COMPARISON OF TRADITIONAL AND CLIMATE-CONTROLLED MUSHROOM CULTIVATION PROCESSES

Leiva-Lázaro, F.J.[(a)], Blanco-Fernández, J.[(b)], Martínez-Cámara, E.[(c)], Latorre-Biel, JI[(d)], Jiménez-Macías, E.[(e)]

[(a,b,c)] Department of Mechanical Engineering. University of La Rioja. Logroño. Spain.
[(d)] Department of Mechanical, Energy and Materials Engineering,
Public University of Navarre, Tudela, Spain.
[(e)] Department of Electrical Engineering. University of La Rioja. Logroño. Spain.

[(a)] francisco.leiva@unirioja.es, [(b)] julio.blanco@unirioja.es, [(c)] e.camara@eolicas.com,
[(d)] juanignacio.latorre@unavarra.es, [(e)] emilio.jimenez@unirioja.es

ABSTRACT

Originally mushroom cultivation was carried out in caves that have gradually been replaced by climate controlled chambers, to control climatic conditions, requiring only energy consumption and cooling systems. The climate controlled chambers allow higher control over the weather conditions inside the growing chambers, temperature, and humidity, compared to the traditional cultivation process.

However, this advantage implies an increase in energy consumption, much higher than the traditional cultivation process, due to the demand of the Heating, Ventilating and Air Conditioning system (HVAC). As a result, the climate controlled cultivation process requires higher investments that the traditional cultivation process. The results of this study indicate that traditional cultivation systems have higher average production than climate controlled systems. Furthermore, higher investments are needed in climate controlled cultivation systems. However, traditional cultivation systems are totally dependent on weather conditions, as a result, cold and hot seasons are not favourable for these cultivation systems.

Keywords: Mushroom cultivation, Agaricus Bisporus, Economic analysis, production analysis

1. INTRODUCTION

Agaricus bisporus is a specie of basidiomycota fungus from the Agaricaceae family native to Europe and North America (Leiva et al., 2016). The Agaricus Bisporus is the most cultivated fungus worldwide (Foulongne-Oriol et al., 2014; Tautorus, 1985; Ma et al., 2014; Saravanan et al., 2013) over 70 countries (Ma et al., 2014; Saravanan et al., 2013). It is one of the most consumed vegetable crops worldwide (Wani et al., 2010).

The cultivated edible fungus Agaricus bisporus accounts for 70% of the world annual output of edible mushrooms (Durrant et al., 1991). It accounts for nearly 40% of the world's mushroom supply (Sanchez et al., 2009).

The fungus mainly grows on partially decomposed substrate (Donini et al., 2006) in regions with mid temperature and high humidity (Akinyele et al., 2012). In intensive cultivation, Agaricus bisporus is produced on a composted substrate consisting of mixtures of hay, corncobs, wheat straw, horse and poultry manures, cottonseed hulls, corn stover, gypsum and other raw materials (Royse et al., 2009: Burton et al., 1997; González-Matute et al., 2006; Straatsma et al., 2000). The development of fruit bodies of A. bisporus requires a non-nutritional layer of casing soil on top of the nutritious compost (Straatsma et al., 2013). Casing soil has an important role in the cultivation of Agaricus bisporus (Gülser et al., 2003).

Parameters, such as temperature and humidity, must be constantly controlled. Usually, the fungus is cultivated in caves (traditional cultivation) as temperature and humidity are ideal for the cultivation process. However, the traditional cultivation has been replaced by climate controlled chambers, because critical parameters are totally under control.

The research presented, allows to obtain tools for planning environmental and economic strategies in the mushroom production process. Furthermore, the study is a proper tool to identify economic and environmental impact assessment of resources consumption. In addition, the research also allows the selection of alternatives for waste management and comparison between different options within a new process with the objective of minimizing environmental impacts, reduce energy consumption and costs.

As a continuation of Leiva-Lázaro et al. (2015), which was devoted to a general comparison between traditional and climate controlled cultivation of mushroom Agaricus Bisporus variety by the identification of environmental impacts of the production processes, this paper analyses the difference between traditional cultivation and climate controlled cultivation processes throughout an economic analysis, considering expenses and production quantity of both cultivation processes.

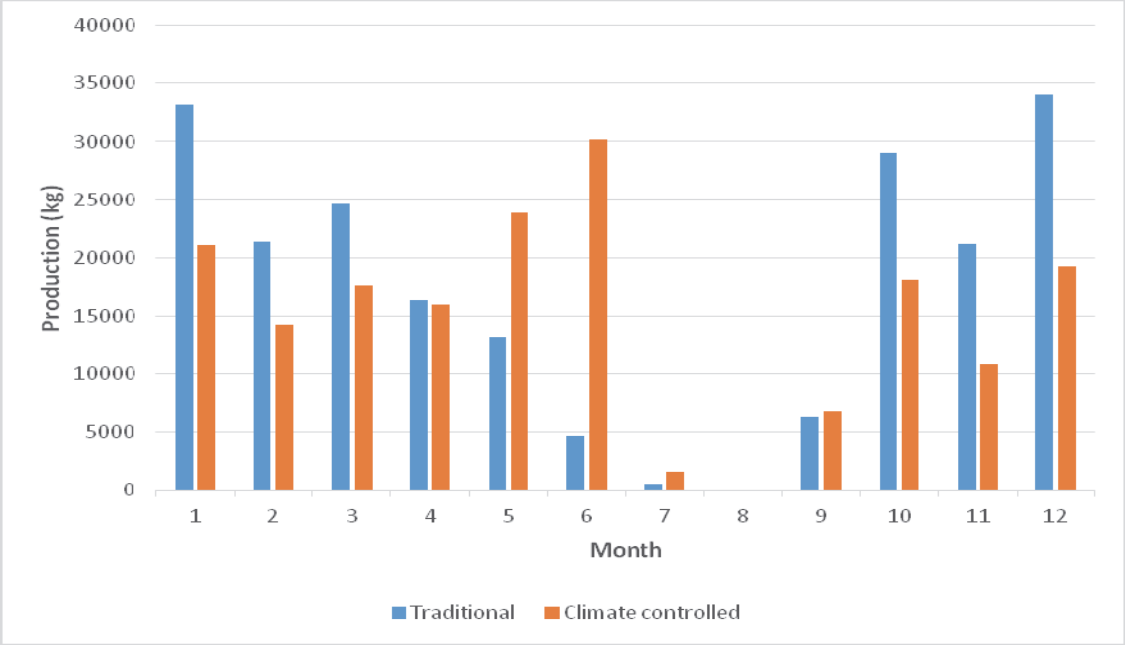

Figure 1: Production in a year for both cultivation processes

2. TRADITIONAL AND CLIMATE CONTROLLED PROCESS

A brief summary of both processes, traditional cultivation and climate controlled cultivation, is presented in this section so that readers can understand the differences which will be analysed without necessity of reviewing the references, although a deeper description can be found in Leiva-Lázaro et al. (2015) , Leiva et al. (2015), and Leiva et al. (2016).

The traditional cultivation process is carried out in cellars formerly used for wine production, which helps to maintain ideal temperature conditions for the mushroom cultivation. These wineries have only a ventilation system that renews the indoor air with fresh air, without control of temperature or humidity inside the room. The cellars are used rectangular 35 meters long, 4.5 meters wide and 2.4 meters high with a front door for input loading and unloading. The ventilation system is placed at the front and rear of the cellar, as a result the air flow inside the warehouse is adequate.

The climate controlled cultivation process takes place in rooms climatically controlled (relative humidity and temperature). These rooms have an air conditioning system and numerous air intakes for a homogeneous distribution in the room. The cellars are used rectangular 32 meters long, 7 meters wide and 4 meters high with a back door for loading and unloading packages of compost and casing material, and a front for staff access. All parameters are constantly controlled and monitored.

The production process includes the following stages:

2.1. Climatization.

The cultivation process conducted in climate controlled rooms, has a constant control of the temperature and a heating system supplied by biomass.

2.2. Ventilation.

The growing process in ventilated chambers features just a ventilation system to keep clean air constantly recirculating through the interior of the chambers

2.3. Preparation of the covering soil.

The first phase of the growing process is to prepare the soil used to cover the compost packages.

The process begins with the disinfection of the area where the covering soil is prepared, in order to prevent the appearance of diseases during the growing process. Peat is deposited in the disinfected area. This peat does not contain sufficient moisture, so water is added to bring the moisture content up to the level required for covering soil. Finally, fungicides are also added to prevent pests and diseases during the cultivation process.

2.4. Preparation of the growing chambers.

The next phase of the process is the preparation of the growing chambers to place the compost packages. The process begins with the disinfection of the growing chambers to prevent the appearance of diseases during the cultivation process. Once disinfection is complete, the chambers are prepared by setting out the cages where the compost packages will be placed. The compost packages are then placed on the cages so that the cultivation process can begin

2.5. Cultivation process.

The next phase is the cultivation process, which culminates with the harvesting of the end product. This process begins once all the compost packages have been placed on the cages in the chambers with the covering soil previously prepared. Then water is added to start the growing phase. Continual fumigation by adding

fungicides and insecticides is required to prevent the appearance of pests during the process. During the cultivation process homogenisation (activation of the mycelium) and fruiting (development of the fruiting bodies) begin. When the fruiting process is completed the fruiting bodies are harvested.

2.6. Waste management.

The final phase is the management of the waste produced during the process. The waste produced is placed in a separate container for collection and treatment at a specific plant.

With the differences presented in the previous description, the temperature and the relative humidity are also different, as shown in Figure2 (Leiva el al. 2015) what will drive the different productions and also to different economic cost, which is the main point of the analysis of this work.

Figure 2: Differences in temperature and relative humidity with traditional and climate controlled cultivation processes (Leiva et al., 2015)

3. METHODOLOGY

This paper focuses on the comparison of existing cultivation processes in the study area from the economic and productive point of view. For the analysis, prices of the inputs used in the production process of both crops have been considered to present an economic comparison of both cultivation processes. Data and energy consumption were measured for the final study.

3.1. Ventilated growing chambers

The growing process in ventilated chambers features just a ventilation system to keep clean air constantly recirculating through the interior of the chambers (Leiva et al., 2015). As a result, the weather conditions inside the growing chambers are not under control, especially in winter and summer, when temperature and humidity levels are extreme for the fungus cultivation.

3.2. Climate controlled growing chambers

The cultivation process conducted in climate controlled rooms, has a constant control of the temperature and humidity (Pardo-Giménez et al., 2014). A computerized environmental control system is an invaluable tool for mushroom culture monitoring environmental parameters such as temperature, humidity, airflow, pressure, and carbon dioxide and oxygen content (Sánchez, 2010). A climate controlled system supplied by biomass and electricity, keeps the temperature at the desired level for an optimal production thorough the year.

4. RESULTS

Data gathered during the study is presented in this part. All data was collected during a year for both cultivation processes, traditional and climate controlled cultivation process. Expenses and production for both processes were collected for the study presented.

4.1. Mushroom production

Both cultivation processes under study were analyzed under the productive point of view through a year. Inputs and outputs by both crops, have been collected to make a comparison between the two cultivation processes. The amounts produced by each cultivation process is collected in Figure 1.

Figure 1 shows the production comparison for both cultivation processes thorough a year. In summer, mainly the climate controlled cultivation process is used because the temperature is very high and the humidity very low for the cultivation process. Using the traditional system in hot conditions will result in a poor production because the climate conditions are not proper for mushroom cultivation. However, using the climate controlled with high temperatures will result in high expenses for the amount of electricity used by the climate system to cool down the temperature of the outer air.

Time required for both processes are slightly different. The traditional cultivation process requires an average of 63 days. Oppositely, the climate controlled cultivation process requires less time, 58 days. Compared data is shown in Figure 3.

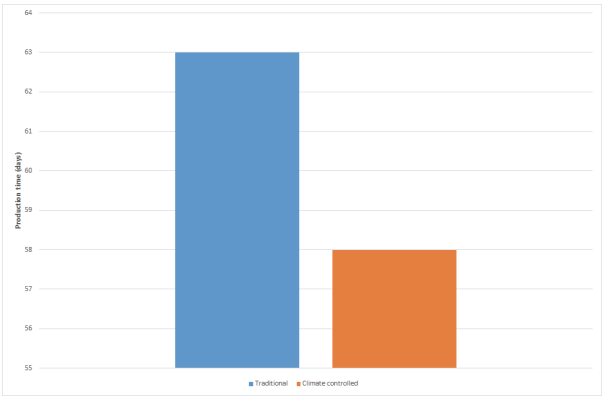

Figure 3: Time required for the cultivation process

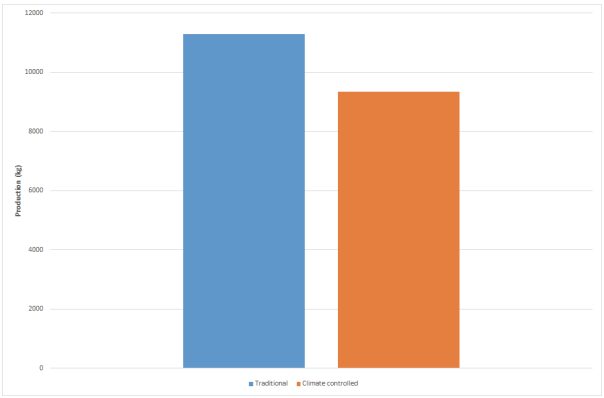

Figure 4: Quantity produced per chamber

The time required for the cultivation process is a bit lower in the climate controlled process. However, the amount produced per chamber is higher in the traditional system (Figure 4).

Figure 4 shows that the quantity produced per chamber, is slightly higher in the traditional rather than in the climate controlled process. The average quantity in the traditional process is 6.82 kg/cultivation package, and in the climate controlled process is 5.65 kg/ cultivation package.

Despite the fact that the climate controlled process guarantees a great control over the climatic conditions inside the chambers, the production is lower than the traditional process

4.2. Economic analysis

Both cultivation processes under study were also analysed under the economic point of view. For the study, inputs used for both cultivation processes, are equal in quantity.

Climate controlled chambers, have higher demand of energy, therefore, energy consumption is considerable higher compared to traditional processes. Furthermore, the Heating, Ventilating and Air Conditioning system (HVAC) needs to be disinfected and maintained continuously. As a result, the investment required for this process is considerable higher than traditional systems (see Figure 5).

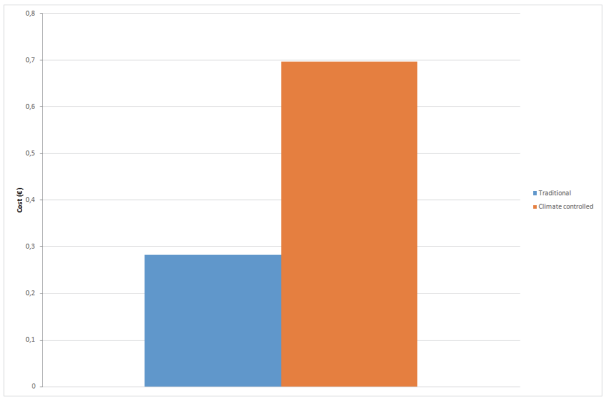

Figure 5: Cost of a kg of Agaricus Bisporus cultivation process

Figure 5 shows that the expenses for the climate controlled cultivation process is remarkably higher than the traditional process. The average cost to produce a kg of Agaricus Bisporus using the climate controlled cultivation process is 0.7€/kg. On the contrary, the average cost in the traditional cultivation process is less than half, 0.28€/kg.

5. CONCLUSIONS

The climate controlled cultivation process provides greater control of the temperature and relative humidity inside the cultivation chambers throughout the process. The climate controlled process allows to carry out the process at any time of year, because it does not depend on external conditions of temperature and humidity. However, energy demand is greater than the traditional cultivation process. In contrast, the traditional process is directly dependent on environmental conditions. As a result, the climate controlled process is faster, requiring less time to complete the cultivation process than the traditional process.

Conversely, the traditional cultivation process is much productive than the climate controlled system. Additionally, the investment needed is much lower in the traditional process for the ventilation system.

ACKNOWLEDGMENTS

This paper has been partially supported by the ADER Project: “Producción sostenible del champiñón de La Rioja y mejora de la protección ambiental, a través de la investigación de Ecoindicadores del Análisis de Ciclo de Vida (ACV)”.

REFERENCES

Evans W.A., 1994. Approaches to intelligent information retrieval. Information Processing and Management, 7 (2), 147–168.

Akinyele, J.B., Fakoya, S., Adetuyi, C.F., 2012. Anti-growth factors associated with Pleurotus ostreatus in a submerged liquid fermentation. Malaysian Journal of Microbiology 8, 135-140.

Beetz A, Kustudia M (2004) Mushroom cultivation and marketing. Horticulture production guide.

Burton, K.S., Smith, J.F., Wood, D.A., Thurston, C.F. (1997). Extracellular proteinases from the mycelium of the cultivated mushroom Agaricus bisporus. Mycological Research. Volume 101, Issue 11, 1997, Pages 1341-1347.

Donini, L.P., Bernardi, E., Do Nascimento, J.S., 2006. In vitro development of Agaricus brasiliensis in media supplemented with different brans. Pesq. Agrop. Brasileira 41, 995–999.

Durrant, A.J., Wood, D.A., Cain, R.B. (1991) Lignocellulose biodegradation by Agaricus bisporus during solid substrate fermentation. Journal of General Microbiology. Volume 137, Issue 4, 1991, Pages 751-755.

Dutta, S., 2013. Role ofmushrooms as nutraceutical an overview. Int. J. Pharma. Biol. Sci. 4, B59–B66.

Foulongne-Oriol, M., Navarro, P., Spataro, C., Ferrer, N., Savoie, J.M., 2014. Deciphering the ability of Agaricus bisporus var. burnettii to produce mushrooms at high temperature (25°C). Fungal Genetics and Biology 73, 1-11.

González-Matute, R., Rinker, D.L.(2006). Compatibility of ammonia suppressants used in poultry litter with mushroom compost preparation and production. Bioresource Technology. Volume 97, Issue 14, September 2006, Pages 1679-1686.

Gülser, C., Pekşen, A. (2003). Using tea waste as a new casing material in mushroom (Agaricus bisporus (L.) Sing.) cultivation. Bioresource Technology. Volume 88, Issue 2, June 2003, Pages 153-156

Leiva, F., Saenz-Díez, J.-C, Martínez, E, Jiménez, E, Blanco, J. (2016). Environmental impact of mushroom compost production. Journal of the Science of Food and Agriculture.

Leiva, F.J., Saenz-Díez, J.C., Martínez, E., Jiménez, E., Blanco, J. (2015). Environmental impact of Agaricus bisporus cultivation process. European Journal of Agronomy. Volume 71, November 01, 2015, Pages 141-148.

Leiva-Lázaro F.J., Blanco-Fernández J., Martínez-Cámara E., Latorre-Biel J.I., Jiménez-Macías E. (2015). Mushroom cultivation process, agaricus bisporus variety: comparison between traditional and climate controlled cultivation and identification of environmental impacts of the production processes. The 3nd International Workshop On Simulation For Energy, Sustainable Development & Environment SESDE 2015, Bergeggi, Italy. 21 – 23 September 2015.

Ma, Y., Guan, C.Y., Meng, X.J., 2014. Biological characteristics for mycelial growth of Agaricus bisporus, Applied Mechanics and Materials, pp. 297-302.

Moon, B., Lo, Y.M., 2013. Conventional and Novel Applications of Edible Mushrooms in Today's Food Industry. Journal of Food Processing and Preservation 38, 2146-2153.

Narayanasamy, P., Suganthavel, P., Sabari, P., Divya, D., Vanchinathan, J., Kumar, M.S., 2010. Cultivation of mushroom (Pleurotus florida) by using two different agricultural wastes in laboratory condition. Int. J. Microbiol. 7.

Pardo-Giménez, A., Pardo-González, J.E., Zied, D.C. Evaluation of harvested mushrooms and viability of Agaricus bisporus growth using casing materials made from spent mushroom substrate (Article). International Journal of Food Science and Technology. Volume 46, Issue 4, April 2011, Pages 787-792.

Rathee, S., Rathee, D., Rathee, D., Kumar, V., Rathee, P., 2012. Mushrooms as therapeutic agents. Braz. J. Pharmacogn. 22, 459–474.

Royse, D.J., Chalupa, W. (2009). Effects of spawn, supplement and phase II compost additions and time of re-casing second break compost on mushroom (Agaricus Bisporus) yield and biological efficiency. Bioresource Technology. Volume 100, Issue 21, November 2009, Pages 5277-5282.

Sanchez, J.E., Royse, D.J. (2009). Scytalidium thermophilum-colonized grain, corncobs and chopped wheat straw substrates for the production of Agaricus bisporus. Bioresource Technology. Volume 100, Issue 4, February 2009, Pages 1670-1674.

Saravanan, R., et al., Analysis of nutrients and minerals content in commercially purchased Agaricus bisporus. Research Journal of Pharmacy and Technology, 2013. 6(7): p. 765-768.

Straatsma, G., Gerrits, J.P.G., Thissen, J.T.N.M., Amsing, J.G.M., Loeffen, H., Van Griensven, L.J.L.D. (2000). Adjustment of the composting process for mushroom cultivation based on initial substrate composition. Bioresource Technology. Volume 72, Issue 1, March 2000, Pages 67-74.

Straatsma, G., Sonnenberg, A.S.M., van Griensven, L.J.L.D. (2013) Development and growth of fruit bodies and crops of the button mushroom, agaricus bisporus. Fungal Biology. Volume 117, Issue 10, October 2013, Pages 697-707.

Tautorus, T.E., 1985. Mushroom fermentation. Advances in Biotechnological Processes 5, 227-273.

Wani, B.A., R.H. Bodha, and A.H. Wani, Nutritional and medicinal importance of mushrooms. Journal of Medicinal Plants Research, 2010. 4(24): p. 2598-2604.

Xu, T., Beelman, R.B., Lambert, J.D., 2012. The cancer preventive effects of edible mushrooms. Anti Cancer Agents Med. Chem. 12, 1255–1263.