Using agro-wastes as basic raw materials for cultivation of edible mushrooms in Taiwan

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The output of agro-wastes in Taiwan

According to the estimation made by the Council of Agriculture, Executive Yuan, Taiwan ROC, the total output of agricultural wastes estimated amount to 4.6 million MT in the year of 2007.

The major parts of agro-wastes are from rice straws, livestock and poultry manure, and the yearly output for rice straws alone amounts to 1,363,458 MT, while from livestock and poultry manure reaches to 2,437,242 MT (Table 1). Thus, the output of these two agro-wastes combined reached 3,800,700 MT which account for of 86.05% of the total agro-waste production in Taiwan. The agro-wastes from animal sources livestock and poultry have been properly treated and from rice straws for making composts prior to use as basic raw materials for mushroom cultivation. Nowadays, agro-wastes from rice straws if not use for mushroom raw cultivation materials, most of the rice straws are ended up directly plowed under in situ or burned. It deems important to recycling use of rice straws in paddy rice production areas either for use in growing edible mushrooms or regeneration resource of bio-energy, thus to avoid wasteful of lignocellulosic resource indeed.

Estimated over 300,000 MT of food could be generated from the use of rice straws alone as raw materials for the production of edible mushrooms in Taiwan

According to the method of estimation reported by Professor S. T. Chang(2007), If we could use one third of the output of rice straws, we could produce 306,778 MT of edible mushrooms based on the calculation of an average of 67.5% of biological efficiency (fresh weight of mushroom divided by the dry weight of substrate). However, at present we are only able to produce about 2,000 MT of fresh mushroom products to use rice straws as basis raw materials for cultivation of mushrooms. This shows the potential of rice straws alone remains profoundly huge, optimistic challenges and opportunities to be explored in the transformation of recycling use of agro-wastes in the production of highly valued mushroom products as food sources in the future.

According to Chiu et al.(2000) the biological efficiency of a cultivated mushroom strain ranges from 17 to 250%, thus mushroom cultivation can well be viewed as an effective mean to extract resources left behind in agro-waste.

This waste bioconversion process is simultaneously also a sound environmental protection strategy too. Besides, most edible mushrooms are regarded as a nutrient and healthy food due to their nutriceutical value and their pharmacological potential (eCAM 2005:2(3)285-299). More than ever, there are ample opportunity and challenge ahead of to tackle and to study how to convert rice straw efficiently into highly valued products by growing edible or medicinal mushrooms, among others.

The most extensively used agro-wastes for the production of edible mushrooms in the world

- Wheat and rice straw
- Cotton seed hull and cotton waste
- Sawdust or wood chips
- Wheat and rice bran
- Chicken and horse manure

- Corn cob
- Sugarcane bagasse

Table 1. Output of major agro-wastes in Taiwan in 2007

Kind of waste	Production		Properly treated	
	Amount (ton)	%	Amount (ton)	%
Rice hull	272,691	6.17	272,691	100
Rice straw	1,363,458	30.87	1,363,458	100
Spent sawdust	152,000	3.44	152,000	100
Oyster shell	169,194	3.67	162,000	95.75
Livestock and poultry manure	2,437,242	55.18	2,225,000	91.29
Food processed waste	22,400	0.51	22,400	100

Other agro-wastes have also been used or tried to be used, such as

- Cotton stalk
- Coffee pulp
- Soybean straw
- Banana pseudo stem
- Waste paper
- Grasses
- Groundnut haulms
- Jute stick and caddis
- Water hyacinth
- Powdered oil seed cakes (sunflower, cotton and soybean)
- Sorghum stover

The most popular agro-wastes for mushroom production in Taiwan

- Rice straw
- Sawdust or wood chips
- Cotton waste

- Chicken manure
- Rice and wheat bran

Estimate value generated from recycling use of agro-wastes for mushroom production in Taiwan

These agro-wastes have been converted into a great number of edible and medicinal mushrooms creating a total value of more than US$0.24 billion per year contributing to the prosperous economics of rural areas in Taiwan.

Basic raw materials for modern production of mushrooms in Taiwan

- Cotton waste from a spinning mill > *Volvariella volvacea*
- Rice straw > *Agaricus bisporus, A. bitorquis, A. braziliensis, Clitocybe nuda, Coprinus comatus*
- Sawdust or wood chips > *Flammulina velutipes, Lentinula edodes, Pleurotus spp., Auricularia spp., Agrocybe cylindracea, Hypysizigus marmoreus, Ganoderma spp.*

Advantages of using cotton waste as basic material for growing straw mushroom

- This mushroom can be grown in a plastic mushroom house without a sophisticated climatic control
- Basic raw material needs no fermentation and nutrient supplement
- It can be grown successively 3 to 4 times without necessity to remove spent substrate after each crop.
- Short production cycle
- Cost effective—a. efficiency of the use of mushroom house, b. cheap raw material, c. low labor cost, d. low energy cost.

  Ps: Prices of cotton waste--US$0.03/kg
  Prices of heavy oil—US$0.45/kg
  Labor cost—US$48.48/day/person

Successive growing of 3 mushroom species in the same mushroom house

Straw mushroom (Oct.) →Common white mushroom (Nov. to Feb.) → Straw mushroom (Mar.) → Hot mushroom (April to July) → Straw mushroom (Aug.) → Straw mushroom (Sep.) → Cooking out and removing spent substrate for a new crop of straw mushroom.

Procedures for growing straw mushroom including substrate preparation

- 1st day—loosening, spreading, wetting and pressing of cotton waste.
- 2nd and 3rd day—percolation of wetted cotton waste
- 4th day—filling the wetted cotton waste onto mushroom bed with a thickness of ca.10cm on the top of spent rice straw compost, then closing doors and windows
- 5th day—bed temp. going up to 30-40℃
- 6th day—pasteurizing at 70℃ for 12 hrs or 62-65℃ for 24 hrs.
- 8th day—spawning (open corner windows one night before)> air temp. 30-32℃, bed temp. 37-38℃, closing doors, central and corner windows after spawning.
- 13th or 14th day—spraying water onto mushroom bed and opening doors for 1 day.
- 14th or 15th day to 16th or 17th day—opening corner windows
- 17th or 18th day—appearance of pinheads
- 22th or 23th day—harvesting 1st flush
- 28th or 29th day—harvesting 2nd flush

Ps: Total production—1.2 to 1.5 ton/165 square meters

Rice straw as basic material for growing mushrooms in Taiwan

- There are three types of mushroom production using rice straw as basic material according to the combinations of making compost (Phase I and Phase II), spawn running (Phase III) and cropping.
- Phase I—stacking and composting
- Phase II—pasteurization and conditioning

- Phase III—spawning and spawn running

Table 2. Three types of mushroom production using rice straw compost

Type	Phase I done	Phase II done	Phase III done	Cropping done
1	outdoors	in plastic mushroom house	in plastic mushroom house	in plastic mushroom house
2	outdoors	in tunnel	in tunnel	in climatically controlled room
3	in tunnel	in tunnel	in tunnel	in climatically controlled room

Table 3. Suggested formula for rice straw compost in Taiwan

Ingredient	%
Air dried rice straw	100
Chicken manure	20
Rice bran	4
Soybean meal	1
Ammonium sulfate	2
Calcium super-phosphate	3
Calcium carbonate	2
Gypsum	3

Preparation of rice straw compost and the outdoor processes to be carried out for Phase I in Taiwan

- 1st day—Cutting (2.5-5.0 cm) and wetting of rice straw
- 2nd to 5th day—Wetting of rice straw
- 6th day—Adding all ingredients except soybean meal and gypsum, stacking of mixture into a pile
- 9th day—First turning, adding soybean meal and gypsum, making a pile as above
- 11th day— Second turning, making a pile as above

- 13th day—Turning and mixing with rice bran, then filling

Preparation of rice straw compost and the outdoor processes to be carried out for Phase II in a plastic mushroom house and in tunnel in Taiwan

- 15th day —Pasteurizing at 58 - 60℃ for 6 to 8 hrs
- 16 to 17th day —Reduce compost temp. to 52℃ in two days
- 18 to 21th day —Control compost temp. at 48 - 52℃
- 22 to 24th day — Control compost temp. at 45 - 48℃
- 25 to 26th day — Reduce compost temp. to 25 - 27℃ for spawning

Procedures for growing *Agaricus bisporus* from spawning to harvesting in a traditional plastic mushroom house in Taiwan

- 26th day — Mixing spawn grains with compost as thoroughly as possible, closing the doors and windows, wetting the ground and walls of mushroom house, re-circulating room air.
- 27 to 39th day — Spawn running, keeping compost temperature not over 27℃, maintaining RH at 90-95%, ventilating once in the morning if compost temperature rising not over 27℃.
- 40th day — Casing with wetted disinfected casing soil with a layer of 2.5cm, closing the doors and windows, wetting the ground and walls of mushroom house, re-circulating room ai
- 41 to 47th day — Casing running, keeping compost temperature not over 27℃, maintaining RH at 90-95%, ventilating once (about 30 min) in the morning if compost temperature rising not over 27℃, gradually increasing the water content of casing soil, when 70-80% of the surfaces of casing layer covered with mushroom mycelium, it is ready for scratching.
- 48th day — Wetting heavily in the morning, scratching the casing surfaces down to the interfaces between compost and casing layer in the afternoon or next morning.
- 49 to 50th day — Re-growing of mycelial fragments,

maintaining high RH and CO_2 in the mushroom house, re-circulating the air inside the house if necessary, not introducing fresh air, not spreading water onto casing surfaces.

- 51th day — Wetting heavily, introducing fresh air and re-circulating room air using ventilator and extract fan to lower both temperature and CO_2 as well as RH to promote pinning, keeping surfaces of casing layer moisten by spraying water lightly if it showing a little bit too dry.
- 52 to 58th day — Keeping aerating until appropriate amount of pins and small fruit-bodies formed.
- 59 to 65th day — When pins reaching the size of a pea, spraying water as much as they need, maintaining proper concentration of CO_2(900-1200ppm) and RH at 85-90%, the 1st flush mushrooms will be ready for harvest 20 to 25 days after casing depending on the mushroom strains to be used.

Preparation of rice straw composts and the suggested processes to be carried out for Phase I, II and III, in a tunnel in Taiwan

- 1st day — Cutting and wetting of rice straw
- 2nd to 5th day — Wetting of rice straw
- 6th day — Mixing all ingredients of compost and filling the mixture into a tunnel for conducting phase I
- 7 to 9th day — Compost temp. going up to 75-80℃, controlling oxygen level not below 10%
- 10th day — Moving out Phase I compost, mixing with 5% of Phase II compost (previously made) and re-filling in a tunnel
- 11 to 12th day — Controlling compost temp. at 48 - 52℃
- 13th day — Pasteurizing at 58-60℃for 6 to 8 hrs
- 14 to 15th day — Reducing compost temp. to 52℃ in two days
- 16 to19th day — Controlling compost temp. at 48 - 52℃
- 20 to 22th day — Pasteurizing at 58-60℃for 6 to 8 hrs
- 23 to 24th day — Reducing compost temp. to 52℃ in two days

Growing procedures for *Agaricus bisporus* from spawning to harvesting in an environmentally controlled room

- 25th day — Moving out Phase II compost for spawning and refilling of the spawned compost for spawn running in a tunnel (Phase III).
- 26 to 37 day — Spawn running, maintaining compost temp. at ca 25℃ by air conditioning unit and re-circulating the air in the tunnel, supplying fresh air if it needs.
- 38th day — Moving out of Phase III compost for refilling into iron boxes, then for casing with disinfected soil, stacking compost boxes and moving them in an environmentally controlled room. Maintaining the compost temp. not over 27℃.
- 39 to 40th day — Re-growing of fragmented mycelia, maintaining compost temp. at 27℃, introducing fresh air if necessary, keeping RH at 90-95%, re-circulating the room air.
- 41 to 45th day — Spraying water onto casing layer in consecutive three days, keeping compost temp. not over 27℃, keeping RH at 90-95%, re-circulating the room air.
- 46th day — Spraying water heavily in the late afternoon, maintaining high CO_2 and high RH of the room.
- 47th day — Scratching the casing layer down to the interfaces between compost and casing layer.
- 48 to 49th day — Re-growing of fragmented mycelia in the casing layer, maintaining high CO_2 and high RH of the room, maintaining compost temp. at 27℃.
- 50 to 54th day — Reducing CO_2 to 900-1000ppm by introducing cooled fresh air, lowering air temp. to 15℃, in 3 days, reducing RH to 85-90% for pinning.
- 55 to 57th day — Appearing of pinheads and gradually developing into small fruit-bodies reaching the size of peas, raising air temp. to 16℃.
- 58 to 63th day — Spraying water heavily as necessary, maintaining air temp. at 16℃ until harvesting the 1st flush.

Characteristics of mushroom growing in a traditional plastic mushroom house with rice straw composts and cotton wastes in Taiwan

- Growing different mushroom species in different seasons to adapt different climatic conditions increasing the efficiency of using mushroom house and reducing pests and diseases.
- Supplementing organic nutrients to increase microbial activity to give off heat saving energy cost.
- Growing the second mushroom species without removing the spent substrate of the previous crop saving both raw material and labor cost.
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- All mushroom houses are family owned, hiring outside employee as few as possible.
- Most mushroom growers are relatively old.

Characteristics of mushroom growing in an environmentally controlled mushroom house with rice straw composts in Taiwan

- Most mushroom houses are family owned, hiring outside employee as few as possible.
- Most mushroom growers are relatively young.
- Most growers cultivate single mushroom species whole year round.
- All mushroom farms are small, not more than 10 cropping rooms, each room with not more than 200 square meters of mushroom bed surfaces.
- No big machine for the operation of various works in the farm.
- It is not necessary to supply live steam during Phase I and Phase II to keep the optimum air or compost temperature except for cooking out of the spent substrate at the end of cropping.

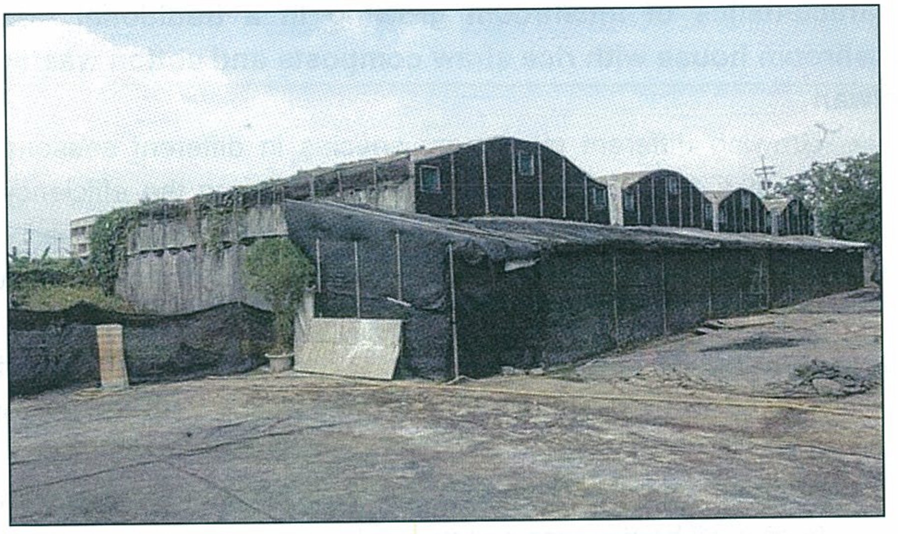

Fig. 1. Traditional plastic mushroom houses for growing straw mushroom or the common white mushroom.

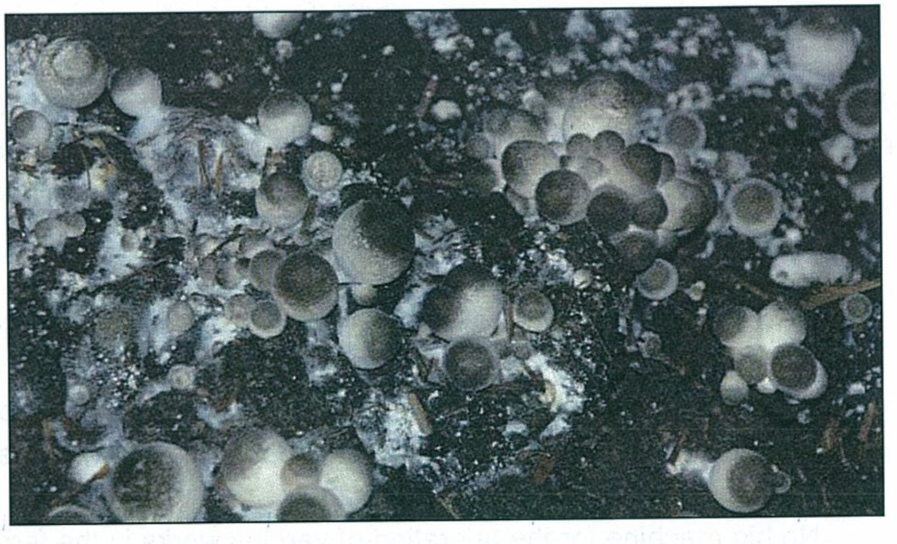

Fig.2.Straw mushroom grown on pasteurized cotton wastes in a traditional plastic mushroom house.

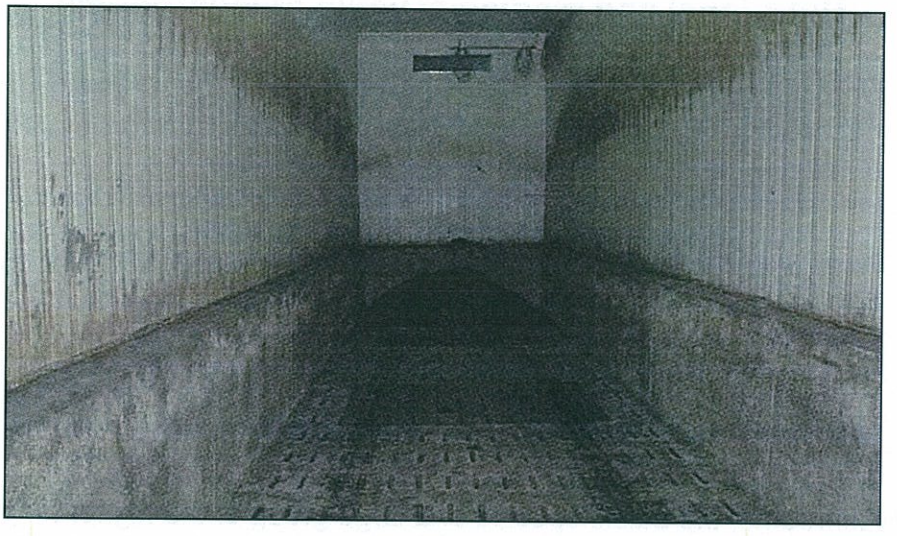

Fig.3. Phase II tunnel for pasteurization and conditioning of phase I compost.

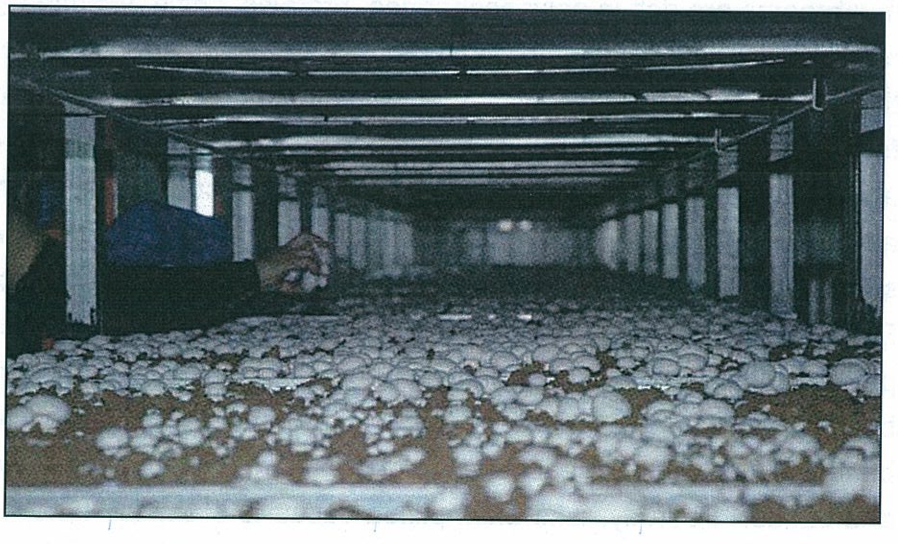

Fig. 4. First flush mushrooms on a mushroom bed.