Development of Integrated Cultivation Machine System for Oyster-Mushroom

K. J. Choe, K. Y. Oh, B. K. Ryu, S. H. Lee, H. J. Park

Abstract: The study aimed to develop a mechanized mushroom growing system for the substrate materials mixing and wetting, materials fermentation and pasteurisation through the design of integrated cultivation machine system for oyster mushroom. The power requirement of the prototype during fermentation operation was measured in the range of 31~33 kg-m and the torque has not so much differ by the kinds and quantity of materials. The work efficiency of conventional method for stacking the heap and turning the heap of cotton waste by tractor rotavator and manual wetting required 78 hours. But the watering, fermentation and sterilisation by the prototype use same operation required 25.5 hours, which can save the operation labour by 67%. The machine can be saved the requirement of heating energy by 63%, and the machine can also be saved the material cost by 44%. It is envisaged that the machine can effectively be used for large mushroom growing farms or joint use mushroom growing group-farmers in a village.

Keywords: Agricultural Machinery, Mushroom Cultivation Machinery, Substrate Material Composting, Mushroom Substrate Production Machinery

Introduction

Nowadays, the oyster mushroom has the largest cultivation area in the country. The cultivation area of oyster mushroom was 737 ha in the 2002, and it occupied 66.8% of total mushroom growing area.

The cultivation of oyster mushroom by farmer has been actively propagated since the development of rice straw bundle use oyster (*Pleurotus ostreatus*) mushroom cultivation method by Rural Development Administration in the 1974. The rice straw bundle making operation is regarded as drudgery for farmer, in addition, the rice harvesting system had been changed from power reaper to combine harvester could not ensure the obtaining proper size of rice straw. Therefore, the oyster mushroom growers have been adopt the cotton waste as the composting material since the 1980s.

The cotton waste composting could be reduced the labor by mechanized operation, however, the cotton waste use mushroom cultivation technology is more difficult than the rice straw bundle use oyster mushroom cultivation method. More over the material cost of the cotton waste is the more high than the rice straw, and the material may more easy contamination by diseases such as Verticillium disease, Penicillium sp. disease etc.

The cotton waste composting operation require heavy duty work such as the watering, stacking the heap and turning the heap and sterilization of composted material in weight of 2.5 ton for standard mushroom growing house that has the mushroom growing bed area of 200 m^2. The current substrate material composting operation has been pointed out to develope towards the production of high quality substrates while reduce the labor input in mushroom production as well. To reduce the requirement of farming labor and production cost in the mushroom growing, the development of integrated cultivation machine system and its utilization technology for oyster mushroom is very important towards the technology development in mushroom growing.

The study aimed to access the feasibility on the input labour reduction in the production of quality substrate and to extend diversify the compost material as well as the development of spawning, spawn growing and substrate loading system.

The authors are **Kwang-Jae Choe**, Senior researcher, National Institute of Agricultural Engineering, Suwon, KOREA, **Kweon-Yeong Oh**, **Byung-Ki Ryu** and **Sung-Hyun Lee**, Junior researcher, National Institute of Agricultural Engineering, **Hwan-Jung Park**, technical advisor, National Institute of Agricultural Engineering. **Corresponding author:** Kwang-Jae Choe, Senior researcher, National Institute of Agricultural Engineering, Suwon, KOREA; e-mail: choikjae@rda.go.kr

Materials and Methods

The prototype designed as fermentation container, the container equipped with mixing screw, speed reduction power train, steam-heating chamber in the bottom, water intake pipe and drainage valves. The substrate material of mushroom mixing mechanism for the machine adopted large size screw shafts attached to bottom of the container.

The compost materials intake from upper site gate, water intake from supply pipe and heating steam supply into below the fermentation chamber and in the space of fermentation chamber. The compost materials are mixed and fermented in the fermentation chamber and mixture screw mixing the different materials during the fermentation of low materials.

The container size of the machine is 6,000 mm length, 2,000 mm width and 2,875 mm height and the machine can receive the composting dry materials of 2,500 kg for one batch.

The fermented and sterilized substrate materials can be discharged at the materials outlet gate by revolution of the screw shaft. The power train of the prototype adopted as following;

Power intake shaft → V-pulley and V-belt → chain and sprocket → spur gear → screw shaft.

The power requirement of the machine was tested with torque-meter (SS-102, 0~100 kgf-m) and the testing unit was installed between tractor PTO and power intake shaft of the prototype. In the material composting test, power source used 3-phase, 6-polar, electric motor and the operating speed of the final drive shaft adopted as 0.9 rpm.

Materials tested are total 2,000 kg in weight and the materials mixture ratio was 40% of rice husker, 30% of cut rice straw of 5 cm size, 30% of cotton waste.

In the primary phase, the machine has operated the screw shaft continuously during materials filling and several hours after the materials filling. The machine operated one hour from every 12 hours during the materials fermentation runs. In the sterilization phase, the machine operated its mixing screw shaft continuously to maintain the uniformity of sterilization temperature.

The capacity of steam boiler was 100 kg/h and the temperature of the fermentation chamber controlled as 50±2C° during fermentation phase, and it was controlled as 65±2C° during sterilization phase by RTD sensor and temperature controller. The experiment was conducted during October and December 2001 in the oyster mushroom growing farm at Poeun, Choong-Puk Province, Korea.

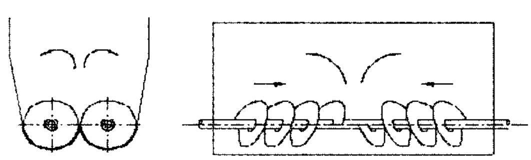
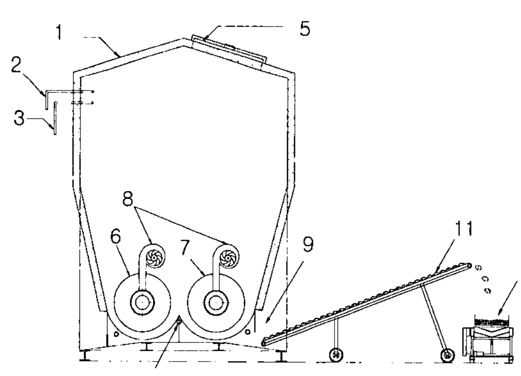


Fig. 1 Dual screw material mixing unit.



1. container
2. water supply pipe
3. 4. steam supply pipe
5. material intake gate
6. 7. mixing screw
8. exhaust blower
9. material discharge gate
10. power train
11. inclined belt conveyer
12. flat belt conveyer

Fig. 2 Prototype for substrate production machine.

Results and Discussion

1. Working system for prototype

The substrate materials mixing, washing, fermentation and sterilization work for oyster mushroom was implemented as following. The working system can be changed during fermentation phase by materials, outdoor temperature and weather condition.

loading raw materials (2,000 kg) mixing, wetting and washing raw material (1 day) heating for material fermentation (55℃, 5 days) heating for material sterilization (65℃, 12 hrs) material cooling (30℃, 12 hrs) discharge of sterilised material

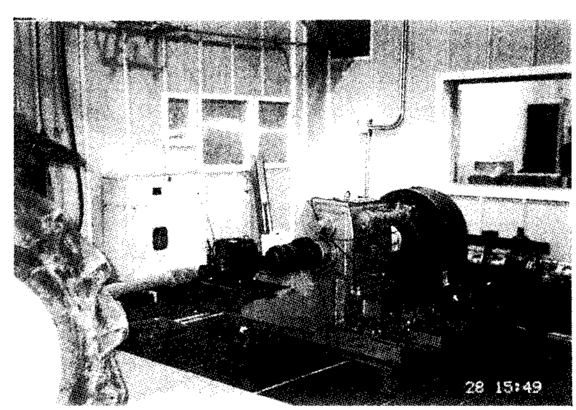


Fig. 3 Calibration of torque-meter by dynamo-meter.

Among the three materials, rice husk used as the spore providing material and the large portion of rice husk has non-volatile organic matters such as cellulose, however, the rice husk had shredded to small particle after the three days of fermentation phase. So, the rice husk did not showed its original shape in the compost.

The materials input order considered as rice husk in the first and cut rice straw in the second, cotton waste and the other materials in the last. Washing the composting materials in the early stage, probably it can leach out some mushroom grow disturbing component in raw materials. The uniform mixture of materials in the fermentation chamber could be seen at 6 hours after the intake all materials.

2. Heating and energy consumption

The heating time and temperature of the raw materials in the fermentation chamber that heated by steam boiler was much effective in consideration of the heating performance. The temperature of materials during fermentation and sterilization from 50℃ to 60℃ needed only 2 hours and it showed much more faster than the conventional mushroom house space heating in sterilization of the material.

In the fuel consumption of the machine, the machine used 200 ℓ of kerosene for heating the fermentation and sterilization of the materials in the mushroom growing house at the late of November. The space heating of fermentation and sterilization for conventional mushroom house used 550 ℓ of kerosene in the same season, so, the machine can be reduced the heating fuel consumption by 64%.

The major factor for lower the fuel consumption than the conventional heating were; the structure of fermentation chamber is semi-airtight enclosure and the machine can use aspiration heat from the fermentation organic material. The machine needed ventilation inside the chamber for fermentation, in particular, the temperature of fermentation material in the chamber can be maintained evenly to ease the fermentation well.

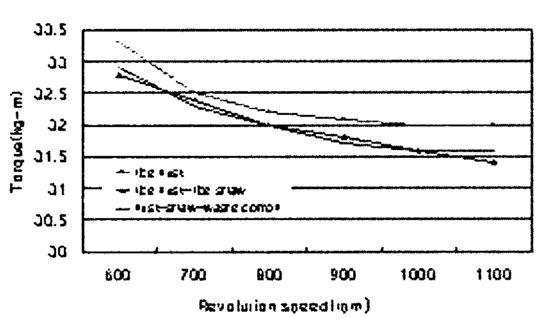


Fig. 4 Variation of torque for intake shaft of the machine.

3. Power requirement of the prototype

The power requirement was measured and analysed by torque-meter by the type of material and the revolution speed of the intake shaft. The materials tested were rice husk only, rice husk+cut rice straw dual, rice husk+cut rice straw+cotton waste triple, and it measured during material fermentation.

In the revolution speed between 600 rpm and 1,100 rpm, the torque level of the machine (4 m length) showed some variation as shown in Fig. 4. The revolution speed of the prototype at 600 rpm was 33 kg-m but when it increased from 600 rpm up to 1100 rpm, the torque level was reduced by 31.5~32 kg-m.

In the variation of torque level by materials, the "rice husk" material at first phase torque was little high but the different material mixture between "rice husk+rice straw" and "rice husk+rice straw+cotton waste" was not so much difference as shown in Fig. 4.

Fig. 5 Discharge and shredding of substrate material.

Fig. 6 Deliver the sterilised substrate material.

The amount of discharged substrate material was increased by the revolution speed of screw from 25 kgf per minute in the 800 rpm to 35 kgf per minute in the 1,100 rpm.

4. Work efficiency

The work efficiency of conventional method for stacking the heap and turning the heap of cotton waste by tractor rotavator and manual wetting required 78 hours, but the prototype use same operation required 25.5 hours which can reduced the labour input of oyster mushroom substrate production by 67%.

The machine can be saved the requirement of heating fuel by 63%, and the machine can also be saved the material cost by 44%. It is envisaged that the machine can effectively be used for large size mushroom growing farms or joint use mushroom growing group-farmers in a village.

5. Effect on oyster mushroom yield

The chosen oyster mushroom variety was Jang-an No. 3 and cultivated in mushroom houses bed area of 65 m^2.

The mushroom yield had analysed between the conventional outdoor cotton waste composting method and the prototype mixed material composting method. The mushroom yield for rice husk, chopped rice straw and cotton waste mixture composting method by the prototype show the more higher yield than the waste cotton by conventional.

The mushroom grown by conventional outdoor compost substrate has contaminated beyond the 3rd phase, but the mixture material composting method by prototype had continued the harvesting of mushroom until 8th phase.

Table 1 Effect of labour and cost requirement

Items	Effect of analysis		
	Conventional	Prototype	Reduction rate
Labour hour (h/200 m^2 of bed)	78.0	25.5	67%
Material cost (Won/kg)	300	167	55%
Production cost (1,000 Won/200 m^2)	1,073	393	63%
Heating fuel (L/200 m^2)	550	200	54%

(1) material mixture ratio : rice husk 40%, rice straw 30%, waste cotton 30%

(2) cost for 1 kg : rice husk 80 Won, rice straw 150 Won, cotton 300 Won

Conclusion

This study was implemented to develop a substrate material wetting and mixing, materials composting, fermentation, pasteurization and spawning through the design of integrated cultivation machinery for oyster mushroom. The proto-

Fig. 7 Spawning of substrate material.

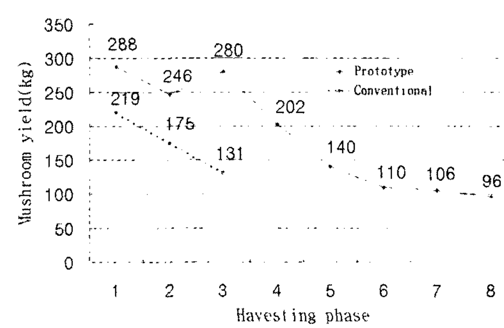


Fig. 8 Yield of mushroom fermentation by prototype.

Fig. 9 Oyster mushroom grown on the bed which substrate was produced by prototype.

type can adopt different materials such as rice husk, cut rice straw and cotton waste to process the substrate of oyster mushroom. The main structure of the machine is consist of fermentation container, screw conveyor, exhaust air blower etc. The maximum input material in the fermentation container was 2,500 kg of dry organic matters for one batch, and the material mixing wetting, fermentation, pasteurization could be achieved within 7 days.

The machine can be saved the requirement of heating fuel energy by 63%, the input labor can be reduced by 67%, and the machine can also be saved the material cost by 55%. It is envisaged that the machine can effectively be used for large size mushroom growing farms or joint use mushroom growing group-farmers in a village.

The spawn inoculated substrate material is wrapped with PVC film to avoid the contamination from germ of disease. The machine and plastic boxes use spawning and substrate handling system can be changed from the heavy duty work to the light duty work, and it can also be reduced the labor requirement of spawning and substrate loading in mushroom growing houses.

Acknowledgment

This research was implemented by financial supports of ARPC, Ministry of Agriculture and Forestry, Republic of Korea.

References

Dong-Ryul Cha and Chang-Hyun Ryu. 1989. Up-to-dated Mushroom cultivation technology, Nong Jin Heo, pp. 630.

Peter Oei. 1991. Manual mushroom cultivation, Tool Publication, Amsterdam, pp. 249.

P. J. C. Vedder. 1978. Modern Mushroom Growing, Educaboek-Culemberg, Netherlands, pp. 420.

Rural Development Administration. 1998. Standard farming textbook-92, Mushroom cultivation Technology.

Van Griensven. 1988. The Cultivation of Mushrooms, Mushroom Experimental Station, Netherlands, pp. 524.