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DESIGN OF OYSTER (PLEUROTUS OSTREATUS) PRODUCTION UNIT TAKING INTO ACCOUNT ITS AGROTECHNIC OF GROWIGN AND QUALITY AND QUANTITY OF ITS PRODUCTION

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ABSTRACT

According to influence of population increasing followed by agricultural soils decreasing there is noticed a necessity of individual food commodities production intensification. There is also needed to think about some new unconventional and alternative sort of food-stuff. An edible mushroom growing is one of the relatively new agricultural branches, whereby on a large scale there are grown species which belong to saprophytic group. The aim of task was the building – technological and equipment – technological proposal of oyster (*Pleurotus ostreatus,* Jacq. P. Kumm) production unit with taking account to its specific agro technical requirements and valid legislative. In the next part of task there were evaluated and compared qualitative and quantitative parameters of sporocarps from two variants which were collected in the first growth wave and accuracy of the proposed oyster production unit. In case of variant A there were used sacks with substrates, which have been exposed to cold shock by 6°C temperature for 4 days and in variant B were used substrates without cold shock. According to reached results the cold shock had almost neither influence on production quantity. There was found out an important fact that crop height from first growth wave wasn´t identical with well-known literature sources. The low crop is connected with high CO_2 content in oyster production unit room, according to our opinion. Other equipment aimed to air humidity regulation, air temperature regulation and room lights was designed correctly.

Keywords: Oyster mushroom , growing , oyster production unit

INTRODUCTION

The foodstuffs as a basic part in case of increasing population nutrition have huge importance in economic sector. That is the reason why all strategies of highly developed countries preferentially lead to foodstuff self – sustainability. According to influence of population increasing followed by agricultural soils decreasing there is noticed a necessity of individual food commodities production intensification. There is also needed to think about some new unconventional and alternative sort of food-stuff. An edible mushroom growing is one of the relatively new agricultural branches, whereby on a large scale there are grown species which belong to saprophytic group. These kinds of higher mushrooms are characteristic by transformation of hardly accessible cellulose and lignin substrates on which they than vegetate. This kind of material is in agricultural plant production often secondary, i.e. nearby product without any bigger potential using. It is suitable to increase an attention to this stock, which should lead to higher effectivity of its using, to liquidation of unwanted plant waste and to obtaining of new attractive product with favorable effects on human organism on the other hand.
The most popular representative of this kind of mushrooms is oyster mushroom (*Pleurotus ostreatus* (Jacq.) P. Kumm). The oyster mushroom is able to use wide scale of organic residues, whereby by its production there is not practically created any waste. Even overgrown straw substrate can be tertiary used for feeding of some farm animal species. The mushroom with its enzymatic complex disturbs lignin impregnation of cellulose mass and consequently increases its nutrition value by essential amino acids and some vitamins synthesis. It offers pulpy fructifications which are suitable for direct consumption, as well as for drying and conservation. It is well known, the oyster mushroom support blood creation, probiotic cultures creation, it decreases allergy reactions symptoms, it eliminates consequences of organism irradiation by various wavelengths, it acts antioxidant, it decreases LDL cholesterol and triglycerides in blood, it regulates cell growth, and it has anti cancers effects and it support immunity system of organism. It contents also lot of vitamins (B, D, C, K), minerals, trace elements (Na, Cr, Cu, I, Se, Zn) and some of fatty acids. At the same time it is also source of natural imunomodulating compound beta-(1,3/1,6)-D-glucan , which is in scientific literature marked as an „pleuran“. The aim of submitted task is to solve the complex specification of space for oyster mushroom growing, characterization and selection of opinion, constructional and technical design of the building, technology and instrumentation facilities for the production process and the legislative side of activity.

MATERIAL AND METHODS

Constructional and technological-instrumental solution of oyster production unit space

Construction

For the purpose of oyster production unit construction there was chosen chose accessible building, which was connected to utilities and road infrastructure. This is a ground floor, part basement building on a plot area of 178 m^2 with unused attic. Taking account of the fact that the hygiene requirements of the Slovak Republic require specific spatial resolution of manufacturing food establishments, it was necessary to change the process layout of the building. The main cellar room is arched cellar with size of 13.240 m x 5.100 m and the area of 67.52 m^2. From the street part there are built three ventilator fans which are secured by a metal bar, while throw the middle fan the gas and water connections are solved. The height of the cellar is 1.900 m. Cellar floor is formed by the rubble stone laid in to the ground. In the part of the floor is built - in a drainage system, which is solved by spall drain. Whole cellar is 1.290 m below the soil terrain. At the time of oyster production unit proposal solution beginning, the cellar wasn´t isolated and air temperature of cellar was consistent with the environment temperature. The relative humidity was ranged around 60%. For the actual construction works the building material was secured by an individual selection procedure held by investor. Wiring accessories, heating and water works as well as the used material were secured by hiring of specialized companies. Technological solution of actual oyster mushroom production service was solved by an authorized firm with long-year practice.

Lighting

Since this is a fully isolated place, the daylight is excluded. Oyster mushroom belongs to the mushrooms which for optimal development of fruiting bodies need a certain light intensity. The lighting of whole room was solved by LED stripes in cold white color and by chip with size of 3528. Per one meter falls on 120 lights emitting diodes treated by silicone coating IP64 for installation and the work in an extremely humid environment. Consumption of the one strip is about 48W. The color was chosen after careful consideration of all the facts, which where available. There was presumption that the cool white color (spectrum with a predominance of blue color intensity of about 6 500 to 7 000 Kelvin degrees), would be the closest to the oyster mushroom requirements, because the mushroom is not green plant, and it doesn´t contain chlorophyll. There is another advantage of mentioned spectrum, because it is among all spectra the nearest to UV radiation, which is necessary for healthy development of some mushrooms species. LED strips were prebuilt on the vault, and they were fixed with silicone to forward by screws attached belt. The total number of bands was 13 with a length of 5 m, which formed together 65 meters luminous strips. Uniform illumination of the space is considered as a one of the benefit of mentioned strips. Another advantage of these lights is that during their operation they do not heat the environment, which means less need of cooling. Power supply is handled by a 12 V voltage by wiring network which is led from distribution point located outside the factory, in which there are two transformers (brand V-TAC) in power of 400W prepared for this purpose. The operation is solved in two ways. The first mode is a manual, and lighting can be switched on or off at any time, we need. The second mode is fully automatic, which means that the lights will be switched on or off according to the settings. There were installed two mutually independent waterproof ceiling lights in to the processing room in case of need or disorder. These are operated from the hallway.

Cooling

An important fact is that before the actual fructification of overgrown substrate is required initiation of procreation, which is carried out by cooling of the entire substrate to a temperature about 5 °C. Cooling was solved through the order by certified specialized firms. Refrigerating unit with an output of 5KW controlled by ELIWELL and by vaporizer 5, 2 KW with two fans is made in the Czech Republic. It serves as a source of coldness for commercial and industrial cooling. Full enclosure of unit provides perfect protection against the rain and moisture. The basic parameters for the correct selection are desired output, the evaporative temperature and ambient temperature. The evaporative temperature is usually about (5) 7 to 10 K below the planned temperature in the cooled space - the value depends on the application and the type of evaporator. Following the consultation there was chosen the unit CH-5-S QO nom. (kW) 4.72, with type of compressor ZR22, diameter (mm) 450, flow rate (m^3/h) 3900, power supply 400V-3ph-50Hz, Pnom 1.58kW, MPP 2.9 A and acoustic pressure in 10 meters 40dBA and weight 90 kg for our kind of spaces.

Heating

Faster of oyster mushroom is solved by alternative heating through to portable electric heaters with fans. The type GUDE GH 3 P was selected in two pieces. Electric Heater GH 3 P is a robust electric heater with 3 kW heat output, fan and spatial thermostat, which is designed for using in agriculture, gastronomy, for assemblies and wherever, where heaters for oil and gas are not proper and authorized. The specification of connection is 230V/50 Hz. Its heating capacity is 3 kW (2,580 kcal/hour). Maximum current consumption is 13 A and output of blowing is 305 m^3/hour. Connection cable length is 1.4 m / H05RN-F 3x1.5 mm^2. The weight of whole device is 5.5 kg and it is also designed for work in humid environments. The expected impact of the fan is about six meters, therefore it will be one heater placed on one side of the 13 meters long room and the second one on the other side, directly opposite to first one. Heating of the air should be slow, which means that the air in the room should not be dried as much as in case of other combustion heaters. Both heating aggregates will be supplied from electrical distribution point located in the access corridor. They are controlled by a thermostat.

CO_2 regulation

CO_2 regulation at the time of task solving was not automated. The original project counted with automated ventilation with triggering system of fans on the base of CO_2 sensor when reaching the critical value of 600 ppm in air. It is known that the decomposition of the substrate by wood- destroying mushrooms creates large quantities of CO_2, which inhibits further development of fruiting bodies. However, it is also known that the CO_2 gas is heavier than O_2; therefore it flows down to the ground. This phenomenon should be partially regulated by mixing of the air through heating or cooling fans, which were installed in the room.

Relative air humidity

For proper growth and development of fruiting bodies of the oyster mushroom is one of the most important parameters relative air humidity. In a dry background the fruiting bodies often get dry and this way its growth is completely finished. Even in repeated increasing of the relative humidity its development is not regenerated. On the contrary high relative air humidity is also insufficient because it helps to spread the competitive microorganisms, fungi and other mushrooms. Another important fact is that even during the various stages of fruiting bodies development demands on relative air humidity are changing. The optimal solution is a fully automated system of humidification, with regulation of desired humidity in different stages of fruiting bodies development. In cultivation practice is most often used oscillating ultrasonic membrane principle. The basis of a steam generator is an oscillator which oscillates at a frequency of about 1700 kHz. Vibrations are transmitted to the ceramic disk which is placed on a float, which vibrates the water. This is turned to microscopic droplets of water mist. Almost every generator has a level sensor which will automatically turn off the generator, when the water level falls. This should avoid the violation of the ceramic disk. The floating body is placed in a container with water. In our case a commercially available portable unprofessional humidifier type Orava HUM-32 with max. 32W power, water tank 3.5 liter was used.

Substrates preparation and observation of temperature influence on fruiting bodies formation

The growing bags with substrates were supplied by wholesale trade buying. Growing medium for our purposes was produced in March 2014 by inoculating by oyster mushroom planting on sterilized straw substrate. The company has many years of experience in the production of oyster mushroom substrates. It uses the strain HK 35, which is in practice used the most. This type of strain is aimed for inoculating of straw substrates in intensive production, as well as for inoculating of wood for extensive cultivation. The substrate itself for starting of trial operation was ordered in 20 pieces of 22 liter cylindrical bags, whereby one bag was weighed about 10 kg. Substrate was ingrown by mycelium in the company places from the date of production until the day of taking (7 days). Then it was taken from the delivering company, transferred and stocked in our production facilities, where it was ingrown at 22 ° C temperature for 17 days. These substrates were appeared perfect overgrowth of white mycelium coating. Total number of substrates (20) was divided into two variants:
Variant A – 10 bags (No. 1-10) with substrates cooled to 6 ° C for 4 days.
Variant B – 10 bags (No. 11-20) with substrates without a cold period, ingrowth at 22 °C.
After four days since the experiments foundation in oyster production unit place, the temperature was increased from 6°C to 13°C. The substrates were stored on the oyster production unit floor freely, without stand, whereby they were laid in the shape of an inverted V. During next every day the increase of fruiting bodies was measured in centimeters. After the harvest phase the fresh mass of fruiting bodies was weight out and achieved crops were evaluated.

RESULTS AND DISCUSSION

Technological-instrument equipment evaluation of oyster production unit

The required temperatures were reached fully automated by heating and refrigeration technology connected to the thermostats. The choice dimensioning of lighting with dominative blue spectrum seems to be sufficient. The same detections could be found in articles of unknown authors, named Oyster Mushroom Cultivation **(Anonym, 2014)**. The air relative humidity increasing was solved by non-professional equipment Orava HUM-32. Device as well as all the previously mentioned technical instruments satisfied our requirements in full measure. According to the digital hygrometer in oyster production unit place the 99% humidity was reached, which is much more than it is necessary for optimal development of fruiting bodies. Oversize humidity can be dangerous for growing due to the possible expansion of unwanted microorganisms. That was the reason for the power of humidifying unit reduction to the minimum value. According to **Jablonský and Šašek, (2006)** high level of humidity causes rapidly expanding of undesirable microorganisms, but we did not mark similar problems. Relatively low 13°C temperature can be the reason. Noticeable defects were indicated during the trial operation, because of the CO_2 increased concentration in the room. The first expression of an oversized gas concentration was unnatural bending of the fruiting bodies. Inhibition of fruiting bodies development from later stocked substrates was the second one, more serious problem connected with CO_2 excess. Following on mentioned facts there is need of CO_2 sensor installation connected to an automatic ventilation system for optimal oyster production unit working. Following of **Jablonský and Šašek ,(2006)**, that the most common problem of the oyster mushroom cultivation is usually the CO_2 concentration in the atmosphere, the assumptions were confirmed.

Evaluation of fruiting bodies production quality and quantity

The first germs of fruiting bodies on growing substrates began to form 4 days after stocking in to oyster production unit with 13° C. temperature. Specifically, on the substrate number 10, included in variant A. Initialization of last fruiting bodies was realized after 11 days from the substrates storage in to oyster production unit. In this case, it was a number of substrates 11 and 19 which means the bags placed in variant B. The results are shown in table 1.

Table 1 Summary of total days from inicialization to sporocarp harvesting

Variant A				Variant B			
Substrate number	Starting of production in days	Ending of production in days	Duration of sporocarp growth in days	Substrate number	Starting of production in days	Ending of production in days	Duration of sporocarp growth in days
1	7	22	15	11	11	22	11
2	6	20	14	12	9	19	10
3	8	22	14	13	9	20	11
4	8	22	14	14	7	19	12
5	6	19	13	15	7	19	12
6	6	20	14	16	9	12	13
7	5	20	15	17	8	20	12
8	9	22	13	18	7	19	12
9	7	20	13	19	11	22	11
10	4	16	12	20	7	19	12
average	10 days	24 days	14 days	average	13 days	23 days	12 days

The first fruiting bodies harvest of the first growth wave began at 16th day of the substrates storage. Last fruiting bodies of the first growth wave achieved harvesting size on the 22nd day of the substrates storage. According to Table 1 the average number of days from storage to initiation of the first fruiting bodies germs is 11 days. The development of the fruit bodies from initialization to the date of collection is 13 days in average. After counting these days required to initialization of fruiting bodies and days required for the development of fruiting bodies together there is given the total number of days required for the first wave of growth. In average conditions the first growth wave deserts 24 days, while the authors **Jablonský and Šašek, (2006)** and **Jánoš, (2012)** are reported 21 days. The resulting difference can be explained by the different temperatures in oyster production unit. While the authors describe growing from 13° C to 21° C, we have grown at a constant 13° C temperature. It is known that higher temperatures accelerate the fruiting bodies development, but these are more susceptible to diseases and pests.

In comparison of variant A and variant B, there was found that chill shock at 6° C for 4 days, had a slight effect on the various substrates onset to bearing. While substrates from variant A began to initiate fruiting bodies on 10th day of storage on average, substrates from variant B started to fruit after the 13-days on average. More important is the fact that the substrates from variant B reached harvesting size on average one day sooner than bags from variant A. There was also found that chill shock was not needed, which means partially contradiction with the finding of **Jablonský, Šašek (2006)**, who argues that there is often necessary cooling to 5 ° C for several days for the mushrooms fructification. The fresh fruiting bodies of mushrooms yields from various substrates harvested during the first growth wave are shown in Table 2.

Table 2 Profit of fresh mushrooms from each substratums in grams

Variant A				Variant B			
Substrate number	The order of begining of parturienty	Duration of havresting in days	profit in g	Substrate number	The order of begining of parturienty	Duration of havresting in days	profit in g
1	fourth	3	906	11	seventh	1	906
2	third	2	766	12	fourth	1	644
3	fifth	5	1 152	13	sixth	3	824
4	fifth	5	804	14	fourth	2	984
5	third	3	1 052	15	fourth	1	1 327
6	third	2	1 032	16	sixth	4	878
7	second	4	860	17	fifth	3	618
8	sixth	4	1 106	18	fourth	3	1 632
9	fourth	3	1 126	19	seventh	1	1 010
10	first	1	1 486	20	fourth	1	1 186
Total 10 290				Total 10 009			

Crop yields from the fruiting bodies of the first growth wave together from the variant A and variant B were 20 299 g, which means, in conversion, 10.14% of the total weight of the substrate. Most authors (**Bela and Khalafalla, (2011)**; **Block et al. (1959)**; **Ginterová and Maxianová, (1975)**; **Jánoš, (2012)**; **Jablonský and Šašek , (2006)** and others) mention that the yield of fruiting bodies is at the level of 15-30% of the fresh substrate total weight, whereby the first wave usually create 70% of the total mushrooms production. However, an exception occurs when the growth during the first wave encounter with problems that limit the fruiting bodies development. This fact is related to these findings. From all individual substrates development observations results that bags with substrates that started to fruit earlier, reached the highest production. Their fruiting bodies grew up in bigger sizes and their evolution proceeded without any problems. In case of fruiting bodies, which joined the bearing later, there were noticed big insufficient. While initially their development run standardly, in the process the individual fruiting bodies started to differentiate in quantitative way. Fruiting bodies growing above were developed further, but fruiting bodies growing lower started to fall behind the growth until their growth was stopped and they wilted. According to our opinion, the problem is the accumulation of CO_2 near the oyster production unit floor, because it is heavier than O_2, and flows down to the ground. This way it inhibits the growth of fruiting bodies which are placed below. In the last days of harvest fruiting bodies in higher places completely stopped growing as well. This had a great impact on yield production decrease. Argument is in agreement with **Jablonský and Šašek, (2006)** and other authors, according to which CO_2 has a significant inhibitory effect on the fruiting bodies growth. This deficiency needs to be solved by ventilation of manufacturing space. Losses caused by excessive concentration of carbon dioxide in the room are not permanent, after regular venting of the gas, the required production of mushrooms will be reached in the second growth wave, as it is mentioned in **Jánoš, (2012)**. Finally, it should be noted that all fruiting bodies obtained from the first harvest were completely healthy, without distortions or other damage. Because of optimal cultivation temperature influence there was prevented to the development of insect pests and other undesirable microorganisms.

CONCLUSION

The building – technological proposal of oyster mushroom forcer – oyster production unit with taking account to its specific agro-technical requirements and valid legislative was solved in submitted task.
Building modifications were proposed and realized in a construction, which was at the time unused and tenanted by author of article. Special attention was paid to the issue of the legislative background for activating of operation to production. Then we oriented in detail to technological-instrumental equipment of operation in four main divisions, namely: air temperature regulation, air relative humidity and CO_2 content regulation. The fourth, very important category was dimensioning of lighting. There was found, that instrumental equipment was dimensioned in good way, thermal regime could be fully automated controlled to the desired temperature. Likewise, moisturizing of place was sufficient. The task dealt with the proposal of innovative LED lighting. It was verified that the blue spectrum is very suitable for oyster mushrooms growing. Major problems were observed in case of CO_2 content in the room, when its concentration increased to the point that the development of fruiting bodies on the substrates, which started to fruit later, was completely stopped. The solution is installation of automated ventilation system, connected to a CO_2 sensor. For agricultural practices there is recommendation of paying increased attention to carbon dioxide in the room mainly and to ways of its elimination.
Next aim of the task was to verify the relevance of the thesis about the onsets to bearing, harvest term and yield crops from two different variants. The variant A run through cold-shock at 6 ° C temperature for 4 days and variant B was to oyster production unit stored without chilling. The results indicate that there was not fundamental difference between observed variants. Crop yield of individual variants was almost identical. According the results, there is recommendation of not to use cold shock in case of strain HK35, because of avoiding of energy costs increasing. The total amount of yields was not identical to statements of the authors about the yields from the first growth wave. While the most authors declare average yields from the first growth wave in amount of 21 % from the total weight of fresh substrate weight, our yield crops were ranged around 10 %. Hypothetic reason is the high CO_2 concentration in the room. Fruiting bodies quality was sufficient, without any damage by pests or other pathogens. It was slightly decreased by rising of CO_2 content followed by formation of funnel-shaped fruiting bodies. According to total summarizing there can be said, that after removing of all deficiencies, identified during the trial operation, the place will be fully suited to purposes of oyster mushroom forcing.

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