MUSHNOMICS

Unlocking data-driven innovation for improving productivity and data sharing in mushroom value chain

D3.5 – Final documentation of the MUSHNOMICS Module

Document	
Deliverable title	D3.5 – Final documentation of the MUSHNOMICS Module
Related Work package	WP3
Responsible editor	PILZE
Contributors	
Delivery date	30.01.2024

Version history			
Author	Comment	Version	Date
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Disclaimer

The MUSHNOMICS Consortium is the following:

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1 Introduction

This deliverable as a simplified technical specification and users' guide describes the key output of the Mushnomics project. This is the Mushnomics module solution developed by Pilze-Nagy Ltd. to offer a technology for household and small scale, hobby or business growers for cities using urban biowastes.

Pilze-Nagy Ltd. can support anyone to start experimenting with oyster mushroom growing at home or at an urban farm by using available biowastes to cultivate delicious oyster mushroom. Pilze-Nagy Ltd. offers a variety of protocols and devices covering the whole value chain - from substrate processing to SMS utilization - to establish urban oyster mushroom growing farm in different scales based on urban biowastes. Starting with the composting drum using the own heat forming during the composting process for pasteurization and ability to record the temperature and CO_2 curves as key indicators for quality compost and food safety and closing the circle with tools for vermicomposting of the spent mushroom substrate.

The key is though to the whole process is the mushroom growing cabinet. This is an insulated box available in different sizes and equipped with ventilation and humidification units to secure the optimal growth conditions for the mushrooms. The control algorithm is based on the actual values recorded by sensors in- and outside of the cabinet. Connected to the internet, remote access to data and intervention into the processes is also an option from your mobile phone. The pasteurized and spawned oyster mushroom substrate filled in plastic buckets with holes on the side are placed on the shelves within the cabinet. Easy to operate and manage, as well as harvest, the cabinet can be the basis of the urban farm or just simply a showcase demo unit in any restaurant.

2 MUSHNOMICS module: the mushroom growing cabinet

2.1 Basic technology specifications

Figure 1: The Mushnomics module: the mushroom growing cabinet

The key function of the module is to secure optimal conditions inside for the growth of oyster mushroom. This is possible by the physically separate space, the sensor integration and data collection, as well as by the software control intervening based on the sensors' data and thresholds set by the user. The module can be operate both indoor and outdoor, though outdoor operations can have its limitations.

- Dimensions:
  - Width: 2100 mm
  - Depth: 1500 mm
  - Height: 2700 mm

- Weigt: 550 kg
- Materials used: steel framework covered by sandwich panels with transparent door in the front.
- Capacity: 9 shelves on 3 levels for the oyster mushroom substrate filled in buckets or wrapped in foil (blocks), a total capacity is approximately 250 kg of oyster mushroom substrate in a batch.
- Water supply: water tank (barrel) placed behind the module separately from where water is pumped into the module for the humidifiers.
- Electric supply:230 V, 50 Hz, type F plug
- Connectivity: internet connection (wifi or cable) necessary for operation and remote access.
- List of equipment included:
    - Electric box
    - Raspberry Pi computer
    - Water pump
    - Ultrasonic humidifiers (6 pieces)
    - Fan
    - Heating mat
- List of sensors included:
    - Temperature (inside, outside)
    - Relative humidity (inside, outside)
    - CO_2 level (inside, outside)
    - Pressure (inside, outside)

2.2 Users' documentation

Prerequisites for installation of the module and actions to do before turning it on:

1. The equipment requires 230V power supply from a grounded (type F "Schuko") socket with 10A load capacity. The Hungarian safety standards can be connected to a socket provided with a 10A fuse and life protection relay, operation with a power source that does not meet these conditions is prohibited!
2. Internet connection via wifi or wired ethernet is necessary for data recording and modification of control parameters.
3. The module should be placed in a horizontal (maximum allowed deviation 1 cm, i.e. 0.25 degree angle) and solid ground with the wheels blocked to avoid unwanted movement. It is prohibited to operate the module on a slope.

4. If operated outside, the module should be placed in a shaded area, in case of continuous sun light even with cooling, the desired temperature cannot be maintained in all cases, while the water and electricity consumption will increase significantly. Also avoid outdoor operation in the case of strong freeze as the forming ice may harm the equipment.
5. The metal cover shields the wifi signals, so in the case of wireless internet used, the electrical box at the back of the module must be in the direction of the source of the wifi signal.

Safety warnings:

1. The equipment has a voltage of 230V and a wet, humid and watery operational environment inside. All the electric part using 230V are in the external technical box mounted on the outside back wall of the device, all the other parts outside the box (i.e. within the cabinet) are already operating at contact protection extra-low voltage. Only low-current equipment and cabling can be found in the closed body itself, this is an exception for the heating unit, which has a water resistance certificate (IP68). The fan is outside of the closed boxed moving fresh air from out to inside.
2. If an abnormality is experienced during operation, the electric supply must be immediately shut down with the circuit breaker within the electric box. The cable plugged into the network must be disconnected (pulled out).
3. The equipment may under no circumstances be operated from a connector without grounding, as well as without a fuse or from a network not protected by a life protection relay!

The module can be turned on and start the operation via the online surface. Before startup the electricity connection and the sensors should be checked, and the water tank fully filled with water. While the module does not require frequent maintenance, the water tank needs to be checked and refilled regularly. The pump must be in water all the time – running out of water may not only risk mushroom production but also harm the pump.

For the operation of the properly installed module, constant electricity is needed. While the module can operate properly without constant internet connection, remote access, data transfer and interventions are not available during offline operation.

After purchasing the module, the user will receive the unique login data for the online surface. If opted, the developers can also have access to provide remote technical support. Following the modular possibilities, after login the user can select the actual device (for example for an urban farm even more modules can be integrated to one surface) by the “Go device” button. For each device the actual measured data (or in case of offline operation the last online registered data) can be seen. By default setting the data of the last 48 hours are visualized on a graph, too.

Under the settings function the threshold of the control parameters and the details of interventions can be changed. It is only advised in case of experienced mushroom farmers, otherwise the user may rely on the default settings provided by Pilze-Nagy Ltd.

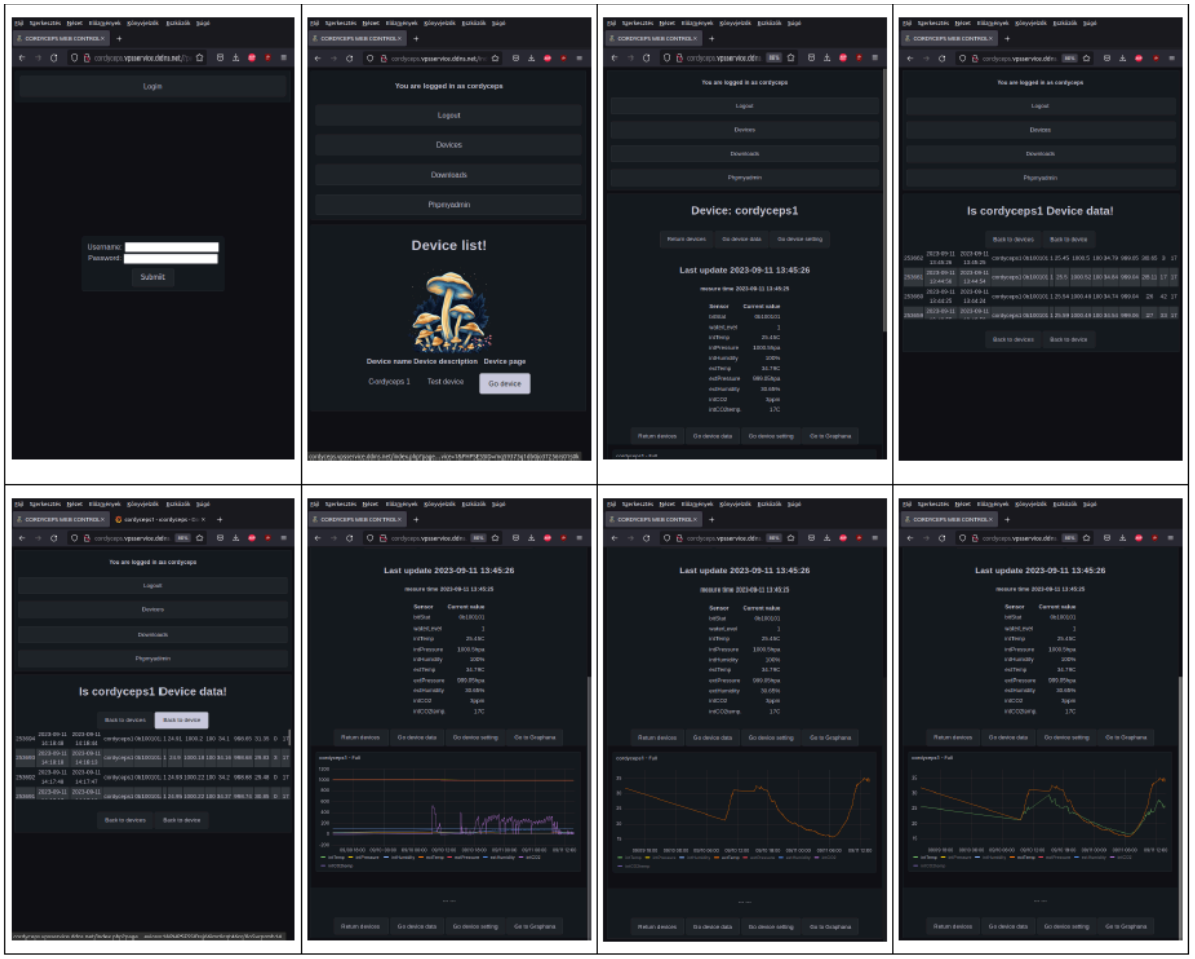

Figure 2: Example print screens of the online surface of the module for data collection

Chart management and data export are possible by using the graphana tool of the online surface. Here, the chart contains all the data at the same time period marked with a different colour. The individual data name and corresponding colour can be found at the bottom of the diagram. Individual data can be viewed separately in the area below the diagram by clicking on the name of the desired data. After clicking on the name of the desired data, all other data will be hidden, thus the diagram scale also changes. By clicking on the name of the selected data again, all data will be displayed again.

On the graphana interface, the user can query all the previous data by selecting the period and data of interest. After the desired time interval has been set, the data can be downloaded, e.g. in CSV format.

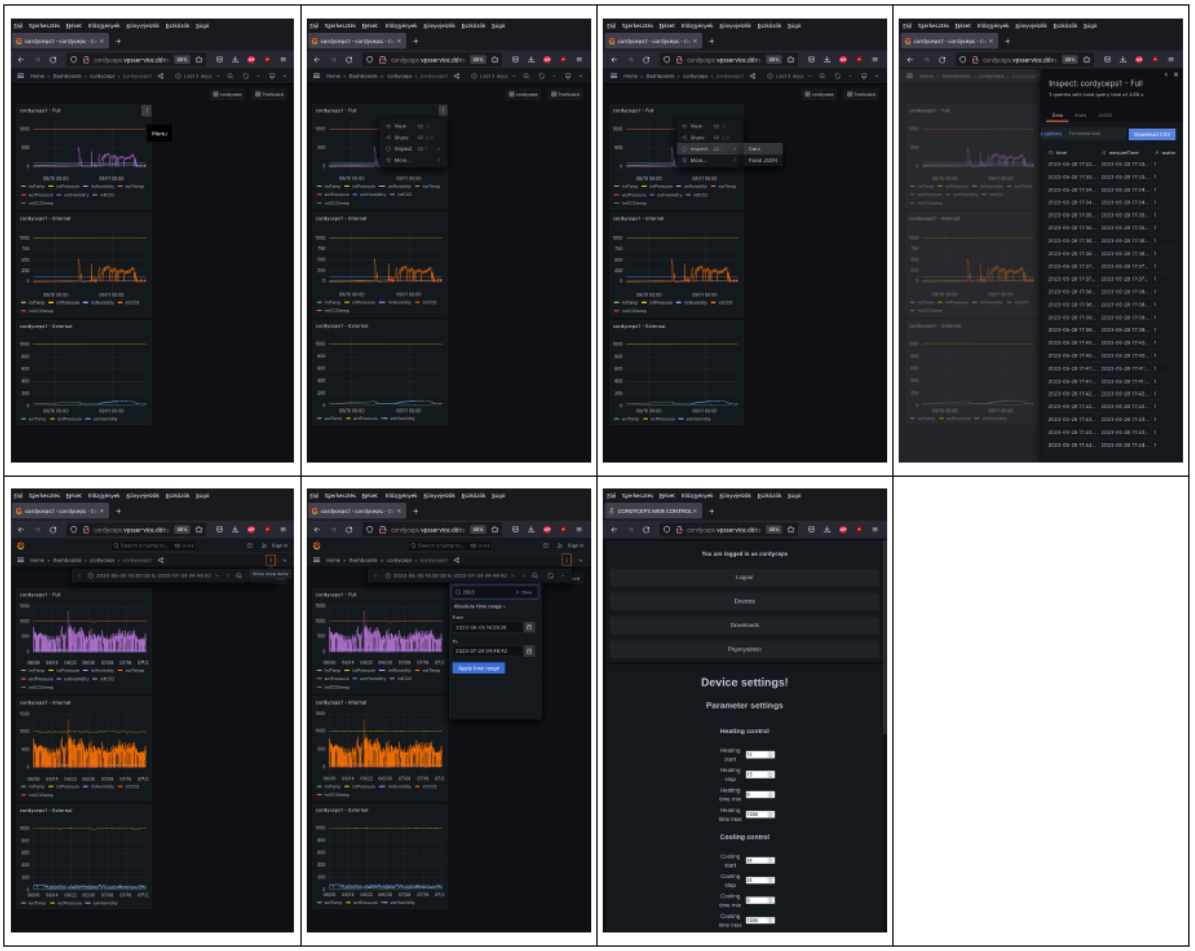

Figure 3: Example print screens of the online surface of the module for graph management and data export

2.3 Quick guide for oyster mushroom growing in the module

Pilze-Nagy designed the module for use in urban settings, ideally used with urban biowastes previously turned into oyster mushroom substrate. For a comprehensive guide on the process on different scales please visit the Mushnomics Platform at platform.mushnomics.org. where after registration you can perform customized calculations for your case.

Pilze-Nagy also offers solutions for the collection of biowaste and substrate preparation. For small and demo scale, there are specialized, cardboard based, thus biodegradable collection bins for coffee grounds that can be directly placed into the module after the substrate preparation and spawning step. For large scale substrate preparation, the horizontal composting drum is offered followed by spawning and filling the ready substrate into buckets. In the drum, the forming heat of composting will secure the conditions for pasteurization, thus electric power is only necessary for moving the drum around which will provide the aeration.

Figure 4: Mushnomics composting drum

Once the pasteurized and spawned substrate is ready, the user can follow the below steps for using the module.

1. Cleaning up the module: to prevent contamination the module must be clean and sterile. Before loading the substrates onto the shelves, the user needs to clean-up the inside of the module and remove all leftovers of previous batches. The surfaces need to be cleaned by spraying disinfection liquid and thoroughly washed. The user needs to respect the rules of sterile working by wearing gloves.
2. Startup the module: the module needs to be plugged in and online, as well as the water tank filled first. After that the substrate (in forms of buckets, blocks, cardboard collecting tubes or other) can be loaded onto the shelves by maintaining at least 30-40 cm between the units on the same shelves. The module can be turned on by logging into the online surface after checking there the control settings. It is advised to wait for the booting of the module and check if everything works.
3. Incubation – spawn run: the first phase of the oyster mushroom growing is the spawn run. In case of using the module outdoor, this phase may not be carried out as the constant temperature inside cannot be maintained with high fluctuation of the outdoor

conditions. During this phase the mycelia produce heat within the substrate units that should be removed by careful and gradual aeration to keep the seed temperate below 34°C. This phase can take of 2-3 weeks closely monitored and controlled by the software based on the sensors' data. After that the pinning is triggered by environmental changes in case of mushrooms – by decreasing the temperature and increasing the humidity.

4. Fruiting: once the substrate is completely colonised with mycelia, the software will apply a sudden drop temperature with also increasing humidity to initiate cropping. During cropping, relative humidity of 80-95% should be maintained depending on the temperature. The software has a calibration of the relative humidity to the moisture content depending on the temperature (based on the Mollier diagram) to maintain the necessary water mass in the internal space. The control algorithm also secures that the CO_2 level is kept on a good value.
5. Monitoring and harvest: though the module maintains the good conditions within the cabinet automatically, the user may monitor the process frequently, especially the water in the tank. The user needs to check the pins and the fruiting bodies, and record every abnormalities and remove immediately contaminated blocks. It is advised to install fly traps/papers to prevent contamination. Once the fruiting bodies are large enough, usually after 3-4 weeks after the trigger, the user can harvest them. Multiple flushes of harvest can be done for a batch. Every time, the user opens the door of the module, it should be kept open for the shortest possible time while good hygiene and careful work are needed to keep clean conditions.

3 Conclusions

The process of the Mushnomics project – from the concept through the design, development and building and finishing with trials and finetuning – has demonstrated the Mushnomics module system. It is tailor-made and modular technology offering a circular solution to turn urban biowastes into oyster mushroom substrate and to grow oyster mushroom.

Through the process, experts of Pilze-Nagy demonstrated that oyster mushroom production on urban biowastes such as coffee grounds and cardboard is possible by applying good substrates recipes and operation protocols for substrate preparation. This solution is now available for cities in form of the Mushnomics module with software-based operation for data collection, remote access and intervention management.

This modular and scalable smart module system is here to realize circular oyster mushroom production in cities on biowaste, and complemented and supported by the Mushnomics digital platform acting as knowledge hub for anyone considering oyster mushroom growing using urban biowastes.