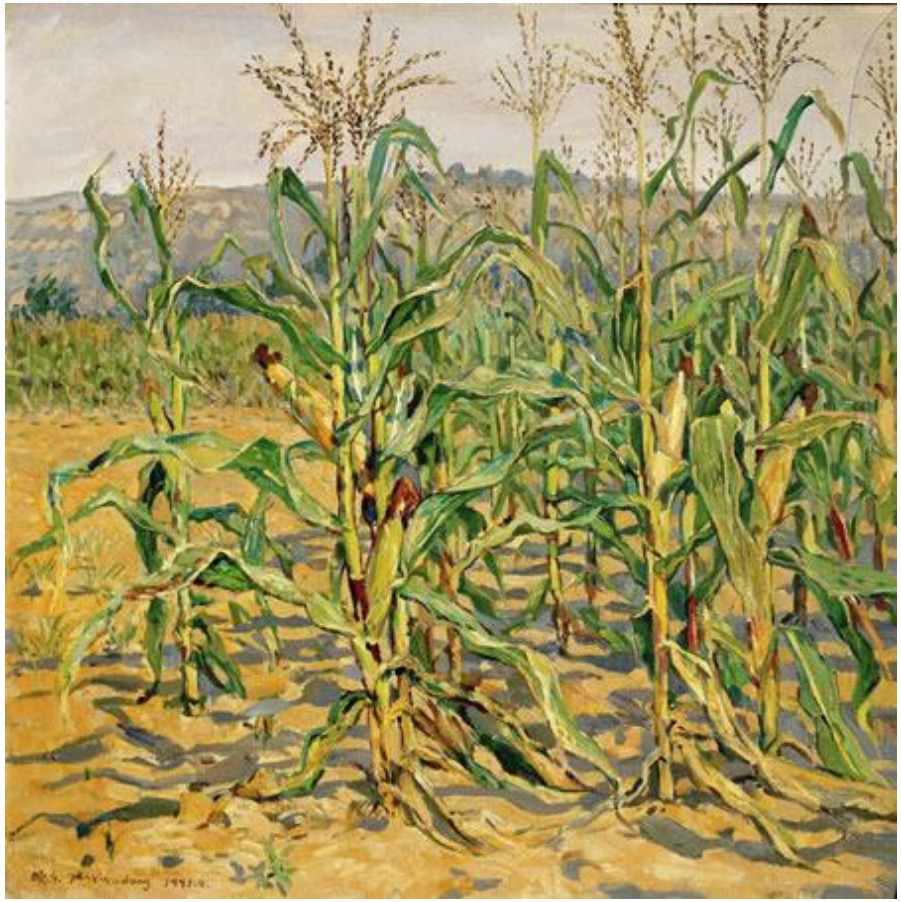
Physical-chemical characteristics of Straws

4. Element composition

- Element composition refers to various elements (mainly organic elements), which does not reflect the chemical composition and structure formed by the combination of elements.
- Mainly includes, carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulfur (S).

Physical-chemical characteristics of Straws

5. Composition of typical straw (%)



Corn straw

Cellulose: 38%

Hemicellulose: 25%

Lignin: 15%

Moisture : 6%

Ash: 5%

C: 49%

H: 6%

O: 44%

N: 0.7%

S: 0.11%

Physical-chemical characteristics of Straws

5. Composition of typical straw (%)

Wheat straw

Cellulose: 40%

Hemicellulose: 28%

Lignin: 17%

Moisture content : 10%

Ash: 4%

C: 50%

H: 6%

O: 43%

N: 0.6%

S: 0.07%

Physical-chemical characteristics of Straws

5. Composition of typical straw (%)

Rice straw

Cellulose: 30%

Hemicellulose: 25%

Lignin: 12%

Moisture content: 4%

Ash: 12%

C: 48%

H: 5%

O: 42%

N: 0.8%

S: 0.09%

Physical-chemical characteristics of Straws

5. Composition of typical straw (%)

Cotton straw

Moisture content: 7%

Ash: 4%

Straw Volatilization: 69%

C: 50%

H: 6%

O: 43%

N: 0.7%

S: 0.2%

Physical-chemical characteristics of Straws

Summary: Main physical-chemical properties of straw

- Chemical composition： Dry matter, cellulose, hemicellulose, lignin, crude protein, neutral detergent fiber, acid detergent fiber, crude ash, soluble sugar, sodium, calcium, magnesium, iron, copper and zinc.
- Physical and thermal properties: bulk density, specific heat capacity, thermal conductivity.
- Mechanical properties: tension, bending, compression, shear, relaxation, creep, friction.
- Thermochemical Engineering: moisture, volatile matter, fixed carbon, ash, elements C, H, O, N,S high calorific value, low calorific value and pyrolysis characteristics.

Utilization type of straw for fertilizer

Utilization type of straw for fertilizer

- **Direct returning to the soil**

After harvest, the straw can be ploughed into the soil, it will be decomposed as fertilizer, so as to improve the soil structure, water retention, bonding and other properties.

Pictures of straw returning directly to the field

Utilization type of straw for fertilizer

- **Returning to the field after feeding**

Straw is firstly used as feed for cattle, sheep, and animal manure is returned to the field as natural fertilizer.

Has risk of bacterial contamination without fermentation

Straw as animal feed

Utilization type of straw for fertilizer

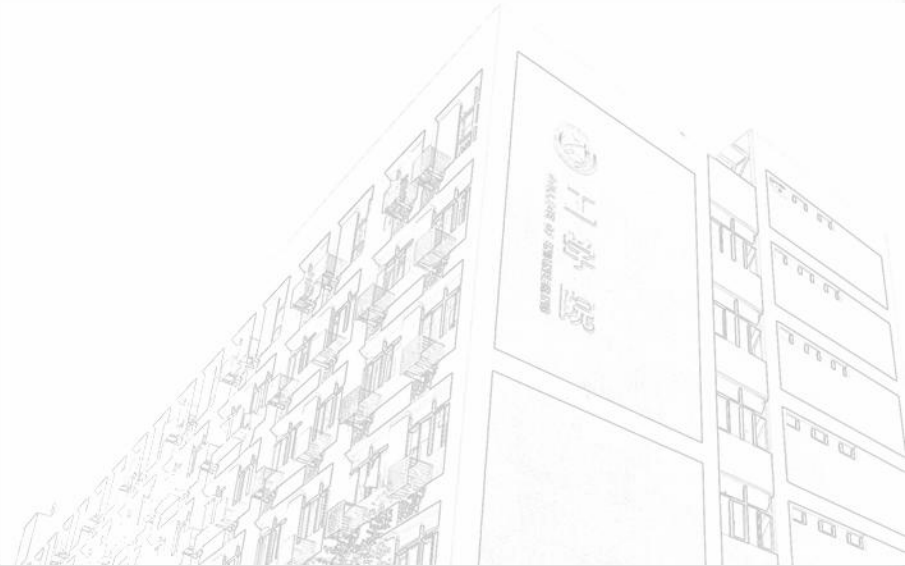
- **Composting fermentation**

Straw is crushed, fermented and composted with livestock or poultry manure, and then applied to the soil as fertilizer.

Perfectly combined with straw feed utilization, which has good ecological benefits

Straw as animal feed

Physical-chemical characteristics of Livestock Manure



Physical-chemical characteristics of Livestock Manure

1. Livestock manure resources

- Beef cattle, dairy cows, broilers, layers, pigs.

Physical-chemical characteristics of Livestock Manure

1. Livestock manure resources

Feces and urine production of main livestock in the whole feeding cycle				
Breed	Breeding cycles(Day)	Fecal production in the whole cycle（kg）	Urine production in the whole cycle（kg）	Total amount of feces and urine produced in the whole cycle（kg）
Pig	170	218	442	660
Cow	365	11060	5402	16462
Beef cattle	540	4578	3056	7634
Layer	455	56		56
Broiler	42	6		6

Physical-chemical characteristics of Livestock Manure

1. Livestock manure resources

Example

A 1000 head pig farm excretes 6 tons of feces and urine per day and 2500 tons of feces and urine per year; If water is used to flush feces, the daily output reaches 30 tons and the annual output is more than 10,000 tons.

Physical-chemical characteristics of Livestock Manure

1. Livestock manure resources

- **From the perspective of environmental protection, farms are polluting place**

  - **Bacterial contamination, phosphorus, nitrogen, heavy metals, etc**

  - **Water source, air, soil and other ecological environment pollution**

    -Odor, greenhouse gas and other air pollution

    -Water pollution

    -soil pollution

    -Easy for communicable diseases

A pool for storing feces

•A large number of livestock manure is one of the agricultural pollution resource.

Physical-chemical characteristics of Livestock Manure

1. Livestock manure resources

- **From the perspective of resource unilization, farms are Useful resource station**

- **Important raw material for fertilizer**
  - **Organic matter**
  - **Rich nitrogen (N), phosphorus (P), potassium (K)**
  - **Organic agriculture**

Physical-chemical characteristics of Livestock Manure

2. Main fertilizer components

Livestock and poultry varieties	Total nitrogen（g/kg）		Ammonium nitrogen（g/kg）	
	Range	Mean	Range	Mean
Broiler	8.6-38	17.2	0.3-2.4	0.8
Layer	10.8-34.6	18.0	1.5-4.1	3.1
Finishing pig	5.2-16.8	9.5	0.8-4.9	2.4
Beef cattle	2.9-5.6	4.2	0.5-1.2	0.9
Cow	2.0-5.7	3.7	——	——

Physical-chemical characteristics of Livestock Manure

2. Main fertilizer components

Livestock and poultry varieties	Total phosphorus（g/kg）		Total potassium（g/kg）	
	Range	Mean	Range	Mean
Broiler	2.3-8.7	3.8	0.6-14.5	5.1
Layer	3.1-7.9	4.8	4.3-13.7	7.0
Finishing pig	2.6-8.2	5.2	0.6-7.3	4.2
Beef cattle	0.8-2.3	1.4	0.7-3.7	2.1
Cow	—	—	—	—

Physical-chemical characteristics of Livestock Manure

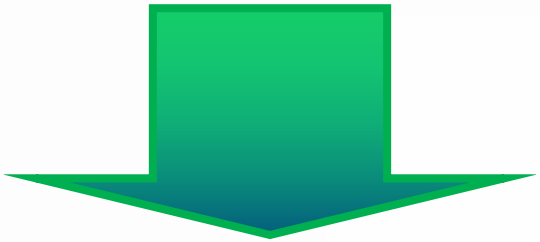
3. Fertilizer value of livestock manure

Example, China

Total amount of livestock manure is about 3 billion tons

Total capacity of N, P and K is about 633 million tons

Equates to



Urea
493 million tons

+

Superphosphate
120 million tons

+

Potassium chloride
338 million tons

Definition and Function of Organic Composting Fertilizer

Organic Composting Fertilizer

1. Definition

- Carbon containing materials mainly derived from plants and / or animals, and applied to soil to provide plant nutrition as its main function.

(GB/T 6274-1997)

- It is mainly fermented by straw and livestock manure.

Inorganic fertilizer= Chemical fertilizer

1. Definition

- Fertilizer produced by chemical synthesis
- It includes nitrogen, phosphorus, potassium and compound fertilizer.
- Inorganic fertilizer is mineral fertilizer, also known as Chemical fertilizer.

Which is better?

Organic Fertilizer

Chemical fertilizer

Problems caused by excessive use of chemical fertilizer

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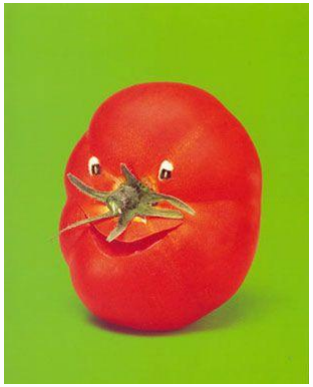
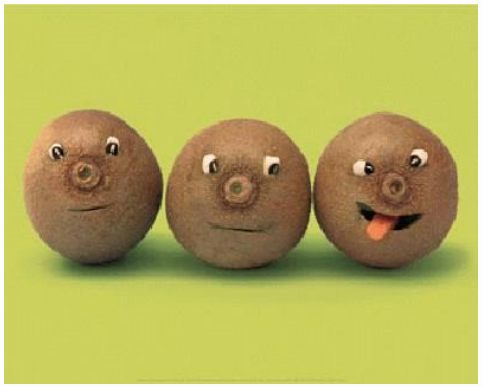
Appropriate use can benefit Crop Growth

Excessive use causes serious environmental pollution, soil hardening and uneven nutrients.

Organic Composting Fertilizer

Nutrition of organic fertilizer

- Contains various nutrient elements required for crop growth, such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and trace elements.
- The nutrition of organic fertilizer is more active, high utilization efficiency, which can balance soil nutrients.


Organic Composting Fertilizer

Function

- Increase and renew soil organic matter. An appropriate amount of soil organic matter is a necessary condition for high, stable and high-quality crops.

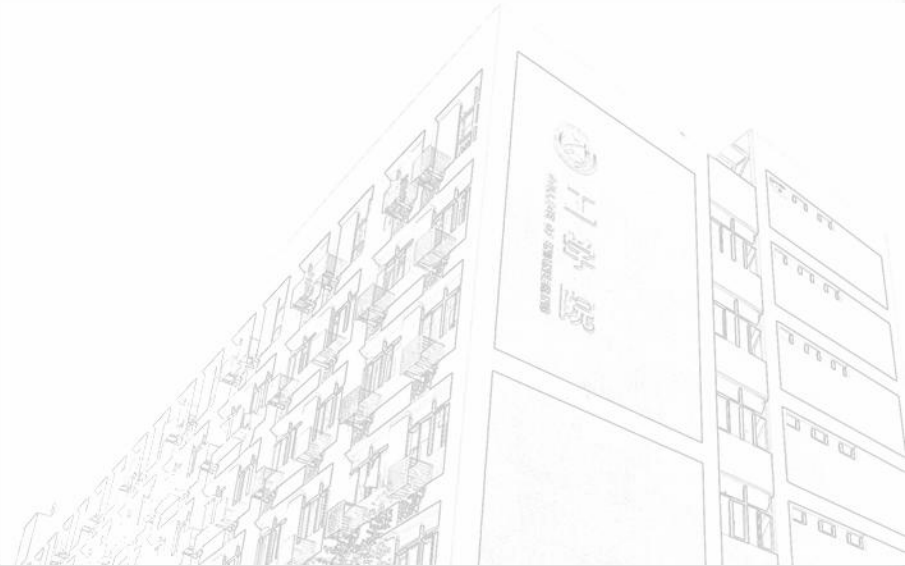
- Improve soil physical and chemical characteristics. it can be fast decomposed by microorganisms to form a new material, **Humus.**

Function of Organic Fertilizer

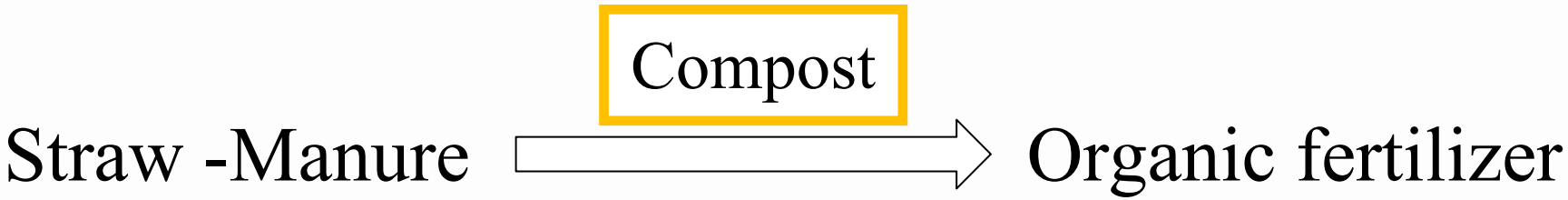
Environmental protection


- Using organic fertilizer can reduce environmental pollution, soil, water and air pollution.
- Humus in organic fertilizer can reduce the pollution of heavy metals in soil.

Composting Fermentation Type of Straw and Livestock Manure



What is composting



- With livestock manure and straw as the main raw materials, they are continuously degraded to a stable state through the action of microorganisms under certain conditions, and become fertilizers suitable for land use.

Composting Fermentation

1. Fermention Types

- **Aerobic composting**

  - With oxygen/air, decomposed by Aerobic microorganism
  - Fermentation process， complete decompose, No odor
  - High temperature (55-60 ℃, sometimes as high as 80-90 ℃)

- **Anaerobic composting**

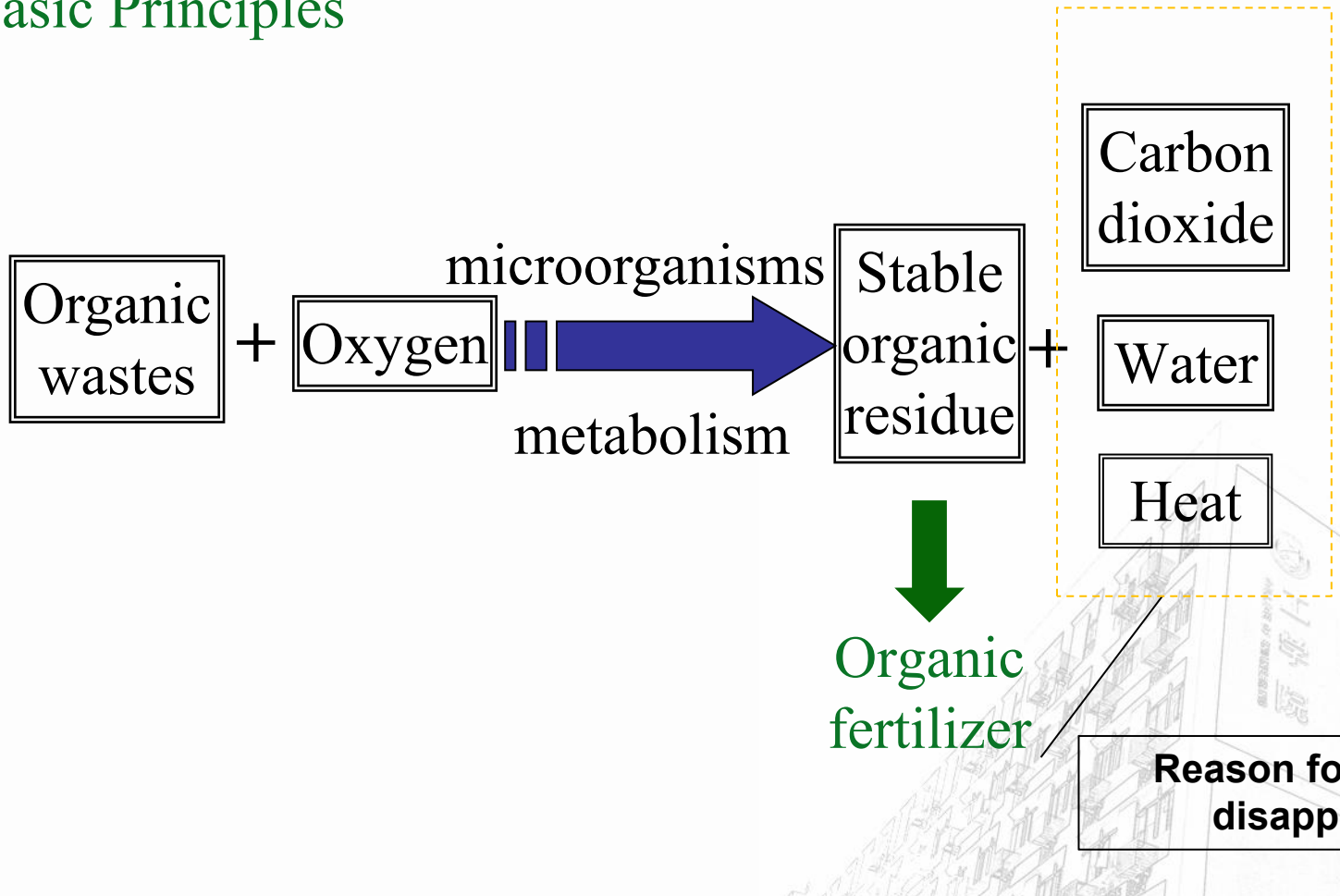
  - Without oxygen/air, decomposed by Anaerobic microorganism
  - Fermentation process, uncomplete decompose, odor left
  - Low temperature (30-50 ℃)

Which is better?

Aerobic Composting Fermentation

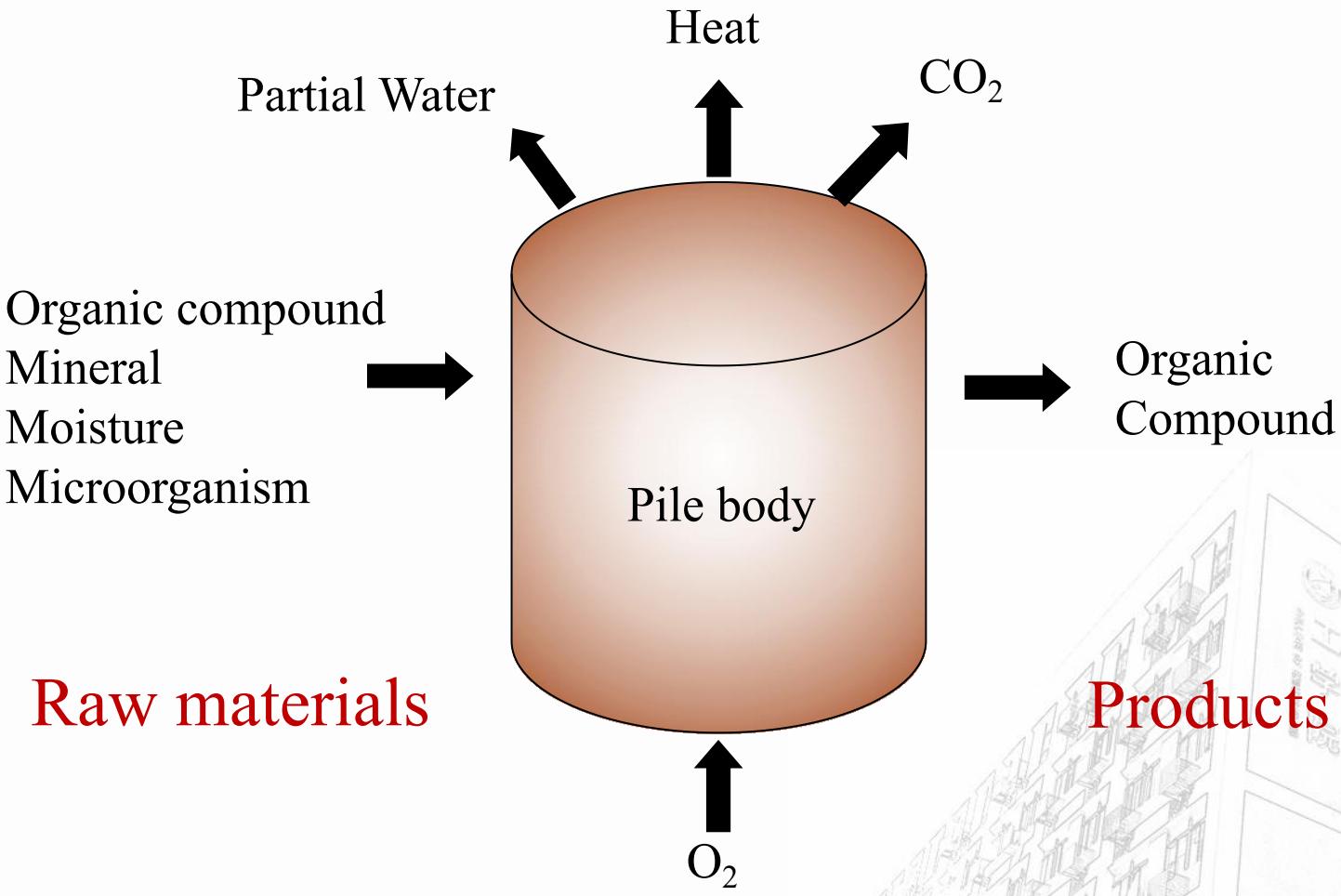
High temperature Aerobic Composting

Basic Principles



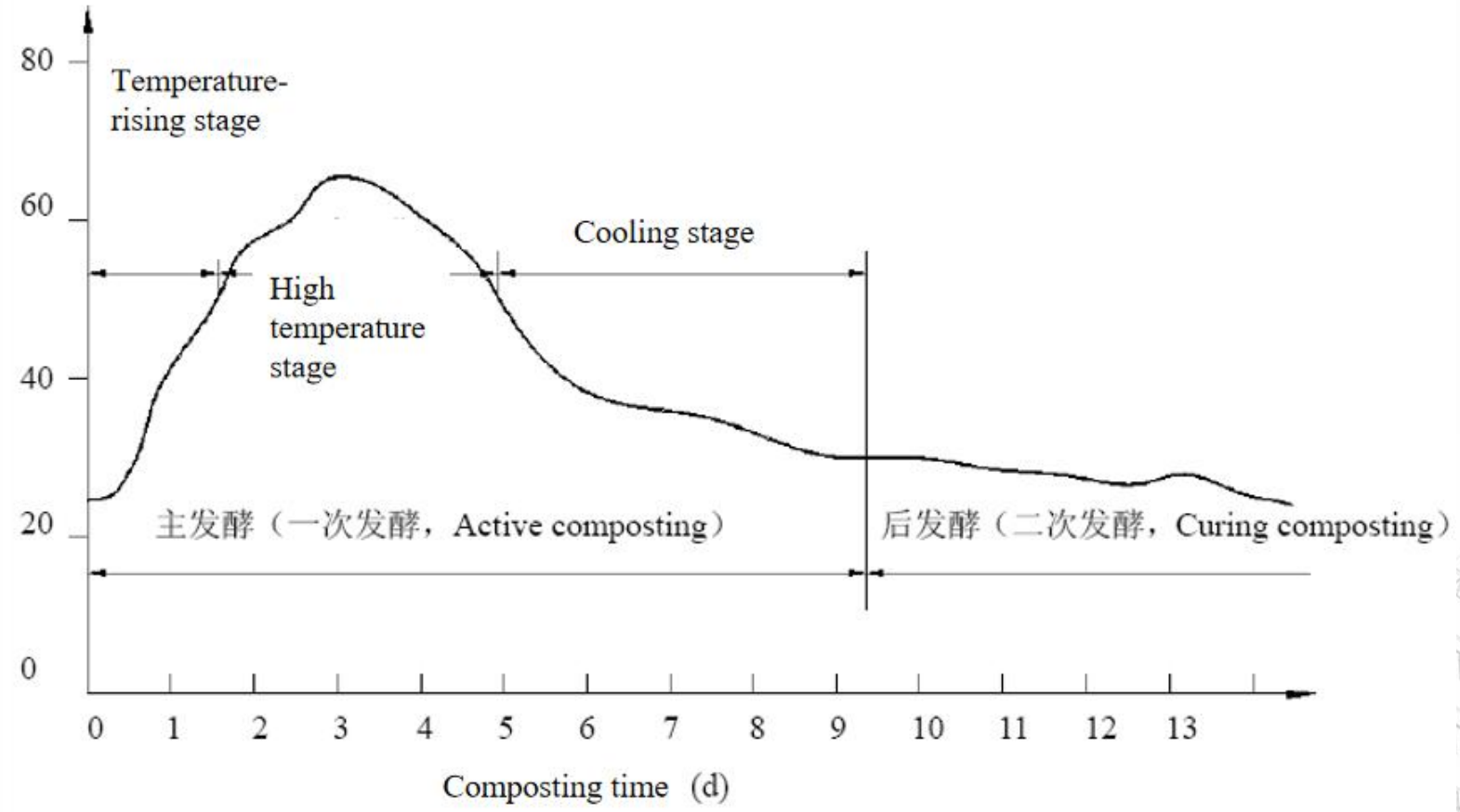
Aerobic Composting Fermentation

Basic Principles by figure



Aerobic Composting Fermentation

Composting process and temperature change



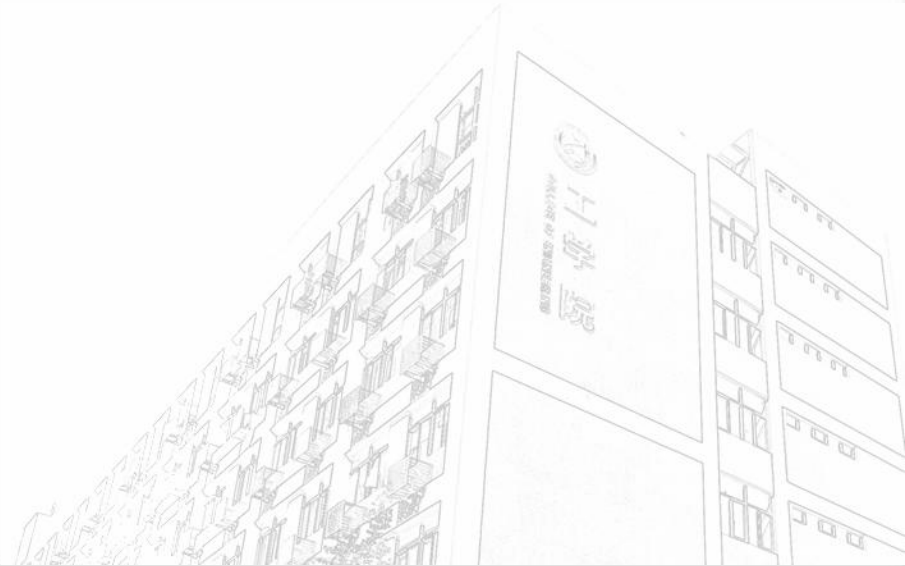
Aerobic Composting Fermentation

High temperature

- Advantages
  - ➢Changing the straw and manure characteristics.(Weight reduction, easy transport and storage.)
  - ➢Reducing the contamination risk.
  - ➢Killing the bacteria.
  - ➢Avoiding the disease
  - ➢……

How to do?

Aerobic Composting Fermentation

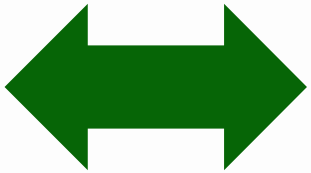


Aerobic Composting Fermentation

Pay attention on Influencing Factors

- 1）Moisture
- 2）The ratio of carbon to nitrogen

  C/N
- 3）PH Value
- 4）Organic matter content



Raw material
Straw
manure

- 5）Oxygen Content
- 6）Temperature

Composting process

Aerobic Composting Fermentation

Pay attention on Influencing Factors

- 1）Beginning Moisture : **50%-60%**
- 2）The ratio of carbon to nitrogen C/N: **20～35**
- 3）PH Value : **7.5-8.5**
- 4）Organic matter content: **20%-80%**

- 5）Oxygen Content : **5%-15%**
- 6）Process Temperature: **45℃-65℃**

How to Control Influencing Factors?

Aerobic Composting Fermentation

Aerobic Composting Fermentation

Pay attention on Influencing Factors

- 1） Moisture
- 2） The ratio of carbon to nitrogen C/N
- 3） PH Value
- 4） Organic matter content
- 5） Oxygen Content
- 6） Temperature

1) Get the characteristics of raw materials, by Lab analysis or by book
2) Simple calculation for the characteristics of compost mixing.
3) Make a plan for mixing ratio of straw and manure.

Loose the mixing composting properly!!

Why the data for Influencing Factors

Influencing Factors -Moisture

- Initial moisture content of compost:
  - 50%-60%
- Reasons
  - Too low water is not conducive to microbial growth. If the water content is less than 10-15%, the metabolism of bacteria will generally stop.
  - Too high water is easy to block the gap in the stack, lead to anaerobic fermentation.

Why the data for Influencing Factors

The ratio of carbon to nitrogen C/N

- Initial C / N ratio of compost:
  - 20～35
- Reasons
  - Fermentation process is the activity of microorganism
  - The consumption for C and N is different.
  - This is the best condition for life cycle of microorganism

Why the data for Influencing Factors

Influencing factors -Oxygen Content

- Appropriate oxygen content of compost
  - 5%-15%
- Reasons
  - If oxygen content less than 5%:

    It will cause anaerobic fermentation and produce odor.
  - If oxygen content higher than 15%:

    It will cool the compost reactor and lead to the survival of a large number of pathogens (bad bacteria).

Why the data for Influencing Factors

Influencing factors -Temperature

- Suitable temperature range for composting process:
  - 45℃-65℃
- Reasons
  - If over 65 degrees:

    It will Inhibit microbial growth.
  - If the temperature is too low:

    The purpose of aerobic composting can not be achieved

Why the data for Influencing Factors

Influencing factors -Temperature

Suggested temperature and Days maintained

Country	Temperature	Days（d）
China	50~55	5~7
Austria	65	6
Belgium	60	4
Denmark	55	14
France	60	4
Italy	55	3
Holland	55	2

Why the data for Influencing Factors

Influencing factors -PH Value

- The pH range of composting raw materials shall meet:
  - 3-12
- Suitable pH for composting at high temperature stage:
  - PH 7.5-8.5

    Microorganisms have maximum decomposition abitity
  - PH Can be adjusted by lime

Why the data for Influencing Factors

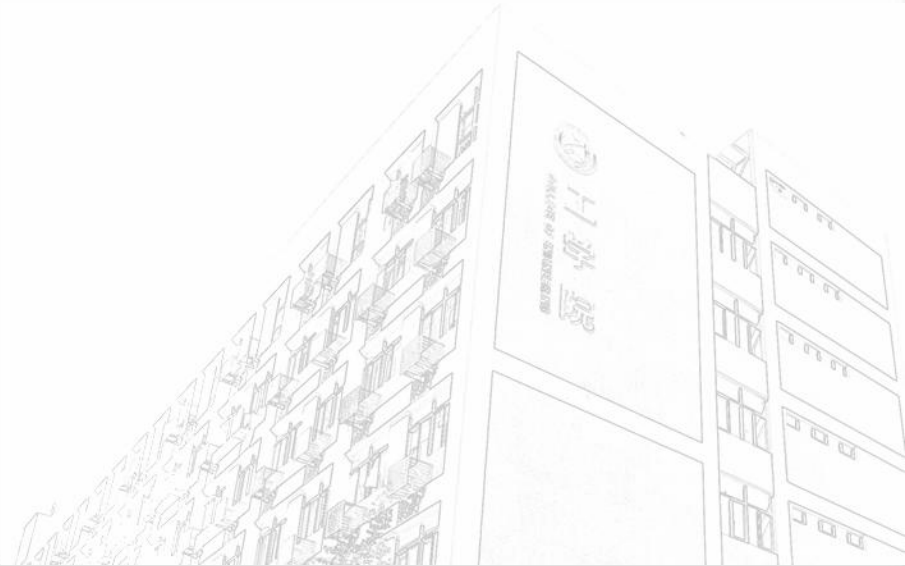
Influencing factors -Organic matter content

- Suitable range of organic matter content in composting process:
  - 20%-80%
- Reasons
  - Less than 20%

    The heat generated in the composting process is too low, which can not reach a high-temperature decomposition.
  - Above 80%

    The composting process requires a lot of oxygen, not easy to control, often produce odor.

Explain the practical skills through specific composting examples



1. Fermentation of straw and livestock manure

1）Raw material preparation

- Dry Wheat Straw: Carbon content is about 50%
- Cattle manure： Nitrogen is about 0.4%

100 kg Dry Wheat Straw + **416kg** Cattle manure

Reach a proper C/N as 30

1. Fermentation of straw and livestock manure

2) Compost site selection:

The compost fermentation site is best selected in a flat place, not windy, and sunny side.

Fine soil is paved at the bottom of the pile

A layer of straw can be paved on it.

1. Fermentation of straw and livestock manure

3) Straw treatment:

Crush the straw to 3 ~ 4 cm. If it is dry straw, add water and fully mix it to make the straw absorb water until the water content reaches 60% ~ 80%.

If it is fresh straw, adjust the water adding

If the moisture of fresh straw is high than 80%, Air drying

1. Fermentation of straw and livestock manure

4) Livestock manure treatment:

If moisture content is about 50%, it can be directly used for subsequent fermentation.

If it is dry manure, add water in the ratio of 1:1 to mix evenly.

If moisture content is high than 50%, Air drying

1. Fermentation of straw and livestock manure

5）Raw material mixing:

The broken straw and manure shall be fully mixed and piled into a long ridge 1.5 ~ 2.5m wide and 1.4 ~ 1.6m high.

If in winter, the top can be covered with semi-wet straw.

If it rains, it can be covered with plastic film, but it does not need to be sealed for aerobic fermentation. After the rain, uncover the plastic film in time.

1. Fermentation of straw and livestock manure

6）Fermentation process control:

Generally, the material will be fermented within 1 ~ 2 days (slower in winter), and the internal temperature can reach more than 50 ~ 70 ℃.

After the third day, it is recommended to loosen, such as inserting a wooden stick or long rake into the material for different places.

- After 2-3 days, it can be loosened again, and the fermentation can be successful in about 10 days.

1. Fermentation of straw and livestock manure

- **Signs of successful fermentation:**

The temperature remains unchanged

The material has no odor of feces

The pile is full of a large number of white hyphae.

Several points needing attention

- 1) Compost fermentation is aerobic fermentation and must not be sealed. If you need to seal with plastic film in order to keep warm in winter, should also uncover the loose pile of film regularly.

- 2) Loose node: each time the fermentation produces a high temperature of more than 50 degrees, the loosening treatment can be carried out after the temperature drops;

- 3) Pay attention to rain: rain proof devices can be prepared around the pile;

Skills to judge whether the fermentation is good or bad

- Observe the fermentation temperature. The higher the temperature, the better. The longer the high temperature is maintained, the better.
- Observe the straw after fermentation. The straw is easy to be broken and has a certain white hyphae means a good fermentation.

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Lab practical composting process

Performed for Show

1. Fermentation of straw and livestock manure

Experimental raw material

Fresh pig manure

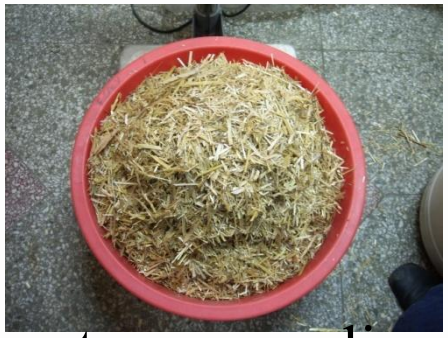
Long wheat straw（2～5cm）

1. Fermentation of straw and livestock manure

2. Composting Experimental Process

Pig farm

Manure sampling



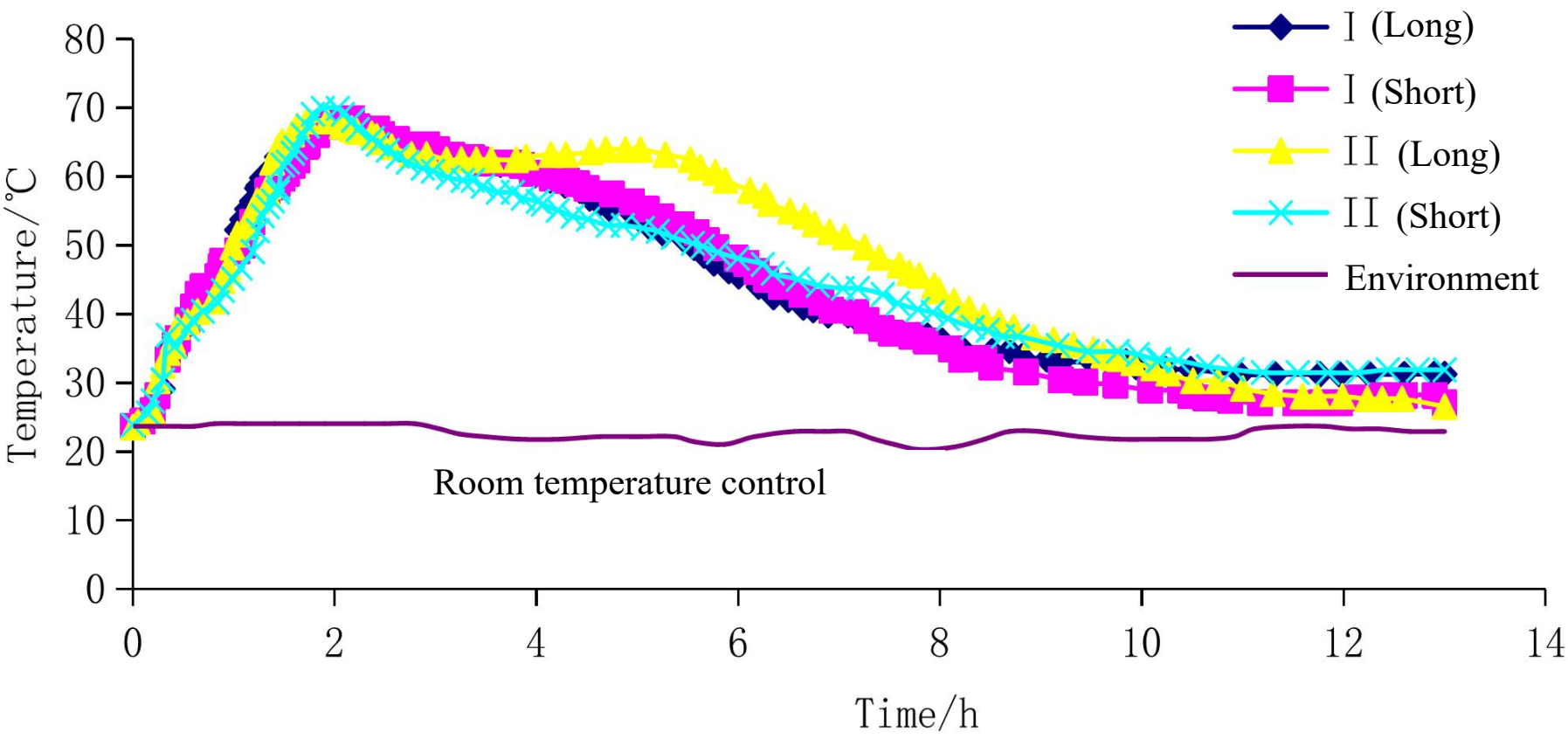
straw sampling

Artificial mix straw and manure

Compost by a lab reactor

1. Fermentation of straw and livestock manure

3. Reactor temperature change



1. Fermentation of straw and livestock manure

4. Color and Odor Changes

(a) Test 1

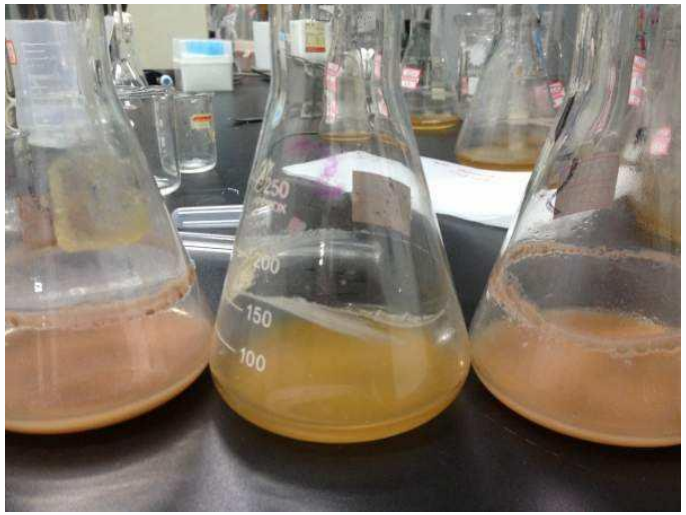
(b) After fermentation

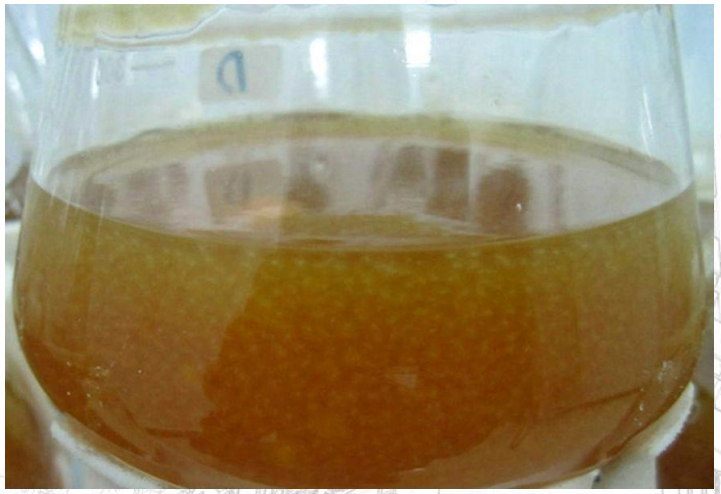
(c) Test 2

(d) After fermentation

2. Making Straw Manure Water Fertilizer

- Put 2000 kg of various straw into a 3000 kg water tank
- add 100 kg of animal manure and urine
- cover with a simple film for 7-10 days
- Then obtain about 3000 kg of liquid organic fertilizer.





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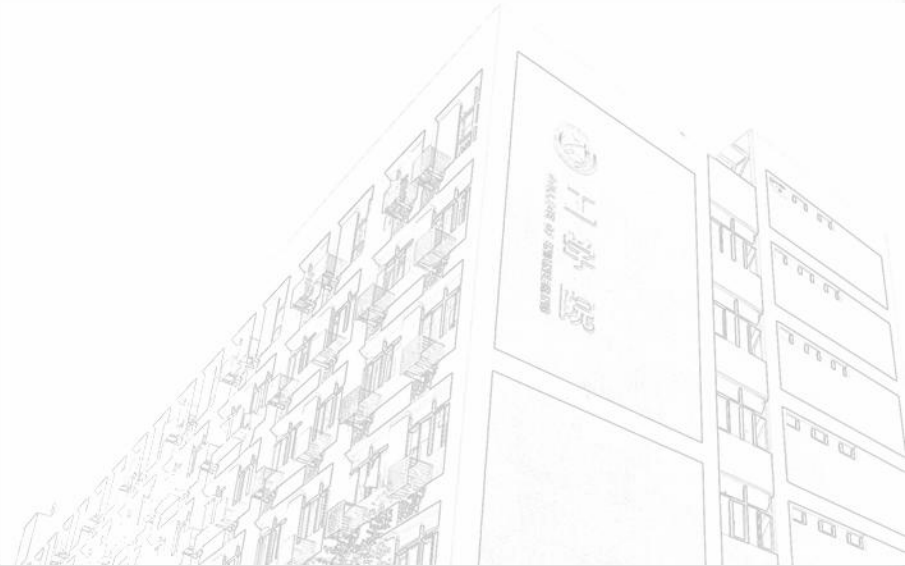
Large scale composting Technology

Common Engineering examples



Stacking composting(Since 1950s)

- Composting materials are stacked in strip stacks, which can be one or multiple parallel strip stacks.
- The section of the stack can be trapezoid, irregular quadrilateral or triangle.

Stacking composting(Since 1950s)

- Characteristic:

The aerobic state in the stack body is realized by turning regularly.

- Turning mode:

Manual or mechanical

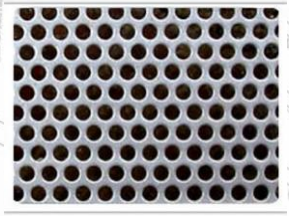
Stacking composting(Since 1950s)

Mechanical turning is going, hot steam is visible

Static composting (since 1970s)

- Composting materials are stacked in large quantities.
- Ventilation system is equipped .

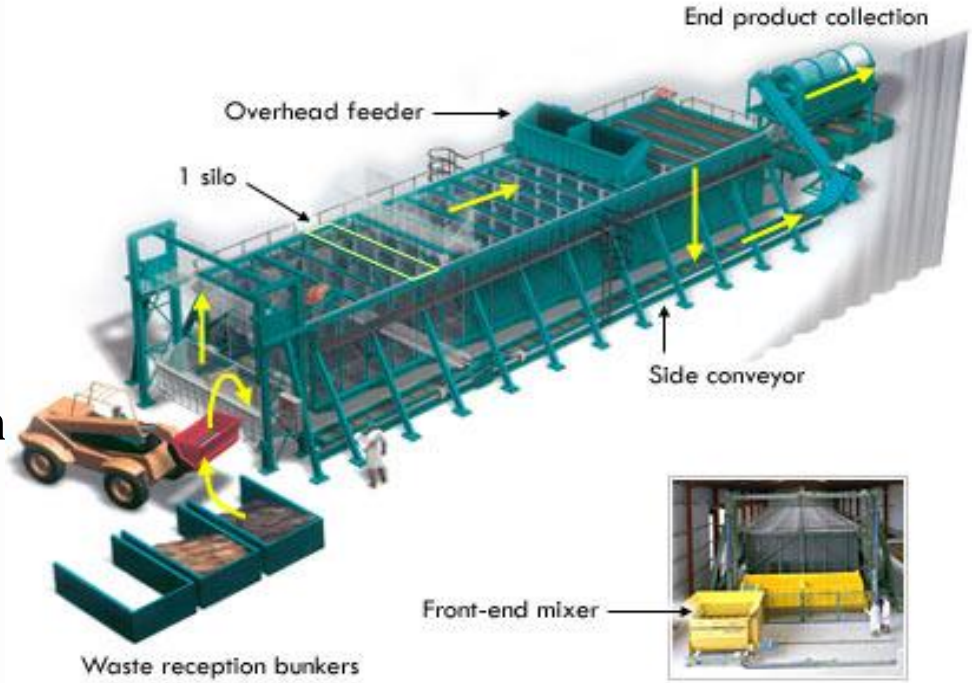
- Key point:
  - There is no material turnover in the composting process.
  - The aerobic state in the reactor is provided by ventilation through the blower.



Trough composting (Modern engineering mode)

- Characteristic:

  - The composting process takes place in long and narrow tanks.
  - Combination of controlled ventilation and regular turning.
  - A turning machine can move on the track.
  - When the fermentation finish, Materials are just moved out of the tank



Trough composting (Modern engineering mode)

Shandong Zhucheng golden land organic fertilizer Co., Ltd

Trough composting workshop

Trough composting (Modern engineering mode)

Shandong Zhucheng golden land organic fertilizer Co., Ltd

Trough composting workshop-inside

Material: straw and poultry manure

Reactor composting(Since 1980s)

- Characteristic:
  - Composting is performed in a sealed reactor
  - Forced ventilation is adopted with little or no turning.
  - Sensors can be used for temperature control, O^2 control.

- Advantage
  - Can not be affected by weather, no odor pollution.
  - Better system control.

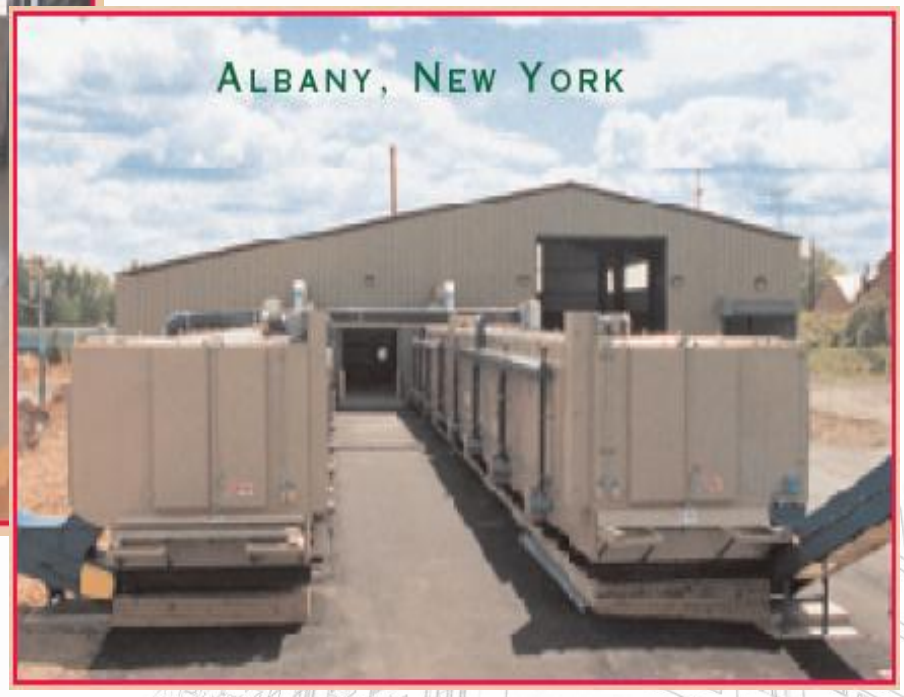
Reactor composting(Since 1980s)

Domestic, small scale

Reactor composting(Since 1980s)

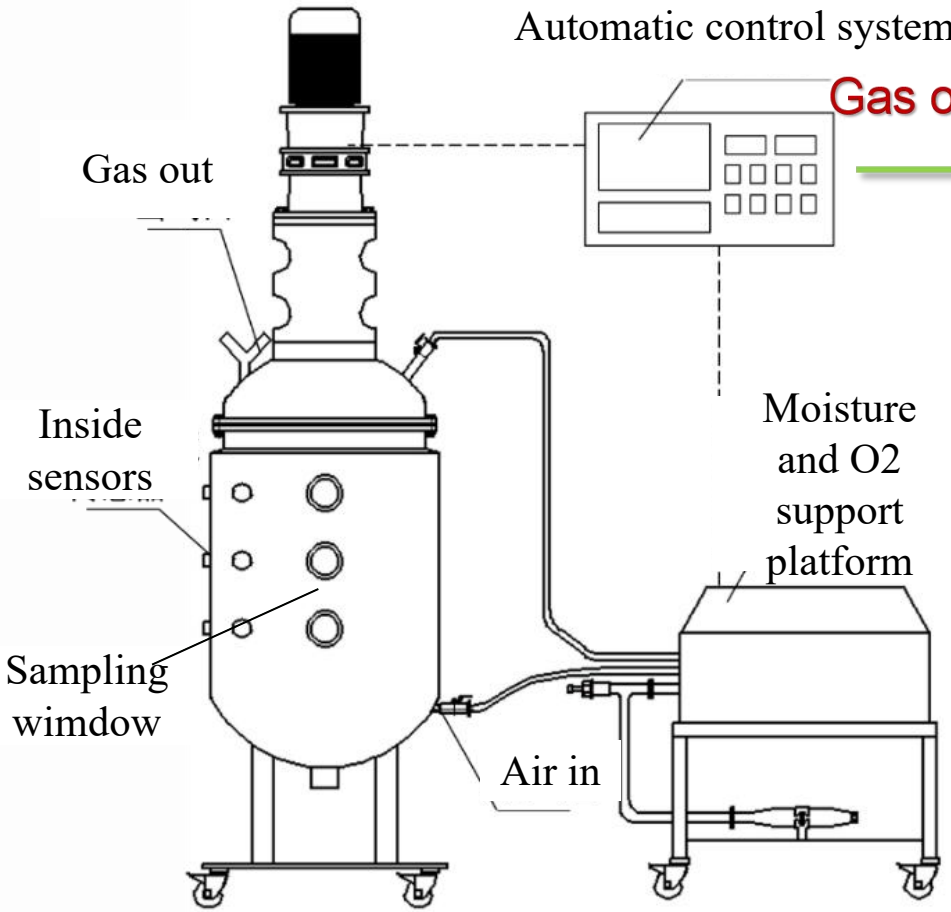
Movable reactor

Reactor composting(Since 1980s)



Large factory scale

Reactor DIY(customized)



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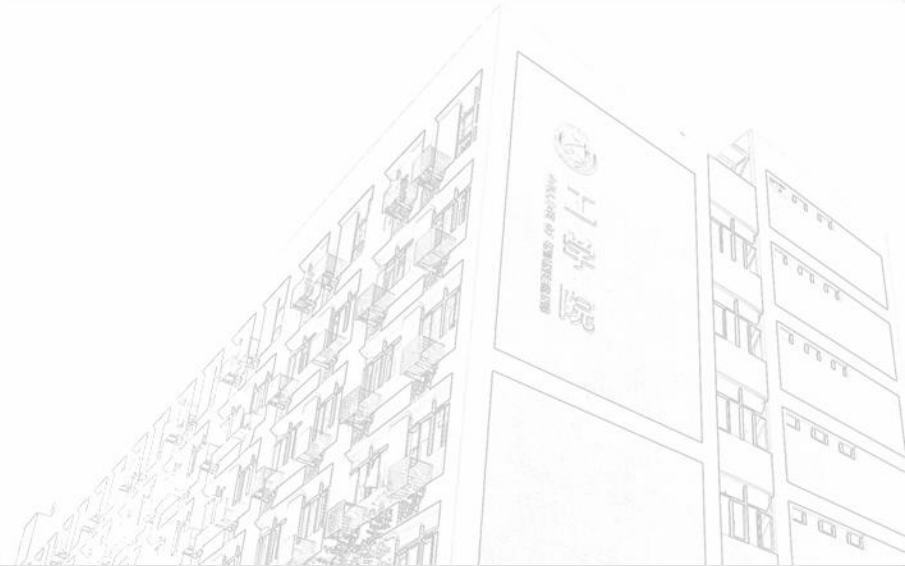
Evaluation of Composting Fermentation



1. Standard for composting product

NY Industry Standard (NY 525-2002)

- **Appearance**

Organic fertilizer is brown or grayish brown, grayish white (color)

- pellets or powder,
- without mechanical adulteration
- No odor, no longer attract mosquitoes
- show loose structure.

1. Standard for composting product

Items	unit	Standard limit
impurity	%	≤3
particle size	mm	≤12
Ascaris egg mortality蛔虫卵	%	95~100
Coliform value 大肠杆菌		0.01~0.1
cadmium(Cd)	mg/kg	≤3
mercury(Hg)	mg/kg	≤5
Lead (Pb)	mg/kg	≤100
chromium(Cr)	mg/kg	≤300
arsenic(As)	mg/kg	≤30
Organic matter (C)	%	≥10
Nitrogen(N)	%	≥0.5
phosphorus(P)	%	≥0.3
potassium(K2O)	%	≥1.0

1. Standard for composting product

Table 1 Technical index of organic fertilizer

Technical index	Range
Organic matter content (on dry basis)/(%)	≥ 30
Total nutrients (N+P+K content) (calculated on dry basis)/(%)	≥ 4.0
Moisture content/(%)	≤ 20
pH value	5.5-8.0

Germination test with cucumber seeds

Phytotoxicity analysis

Take 10g compost product + 100 mL water, mixing, filtering to get test liquid. Put the seed in the liquid plate for test (30℃, 48h)



Germination test of sensitive plant seeds is the most direct and rapid method to test the fertilizer whether can be used.

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Application Skills of Organic Fertilizer

Application Skills of Organic Fertilizer

- 1) Ensure fully decomposed and fermented before application: the decomposed organic fertilizer has high nutrient conversion rate and will not damage vegetable seedlings;

- 2) Only organic fertilizer is applied. It is recommended to use fermented fertilizer 60% + vegetable garden soil 40%;

- 3) Organic fertilizer + chemical fertilizer. Generally
- 1:1 or 1:2 ratio.

Application Skills of Organic Fertilizer

4) Apply organic fertilizer deeply or cover it into the soil as far as possible, reduce the loss, waste and environmental pollution of fertilizer;

5) The basic fertilizer should be applied deeply or early at the seedling stage, especially the application amount of nitrogen fertilizer at the seedling stage should be strictly controlled;

6) The lack of organic matter in soil is easy to cause low yield. Applying more organic fertilizer can not only improve vegetable yield and quality, but also supply green products.

Application skill for Straw Manure Water Fertilizer

- 100 kg liquid fertilizer + 300 kg water, mixing completely
- If possible, add 2 kg of urea will be excellent.
- It can be used for soil fertilizer, also can be fertilize on vegetable leaves.

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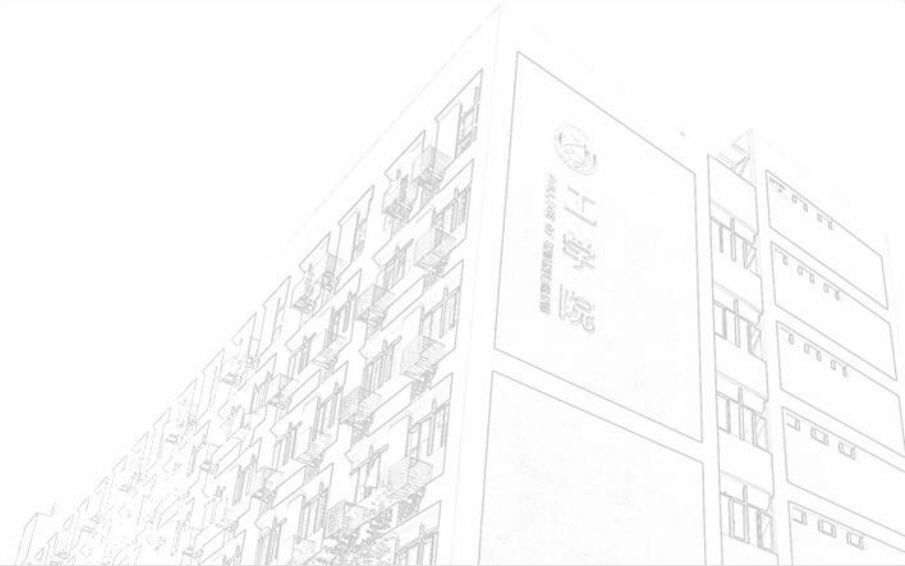
A quick glance on Modern manufacturing process and machinery



Organic fertilizer modern manufacturing process

Modern manufacturing process and machinery

Pretreatment Equipment - Modulation Mixing Device

Modern manufacturing process and machinery

Tipping equipment

- It is mainly used for high temperature aerobic fermentation of livestock manure and straw.

Modern manufacturing process and machinery

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Crushing Equipment

- It can crush inorganic fertilizers and organic raw materials with moisture content below 10%.

Dispensing Equipment

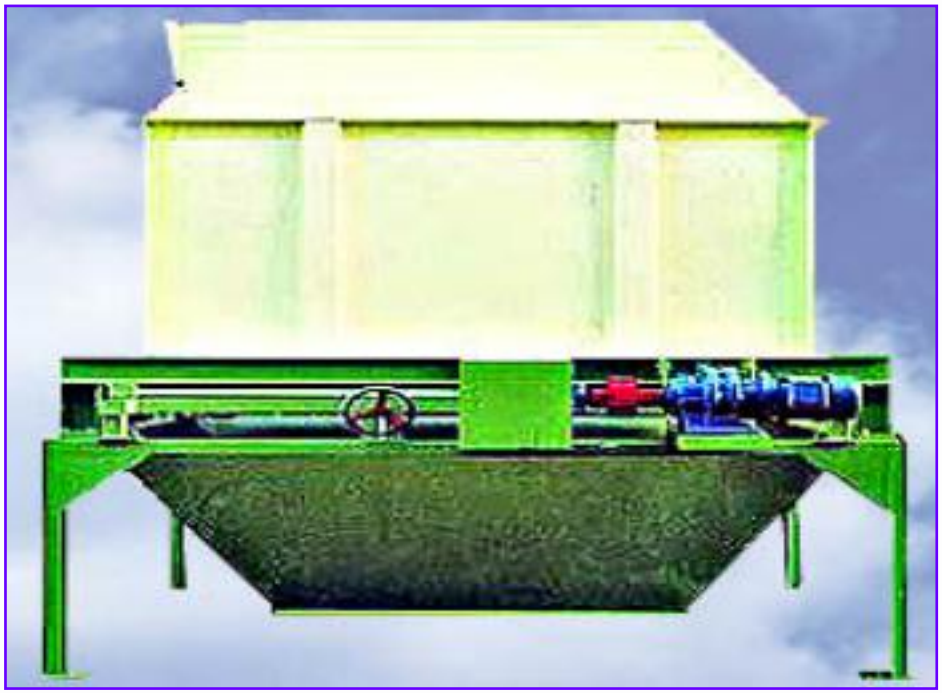
- It is applied to dynamic metering and batching control of fertilizer.

Modern manufacturing process and machinery

Pelletizer

- It is mainly used for granulating the fertilizer after straw and livestock manure fermentation. The materials input to the disc are sprayed with an appropriate amount of liquid by the atomizing nozzle and rotated by the granulation disc to make granular finished products.

Cooling and Drying Equipment -CCS Countercurrent Cooler



- The air flow direction is opposite to the material flow direction to take away the moisture in the material and reduce the material temperature.

Modern manufacturing process and machinery

Screening Equipment - Drum Screening Machine.

- It is mainly used for screening powdery or granular materials in fertilizer plants.

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Thank you very much for your attention!

Please contact me for any question!

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