ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LIX 15 Number 5, 2011

THE USE OF WASTE CELLULOSE IN PRODUCTION OF WHITE MUSHROOM SUBSTRATE

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Received: June 2, 2011

Abstract

KAMENÍK, I., MAREČEK, J.: *The use of waste cellulose in production of white mushroom substrate.* Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 5, pp. 131–136

The employment of industrial wastes in agricultural production is one of the possible ways of waste management. Composting of organic waste can cut the cost of transport and disposal of these wastes while obtaining cheep resource materials for the production of composts. Apart from composting or using wastes in the biogas plants, there is yet another possibility of using local organic waste and it is its employment as a component of substrate (compost) for the white mushroom growing. This study deals with the use of waste cellulose in the production of white mushroom substrate. The aim of this study is to evaluate the impact of cellulose content in the substrate on the level of mushroom crop when the mushrooms are grown in the form of compacted substrate designed for small growers. The greatest emphasis is placed on matters of efficient yield of the mushrooms and which are considered to be indispensable for achieving production results over a longer period. This means first and foremost the growing methods and growing environment in the small growing plant. This way the growers could overwhelm the very complicated calculation before the compost preparing. Thanks this way the producers can obtain the utmost probability of the stable crops in the package form of the substrate. The research shows the potential for using of the waste material and fostering the environment friendly food production.

growing plant, composting, substrate, white mushrooms, celulose, waste material

Discovering the best method of growing mushrooms has been a long and complicated task based on life experience of growers and research workers. As the growing spread from small-scale home growing to the form of industrial production, the growers gradually employed more modern methods of mushroom growing in the large-scale production – both in the substrate production and the mushroom growing (Jablonský *et al.*, 2006). And still in the late 1990s mushroom growing spread, above all the white mushroom (Agaricus bisporus), utilizing substrate compacted into the form of wrapped compact substrate block. In the Czech Republic this form is employed attracting more and more users among small-scale mushroom growers. This trend has resulted in industrial production of bale substrate which is, together with cover soil, sold as a growing kit. Small growers can harvest their own fresh white mushrooms for weeks. The substrate producers do their best to produce quality substrate at low cost. Apart from other methods, this can be achieved by employing biologically degradable wastes used as the resource material component of the substrate. Mushroom growing isn't just a rapidly expanding agribusiness; it's also a significant tool for the restoration, replenishment and remediation of Earth's overburdened ecosphere (Stamets, 1983). One of the rational methods of waste utilization involves locally available wastes. This study deals with the use of cellulose dust formed as a waste during the nitrocellulose (gun cotton) production in Synthesia, a. s. in the town of Pardubice – Semtín. The dust is a mixture of cellulose, hemicelluloses and lignin, often referred to as "pulp". The cellulose dust is disposed of by burning it in an incinerator. The cellulose comprises 89–92 % of the waste in question (Plíva, 2006). Cellulose is a polysaccharide occurring in great amounts in nature; its summary formula is (C6 H10 05)n and it is industrially produced from wood by separating it from lignin and hemicelluloses (Sonnenberg, 2009).

In the resource material composition of the mushroom substrate, the dust serves as a source of carbon (C) for the metabolism of micro-organisms and to substitute cereal straw. Cellulose contains a minute amount of nitrogen, so adding cellulose does not enrich the compost mixture by a nitrogen source. As the dust contains only a minute amount of lignin which is difficult to break down, the use of cellulose by micro-organisms should be very quick and effective (Alexander, 1996).

The resource material composition of the mushroom substrate can be optimized using the following steps. For the calculation of materials used to determine proportions of the substrate components see Tab. I.

a) Choice of wastes and materials which we intend to compost and specification of their estimated weight;
b) estimation of moisture, content of organic substances, nitrogen and the components and materials, either based on the table overview or using chemical analyses; it is necessary to distinguish whether the values are specified in dry matter or in the original mass;
c) calculation of composition of the compost charge(moisture, organic substances, N, C/N ratio);
d) correction of resource material composition to achieve optimum moisture and C/N ratio. We can correct the moisture by adding or removing liquids. We can reduce the C/N ratio by adding matter rich in nitrogen, by adding mineral N (urea) or by removing the material with a low content of N (Gerrits, 1974);
e) calculation of corrected resource material composition;
f) estimation of losses during the compost maturing. During the maturing process, the weight losses of the mushroom substrate are about 20% of the charge weight, out of which three quarters represent loss of water and one quarter is the loss of organic substances (Griensven, 1998).

The main hypothesis of the present study is verifying whether the use of cellulose as the main component of the substrate does not impair the substrate yield guaranteed by the manufacturer as long as the growing method is observed. Potential decrease in the quality of the marketed substrate, i.e. of the yield represented by the weight of harvested mushrooms, would bring the end-consumer's distrust resulting in expected reduction of interest in the final product – compressed substrate designed for small growers. This fact could jeopardize the whole business plan of the substrate manufacturer and the waste disposal effect would not be acceptable for the substrate producer who has established its marketing strategy by guaranteeing minimum yield from the growing kit.

MATERIAL AND METHODS

Several methods were used in the study, which were applied in their mutual connection, not separately. The analytic-synthetic method was used as a basic method (to determine the composition of the substrate components), inductive and deductive methods (for the interpretation of the research results and formulation of general conclusions) and a method of qualified estimate (for final evaluation of the results).

Selection of facility for the substrate testing

The experiment was carried out in the facility of Mr. Jiří Václavík – Biotechnologie výroby substrátu a žampionů (Biotechnology for substrate and mushroom production) in the village of Dolany

I: *Calculation of materials used to determine proportions of the substrate components*

CALCULATION OF NITROGEN AMOUNT IN SUBSTRATE after phase II

How much nitrogen is in phase II? **2.10 %**

	Wet weight	**Moisture %**	**Dry matter weight**	**N %**	**Total N**
Straw	**24 000**	**15**	20 400	**0.5**	102
Gypsum	1 800	**10**	1 512	0	0
Horse manure	**0**	**0**	0	**1.2**	0
Cellulose	**0**	**0**	0	**0**	0
Other	**0**	**0**	0	**0**	0
Other	**200**	**0**	200	**45**	90
Other	**0**	**0**	0	**7**	0
Total	**26 000**	**15**	22 112	**0.87**	192

Total N = 464.36 kg of N
N to be added = 272.36 kg of N

	Wet weight	**Moisture %**	**Dry matter weight**	**N %**	**Weight of N**
Chicken manure	**10 000**	**30**	7 000	**4**	280

Weight of chicken-manure dry matter 97.27 kg
Wet weight of chicken manure = 138.96 kg

near Pardubice who produces white-mushroom substrate designed for small growers, especially in the form of compressed substrate bales of 10 kg in weight. This bale is used together with bagged cover soil as a growing kit for the white mushroom home growing. According to the grower guide, if the growing conditions are adhered to, the mushroom crops should amount in several growing waves to the total of approx. 20–25% of weight of the substrate bale – i.e. within the range of 2.0–2.5 kg.

Test production of substrate

During the experiment, a standard composition of resource material components of the substrate was drawn up, which is used to produce the substrate in the facility in a standard and repeated manner. The composition is represented by a charge of 24 000 kg of cereal straw (mostly wheat), 10 000 kg of chicken (broiler) manure, 1 800 kg of gypsum and 200 kg of urea. The components are composed based on the available resources of ingredients and in a suitable composition so that the total amount of nitrogen in the substrate is approx. 2.10% after the substrate production has been finished (the so called "Phase II").

Subsequently, experiments were carried out in which a waste component – the cellulose was added, which partially replaces the straw whose volume will be reduced by the amount of cellulose in the charge. Different charges of cellulose were used during the experiment – the experiment started with the dose of 1 000 kg followed by substrate production cycles using the following doses of cellulose: 1 500 kg, 2 000 kg, 2 500 kg and 3 000 kg.

The experiment was carried out between March–October 2009 and it was repeated in the same period in 2010. For the form of the waste cellulose see Fig. 1.

Experimental growing of the white mushroom

Every experimental way of production of substrate as well as standard production were used to grow the mushrooms and the crop was measured.15 bales were randomly chosen for this evaluation. The mushroom growing was carried out following the instructions provided by each producer for small-scale growers together with a complete growing kit. They were grown in an experimental facility which was a room with artificial microclimatic conditions according to the instructions. During the experiment the room temperature as well as the substrate and cover soil moisture readings were recorded in order to provide evidence of the adherence to the growing procedure.For the form of the compacted substrate designed for small growers-growing kit – see Fig. 2.

Crop evaluation

The compressed substrate gives the same crop as the loose substrate in several phases (waves) – generally there are 5–6 harvests where each phase can last 7–10 days (Wood, 1979). The first 3 waves are the most efficient and then the crop decreases dramatically having no significant effect on the substrate crop evaluation. This is why for all the

1: *Form of the waste material: cellulose*

2: *Form of the compacted substrate designed for small growers-growing kit*

experimental samples only weights of the first three crop waves were included in the total crop.

In the experimental farm the crop from every compacted bale was weighed and then an average value from all experimental substrate bales calculated.

No irregularities between each wave were noticed in the course of all the experiment. It was noted that there was better grow-through of the mycelium followed by a higher number of the mushrooms. No change in mushroom sizes was noted compared to the standard size. This suggests that the increase in the crops when using cellulose results from better grow-through of the mycelium due to better use of saccharide components of cellulose which can be better broken down than the cereal straw.

RESULTS AND DISCUSSION

The main aim of the composing process is to obtain a quality nutrient substrate for growing mushrooms.

The important decision for the experiment was to determine the proportion of the cellulose in the substrate. Setting the input parameters of the ingredients without proper knowledge of their actual composition is a relatively frequent problem. Each component was subjected to laboratory determination of composition – in particular moisture and nitrogen content. The charge of cellulose was determined by calculating weight proportions of the substrate components (Table I) using the laboratory values and then recalculating this amount so that at the end of production phase II the volume of the total usable nitrogen was about 2.10%. The experimental production started with the amount of 1 000 kg of cellulose followed by experimental productions with the charges of 1 500 kg, 2 000 kg, 2 500 kg and 3 000 kg of cellulose. The experiment was ended with the charge of 3 000 kg of cellulose where physical properties of the substrate were impaired, especially change in the substrate texture was observed. The substrate became stickier, there was not enough air supply in the parts of the composted pile and the time necessary for aerating had to be increased. It can be extremely time consuming to control a process like this. This, in view of an insignificant increase in the crop, is a more costly process as well as more difficult to monitor. The aim of a substrate producer is to perform a standard control of the process since a well-proven production process is vital to obtain a quality substrate. Any changes may result in an impairment of chemical and physical properties in the following processes of the composing process which may irreversibly harm the substrate quality. Irrespective of the ingredients used, after the end of the fermentation process in the substrate we should have a material where any sample taken at any place in any time of the year should be of the same quality.

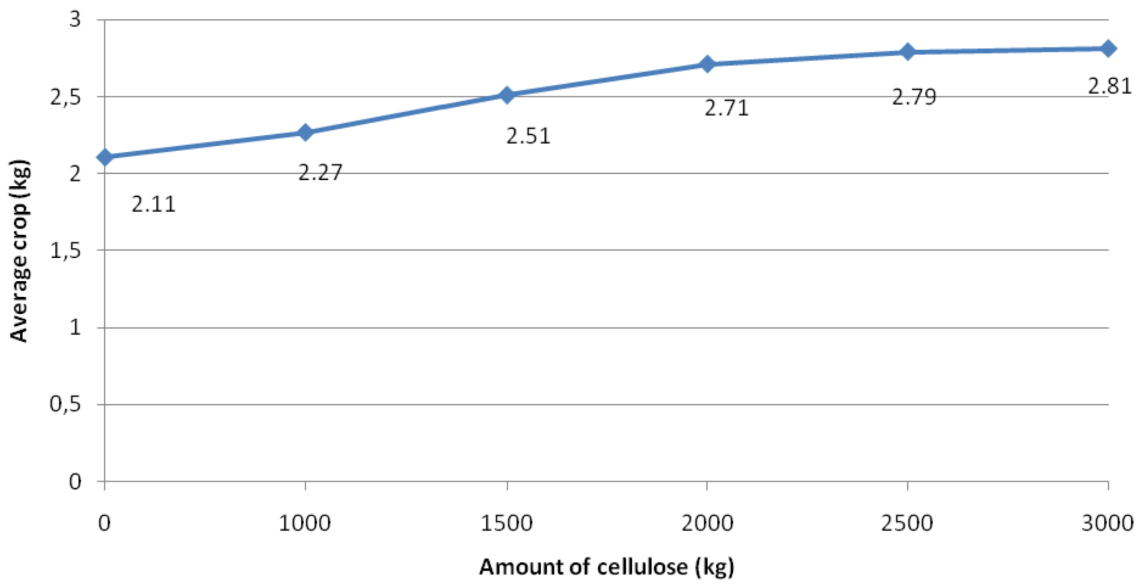
When producing white mushroom substrate using charges up to 2 500 kg no significant changes were noted in the chemical composition of the transforming components nor in the physical properties of the substrate as compared to the standard composing process without the charge of cellulose.

The results of the research show that using the new ingredient, cellulose, resulted in an increase in the mushroom crops. Each increase in the cellulose volume in the monitored substrate brought an increase in the crop. Although all the rises in the crop yield were positive, they statistically represent only a negligible difference. However, from the practical point of view, they present a significant factor as the objective of the experiment was to verify the possibility of employing a waste which should not reduce the final product crop, i.e. that of white mushrooms. For the average crops and the celulose amount in the substrate see Tab. II.

In conclusion, it can be said that it is possible to employ waste cellulose in the facility in question, however with some limits. In the given case the substrate producer is not recommended to use for its standardised production process more than 2 500 kg of cellulose per one charge of ingredients. The total production capacity of the farming facility allows the use of approximately 80 000 kg of waste cellulose annually. This represents half of the waste produced by the local waste producer.

II: *Average crops and the celulose amount in the substrate*

Average crop(kg)	2.11	2.27	2.51	2.71	2.79	2.81
Amount of cellulose (kg)	0	1 000	1 500	2 000	2 500	3 000



3: *Curve of the average crop dependence on the cellulose amount in the substrate*

SUMMARY

The decision made by the white-mushroom substrate manufacturer whether or not to employ local organic wastes should be based on a total analysis of his business plan and on the evaluation of conditions for the substrate manufacture in question. This analysis should properly evaluate the importance of local waste resources, taking into account the economical factors determined by the waste availability, its price and costs of transport and storage on the farm. The most important factor when making decision on the use of local waste is the evaluation whether the use of the waste as a substrate component will not cause negative change in the quality of the product itself – i.e. the substrate. The decisive indicator of the substrate quality is its yield represented by the weight of mushrooms cropped from a certain volume of the substrate.For curve of the average crop dependence on the cellulose amount in the substrate see Fig. 3. In the experiment, industrial organic waste, cellulose, was used as a carbon component of the mushroom substrate to partially replace cereal straw. The results of the experiment have shown that cellulose can be used as a material component in the production of the white-mushroom substrate, as no negative impact on the mushroom yield has been found. However the waste amount incorporated in the substrate is limited by negative changes in the substrate texture and by more difficult control of the fermentation process.

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