# MUSHROOM CULTIVATION PROCESS, AGARICUS BISPORUS VARIETY: COMPARISON BETWEEN TRADITIONAL AND CLIMATE CONTROLLED CULTIVATION AND IDENTIFICATION OF ENVIRONMENTAL IMPACTS OF THE PRODUCTION PROCESSES

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## 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Originally mushroom cultivation was carried out in caves that have gradually been replaced by climate controlled chambers, to control climatic conditions, requiring only energy consumption and cooling systems.

This paper presents a "cradle-to-gate" live cycle assessment (LCA) study of the process of mushrooms cultivation of the Agaricus bisporus variety. This study is based on real data gathered from a growing plant throughout a year, in order to provide accurate information of the environmental impact of various activities that is composed the production process. A comparison of two types of cultivation processes is performed: traditional cultivation and climate-controlled cultivation.

A general analysis of the main stages of the production process reveals a greater impact on the climate controlled cultivation process than in the traditional cultivation process.

Keywords: Environmental impact, Life Cycle Assessment, Mushroom cultivation, Agaricus Bisporus

## 1. INTRODUCTION

Agaricus bisporus, is a kind of fungus basidiomycete of the Agaricaceae family. Within the family of fungus, the Agaricus Bisporus is the most cultivated specie worldwide (Foulongne-Oriol et al., 2014; Tautorus, 1985; Saravanan et al., 2013) and is one of the most important vegetable crops worldwide. It is mostly used in cooking and is the most consumed food in the world (Foulongne-Oriol et al., 2014), because of its valuable nutritional properties (Wani et al., 2010).

## 2. METHODOLOGY

### 2.1. Life cycle assessment

The live cycle analysis or live cycle assessment (LCA) consist on a methodology that analyses and evaluates the environmental aspects and the potential impact of a material, product or service throughout the period of their life cycle (Leiva-Lázaro et al., 2014). LCA is an effective tool for decision-making (Azapagic et al., 1999) under the ISO standard 14040 (Martinez et al. 2009).

LCA helps in making decisions to choose the best alternative (Guinee, 1993), providing a basis to evaluate possible improvements in the environmental performance of a process or product (Azapagic et al., 1999). It is considered a powerful tool for sustainability.

The scope of the LCA methodology includes the extraction and processing of raw materials, manufacturing and assembly processes, product distribution, use of materials, maintenance, recycling and final disposal (Nash and Stoughton, 1994). It is an approach "cradle to grave" (Jiménez et al., 2014) that reviews the environmental effect of the processes, previously mentioned, in a holistic way (Barton, 1996).

LCA includes all loads and impacts on the life cycle of a product or a process, not focusing just only on emissions and waste generated during the process, unlike other systems of environmental impact (Leiva et al., 2015).

LCA can be used as a tool to identify critical points in the production process in order to identify possible solutions (Belussi et al., 2015). It is also a tool to review all the environmental aspects and potential impacts of a product, as it considers all aspects and phases of a product or process (Jiménez et al., 2014).

## 3. A CASE STUDY: CULTIVATION PROCESS (TRADITIONAL AND CLIMATE CONTROLLED PROCESS)

The cultivation process studied in this paper is divided into two methods currently used in the study area: Traditional cultivation and climate controlled cultivation.

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.

### 3.1. Modeling and analysis of the cultivation process

In the present study two types of cultivation processes are presented: traditional and climate controlled cultivation processes. The production process includes the following stages:

- Climatization.

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

- Ventilation.

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

- 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.

- 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

- 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.

- 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.

## 4. SIMULATION RESULTS

Field measurements made during the study are presented. Concentration of CO2 measurements were performed inside the cultivation chambers, both in traditional and climate controlled cultivation. Measurements of temperature and relative humidity were also carried out.

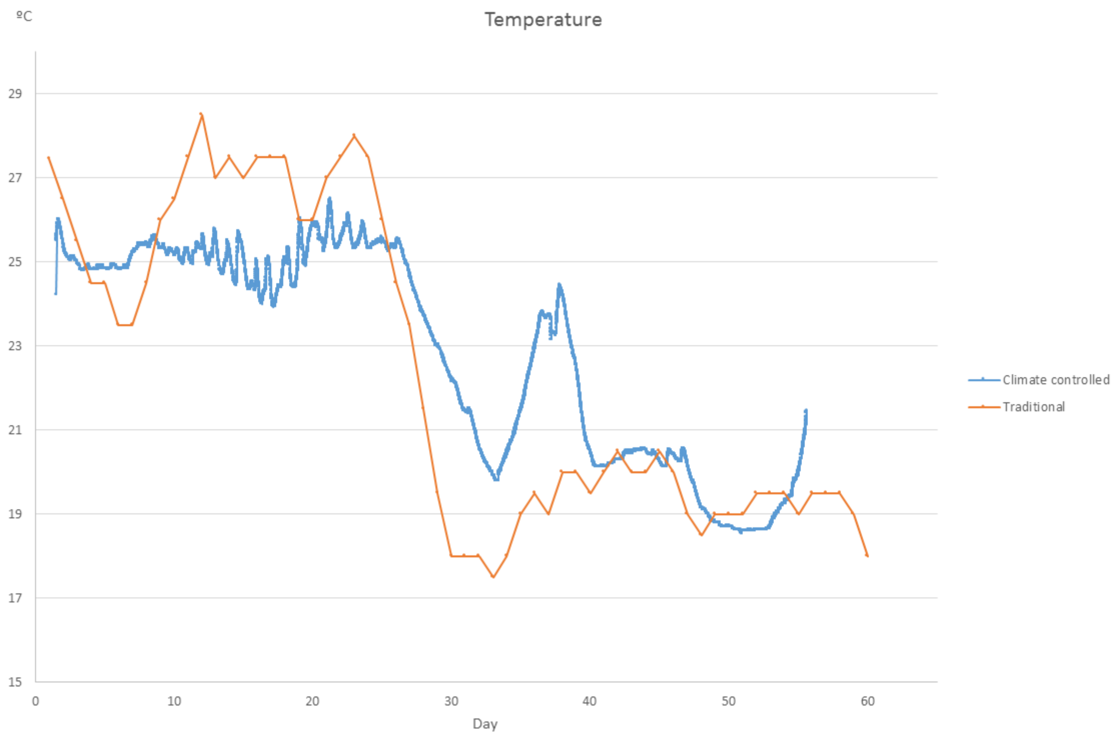

Figure 1: Temperature during the cultivation process

### 4.1. Temperature

Temperature is a very important parameter to control during the process. During the incubation phase it is critical to control the temperature to get a proper development of the mycelial activity. During the fruiting phase, it is important to maintain a suitable temperature for the proper development of fruiting bodies (Foulongne-Oriol et al., 2014; Largeteau et al., 2011)

The climate control system provides a high temperature control during the production process, especially during the incubation phase where the mycelial activity is considerable, rising high temperatures. The compost temperature remains constant during the incubation phase (Figure 1), effectively varying the temperature of the compost for the following stages according to the needs of the fungus.

The climate controlled cultivation allows greater control over the temperature. The temperature of both the compost and the culture room, is more stable in the heated chambers (Figure 1).

### 4.2. Relative humidity

Another parameter controlled during the cultivation process is the relative humidity in the cultivation chambers. It is especially relevant during the fruiting phase, as it will affect the development of the fruiting bodies. The relative humidity of the room is considerably reduced during the fruiting phase (Fig. 2).

The climate controlled process also allows greater control over the relative humidity of the chamber than in traditional process. Climate controlled cultivation chamber offers a more stable relative humidity is more stable with progressive changes than in traditional processes (Figure 2).

### 4.3. CO2 emissions

CO2 emissions are present throughout the process. Higher concentrations occur during the incubation phase where the mycelial activity is elevated (colonization of the substrate). As a result high CO2 emissions, above 10,000 ppm, can be found (Figure 3). A sudden drop in CO2 emissions occurs because the mycelial activity is reduced dramatically once the substrate is fully colonized.

After the incubation phase, CO2 emissions in the following phases are much lower because the mycelial activity is lower.

### 4.4. Impact categories

In this section the environmental impacts are quantified in the different categories studied using the CML method.

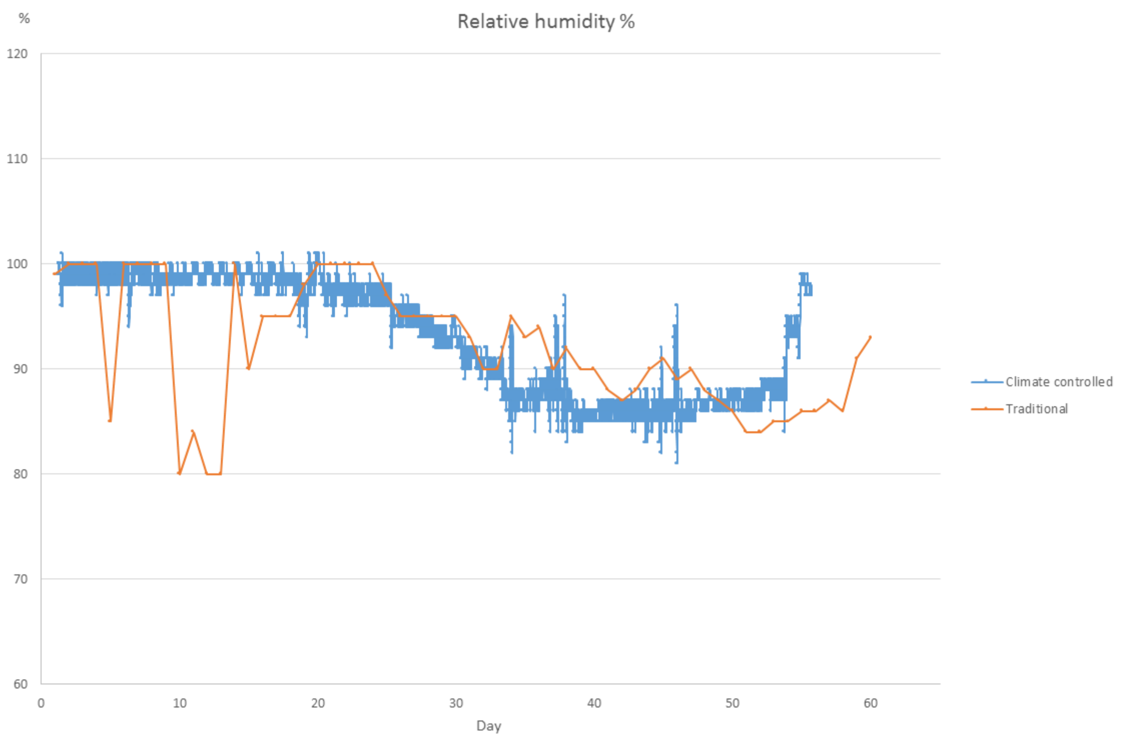

Figure 2: Relative humidity during the cultivation process

The climate controlled cultivation process has a greater impact in all categories due to a greater number of inputs consumed. The climate control system, with a higher energy demand than the ventilation system, has a higher percentage of impact on all impact categories studied.

## 5. CONCLUSIONS

The conducted study shows a greater impact, in all impact categories studied, in the climate controlled cultivation process than in the traditional cultivation process. The impact is higher because the energy demanded by the climate control system is much higher than the energy demanded by the ventilation system.

Although the impact is greater, the climate controlled cultivation process provides greater control of the temperature and relative humidity inside the cultivation chambers throughout the process. In addition, the time required for each chamber is considerably lower in the climate controlled process, average of 58 days per chamber, than in the traditional process, average of 63 days per chamber.

Although energy demand is greater, the climate controlled process allows carrying out the process at any time of year, because it does not depend on external conditions of temperature and humidity. By contrast, the traditional process is directly dependent on environmental conditions

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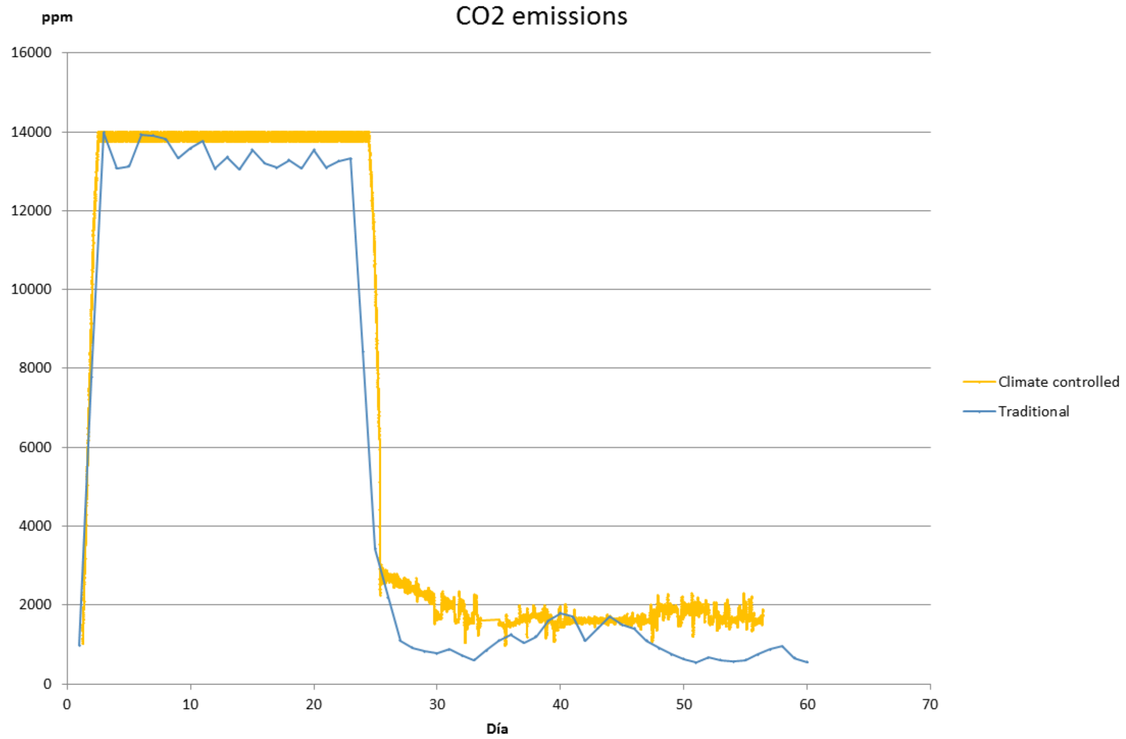


Figure 3: $CO_2$ emissions in the cultivation facilities

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