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Research and evaluation of the quality of vacuum button mushrooms picking

Badania i ocena jakości pieczarek wyrywanych z podłoża przy użyciu chwytaków podciśnieniowych

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Abstract: Automation is becoming an increasingly common field in industrial-scale cultivation. In the case of mushroom cultivation (Agaricus bisporus), intensive research is being conducted on the uprooting of individual objects and the cutting of all mushrooms above the substrate surface. Automation eliminates problems associated with manual harvesting and increases the efficiency of this process. The paper contains descriptions of the mushroom growth environment and the uprooting tests carried out. Based on them, a test stand was designed and an experiment was developed, the aim of which was to assess the quality of uprooting a single mushroom and to analyze damage to its cap. The use of various types of vacuum grippers was considered for uprooting the object, which were analyzed in terms of the possibility of grasping the mushroom and causing mechanical damage to it.

Keywords: button mushroom, suction cup, vacuum, harvesting

Streszczenie: Automatyzacja staje się coraz powszechniej wdrażaną dziedziną w uprawie na skalę przemysłową. W przypadku uprawy pieczarek (Agaricus bisporus) prowadzone są intensywne badania dotyczące wyrywania pojedynczych obiektów, jak i ścięcia wszystkich owocników nad powierzchnią podłoża. Automatyzacja pozwala wyeliminować problemy związane z manualnym zbiorem oraz zwiększyć wydajność tego procesu.
W pracy zawarte zostały opisy środowiska wzrostu pieczarek oraz przeprowadzonych badań wyrywania owocników. Na ich podstawie zaprojektowano stanowisko testowe i opracowano przebieg eksperymentu, którego celem było dokonanie oceny jakości wyrywania pojedynczej pieczarki oraz analiza uszkodzeń jej kapelusza. Do wyrwania obiektu rozważono użycie różnych rodzajów chwytaków podciśnieniowych, które przeanalizowano pod kątem możliwości uchwycenia owocnika oraz powodowania na nim uszkodzeń mechanicznych.

Słowa kluczowe: pieczarki, ssawka, próżnia, zbiór

Introduction

Mushrooms are produced in over 70 countries around the world [1]. According to data from 2021, the largest producer of mushrooms in the world is China, supplying 41,117,740 tons of mushrooms per year. However, it should be taken into account that this is a statistic for all types of mushrooms. About 22% of the total are Lentinus edodes, or shiitake mushrooms. In addition, the most commonly produced mushrooms are Pleurotus (oyster mushrooms), Auricularia (eared mushrooms, Mun mushrooms), Agaricus (champignons) and Flammulina (flame mushrooms). This statistic shows the leading producers of mushrooms and champignons in 2021. Poland is currently the third largest producer of mushrooms in the world and the first in Europe. Since joining the European Union, there has been an annual increase in mushroom exports. According to the Eurostat latest data from May 7th, 2025 [2], the total export of mushrooms from the European Union countries amounted to over EUR 650 million, of which Poland's share was 50.1%. Market analysis [3] provides the following data for 2024 in Poland, 360 thousand tons of mushrooms were produced, 68% of which were exported. Poland, next to the Netherlands, is the largest producer of mushrooms in the European Union. In reference [2], can be found another statistic data presented in Fig.1.

Manual mushroom picking is a costly and time-consuming process. The specific problems faced by the Polish mushroom industry in the coming years include: insufficient number of qualified employees and increase in production costs resulting from the in-

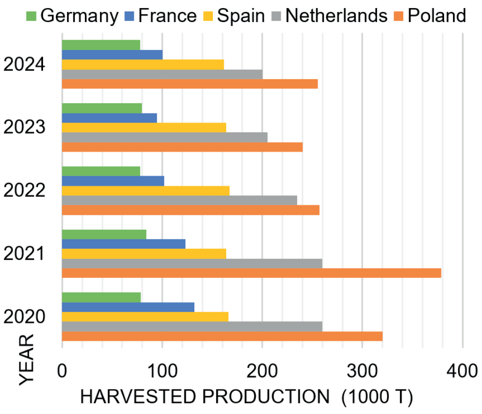


Fig.1. Biggest producers of agaricus bisporus in EU

crease in wages, energy and the cost of the substrate for cultivation. In addition, an important aspect in the mushroom production sector is to ensure hygiene of the workplace in order to prevent the development of fungal and viral diseases. The most common and most difficult to combat are fungal virus X (MVX) and fungal pathogens *Trichoderma aggressivum* [4].

The solution to the specified problems is to create a robotic mushroom picking line, the operation of which is not dependent on the human factor. The first machines for mass mushroom picking were introduced in the late 1970s. High work efficiency was achieved at that time, but the picking concerned all mushrooms, regardless of their size. Modern mushroom farms use partial automation of the process, which allows for the control of mushroom growth conditions via controllers. The parameters read are temperature, humidity, air flow and composition. Until now, the decision about which mushrooms to pick was made by a human.

A mechanized mushroom picking station ensures more hygienic work, due to the possibility of disinfection before and after the robot completes its passage along the shelf. Due to the lack of human contact with the product being picked, the risk of spreading the disease is reduced. Mechanical mushroom picking is characterized by high efficiency and, compared to manual picking, takes much less time. During one round of manual picking, i.e. one passage along the shelf, 4 to 5 people work. At the highest productivity, each person picks an average of 20 mushrooms in 30 seconds. However, it should be remembered that an employee is not able to work with the same high efficiency for 8 hours, and its decrease is noticeable. The reasons are fatigue and weariness due to the repetitiveness of the activities performed. Mushroom picking is monotonous work, which is why mistakes in choosing the right size of mushrooms can very often occur – as a result, complaints from the customer are necessary, which generates unnecessary costs. The problem is the improper classification of mushrooms when picking, which depends entirely on the employee. Decisions are made based on experience or using manual measuring tools. Such work is subjective and requires training of each employee. Another problem that mushroom producers struggle with is high employee turnover. Due to frequent staff changes, a lot of time must be devoted to introducing new employees [5] [6]. Interesting solutions are provided by Mobicchamp, which revolutionizes mushroom harvesting by combining high-resolution visual analysis with AI-driven guidance and real-time projection to boost efficiency, yield, and quality. All while paving the way for future farm automation [7].

The main contributions of the prepared article are: to test the vacuum mushroom capturing technique in workshop conditions, to identify potential damage that would exclude the mushroom from sale, to establish cooperation with mushroom growers and to prepare the basis for further research on the automation of mushroom harvesting and processing.

Agaricus bisporus

Agaricus bisporus, the two-spore mushroom or button mushroom, is the most commonly consumed edible mushroom in the world. It can have two colors – white or brown. It gained its popularity due to the richness of nutrients, vitamins and amino acids. It has a high protein and carbohydrate content with low calorific value and fat. In addition, it is easily available and has a pleasant taste [8] [9]. The size to which mushrooms are grown depends on market requirements. An important parameter determining the decision to harvest is the diameter of the cap (Fig. 2.). It is not symmetrical, it is characterized by irregularity. The market price of the batch depends on it. The diameter of the cap can range from 20 to 50 mm. The height of the mushroom reaches 55 mm, and the thickness of the stem from 10 to 25 mm. The weight of a single mushroom is on average 20–25 g. Due to its delicate structure, there is a risk of the cap and stem detaching if the mushroom is not properly grasped.

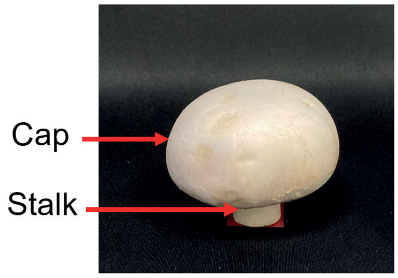


Fig. 2. Typical agaricus bisporus also known as white button mushroom

Test rig

The basic task in the project was to create a gripping system. In this case vacuum picking was chosen. This method is very simple but main disadvantage is a possibility of mechanical damage. The mushroom had to be pulled out in a way that would not damage its structure. Achieving satisfactory results was associated with the implementation of minor assumptions, which included finding the right type of suction cup that would adapt to the curved, irregular surfaces of the cap and selecting a vacuum that would guarantee extraction and would not cause bruising of the delicate surface of the mushroom. The picking tests were preceded by a review of the vacuum cups solutions.

The implementation of specific assumptions required the design of a test rig that would allow for carrying out all the necessary activities. For this reason, the following were separated:

- a part intended for vertical picking for naturally growing mushrooms, typical gantry system guided on precision linear rails, the design allows for taking any position within the mushroom box on the XYZ axes
- vacuum generation module,
- a station for taking photographic documentation.

All sections were built on a frame structure made of aluminium extrusions 40x40, connected together with brackets, screws and washers. The use of this type of connection allowed for quick modifications of the frame, for example moving the place of mounting the camera or adjusting the height of the pressure gauge. The generation of negative pressure was performed on the ejector. The negative pressure was regulated manually by changing the settings of the throttle valve limiting the air flow to the ejector. The negative pressure was read on a digital vacuum gauge connected to the suction line. For more ergonomic work, the frame structure was placed on a workbench. The upper part of the frame was at the height of the chest of an adult person. Test rig is presented in Fig. 3.

Identification of typical cap damage

Before starting the actual research, an experiment was conducted on one object. Its aim was to analyse the impact of various random situations on the appearance of the mushroom. This reflected the appearance of mechanical damage to the mushroom, bruising and how quickly it develops. In one place on the cap, the maximum recommended negative pressure was applied, it was brought to -65 kPa (no 1 in Fig. 4.), in another place, mechanical damage was made (no 2 in Fig. 4.), and in another place, pressure was applied with a spoon (no 3 in Fig. 4.). The resulting effects are shown in Figure 4. All types of pressure on the surface results in unacceptable phenomena during automatic mushroom harvesting causing bruising effects.

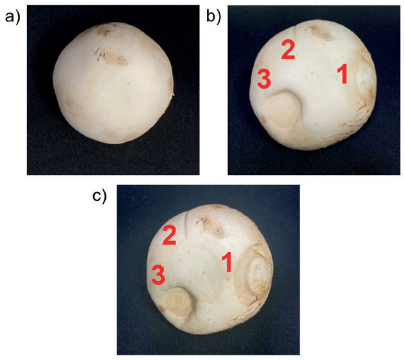
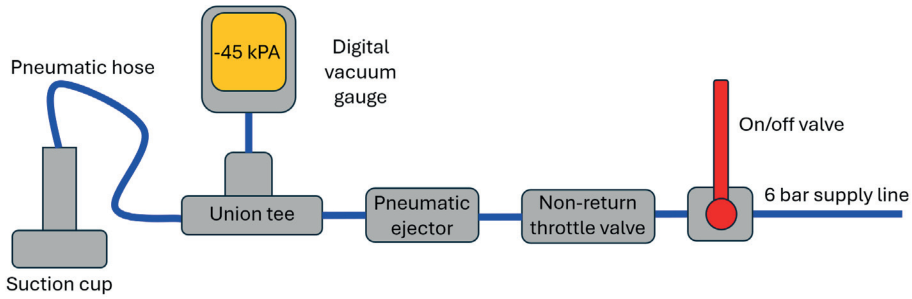


Fig. 4. Test rig for mushrooms picking: 1 – application of high negative pressure, 2 – cutting with a knife, 3 – pressure with a spoon; a) before test; b) 10 minutes after test; c) 24 hours after test

Vertical picking of mushrooms

For vertical picking two types of suction cups were used. First one was PISCO Ø 25 mm sponge cup. Advantage of this cup is is the ability to self-seal and adapt to the shape of the object. The second tested solution was a bellows suction cup made of nitrile rubber NBR – SMC MC 32BM. Both of these suction cups are characterized by similar grip certainty. Preliminary



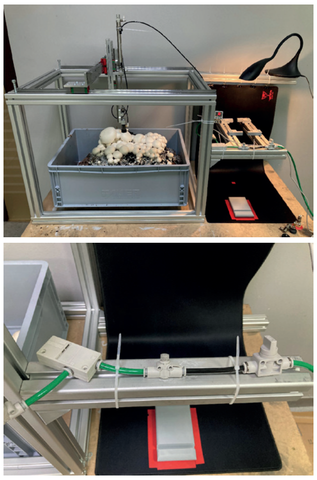


Fig. 3. Test rig for mushrooms picking: scheme and photo

tests have shown that used suction cups met the requirements of no damage to the cap of mushroom and no bruising that could occur around the circumference of the cup.

The requirements for this part of the test were: pulling out a single mushroom from the substrate,

- not damaging the mushrooms growing around it.
- In addition to these two requirements, it was still important to carry out the process without any signs of mechanical damage. Due to the failure of the mushroom producer to meet the deadline, live growing mushrooms were not obtained on time, which is why the test was reduced to an analysis of whether the suction cup was able to pull out the mushroom from the substrate. The mechanisms of damage were identified and determined thanks to the previous test. Based on the visual assessment aforementioned in this paper, it was decided that the rest of the test would be carried out on a suction cup with a 25 mm diameter sponge part glued on, due to the smallest interference with the mushroom surface. The test procedure consisted of indicating mushrooms ready for picking, and then manually positioning the suction cup above the mushroom. After such positioning of the arm, the vacuum was switched on. When the assumed vacuum threshold was reached, a manual movement was performed to pull out the mushroom.

The growth characteristics of mushrooms in the culture conditions were quite diverse. It was impossible to predict where the mushrooms would grow in the mycelium. For this reason, they were distinguished by more or less dense clusters. To conduct the experiment, the substrate with mycelium was obtained in boxes from an actual cultivation near Poznan (Poland). The substrate was collected before the first growth of mushrooms. Examples of substrates with grown mushrooms are shown in Fig. 5 and 6. The growth of mushrooms shown in the photos took place in the laboratory where the research was conducted.

Fig. 5. Typical mushrooms ready for picking

Fig. 6. Group of overgrown mushrooms

Some of the mushrooms were overgrown to a cap diameter greater than 60 mm, some grew in denser clusters, some in more separated ones. In the case of pulling out individual mushrooms, it was speculated that they would be pulled out more easily, because they would not encounter obstacles in the form of neighboring mushrooms. An additional problem with the dense arrangement of mushrooms was the overlapping of caps of different objects and the growth of stems at an angle to the substrate. Then the selection of specific mushrooms for pulling out was impossible and it was necessary to choose those located higher first. The study was conducted on six different groups of mushrooms, which initially grew on the shelves of the mushroom farm, and then were cut off together with the mycelium and transferred to transport boxes. During transport, the substrate loosened on the sides, which is why the results of the negative pressure test in these places were lower. In addition, manual gripper positioning during repeated attempts was imprecise and shifts along the XY plane could occur, causing the mushroom to rub and loosen the substrate in which it grew. The stability of the substrate was reduced, which meant that subsequent attempts resulted in easier uprooting of the mushroom than could be done with automatic harvesting in industry. Tests were carried out for 184 mushrooms. Data obtained from the experiment are as follows (Table 1), where failures should be understood as failure to generate vacuum pressure in the suction cup or breaking the connection during the extraction attempt:

Table 1. Mushroom picking statistics (184 total)

First attempt picking	68	36,96%
Second attempt picking	64	34,78%
Successful picking in more then two attempts	30	16,30%
Failures	22	11,96%

During the tests, damage was also checked, which is summarized in the Table 2.

Table 2. Mushroom damage statistics

Mushrooms without damage	42
Mushrooms with damage	142
Unsuccessful picking in first attempt and damage	49
Picking more than one mushroom	27

Typical damages

Typical mechanical failures noted during the test included the breaking of the cap from the stem (Fig. 7), defragmentation of cap (Fig. 8)

Another unwanted effect was twin picking, which occurs especially in mushrooms with stems that are very close to each other. In tests, this resulted in the extraction of so-called twins (Fig. 9.). This phenomenon also increases sucction force this may cause bruising.

During the test, the vacuum pressure needed to pull out the mushroom increased with each subsequent attempt (Fig. 10). There is a clearly noticeable trend of increasing the negative pressure value needed to pull out the mushroom. The value was increased manually until the grip needed in this process was achieved. The main cause was the clogging of the vacuum system and the suction nozzle (Fig. 11.). A clogged suction nozzle caused the need to pass a larger air flow in order to create a tight connection with the mushroom. The increasing value of the negative pressure is an indicator of the degree of contamination in whole suction line in especially for the filter insert in the suction cup. Unfortunately, the environment in which the mushrooms grow and the surroundings are not free from contamination. Using vacuum systems is associated with risk and a suction nozzle cleaning system should be provided.

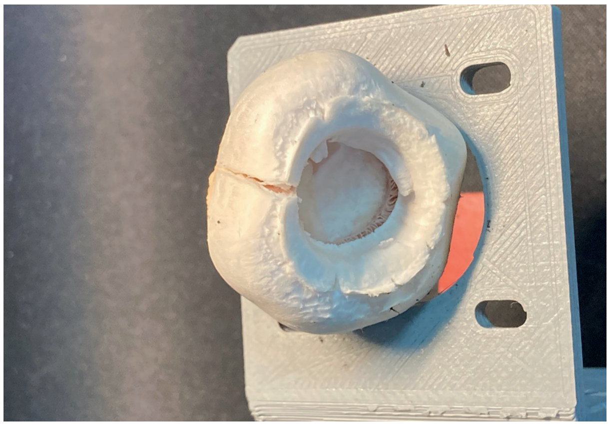


Fig. 7. Cap breaking

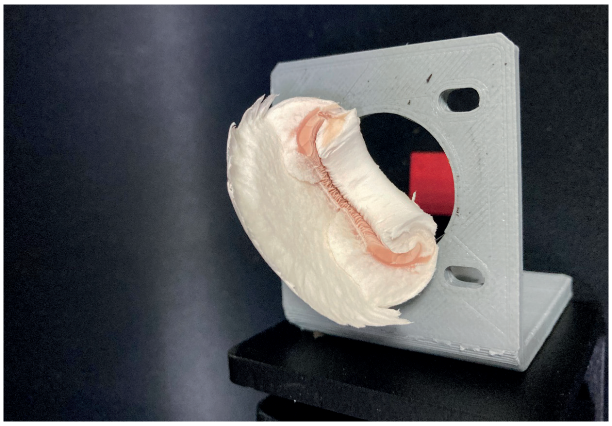


Fig. 8. Cap defragmentation

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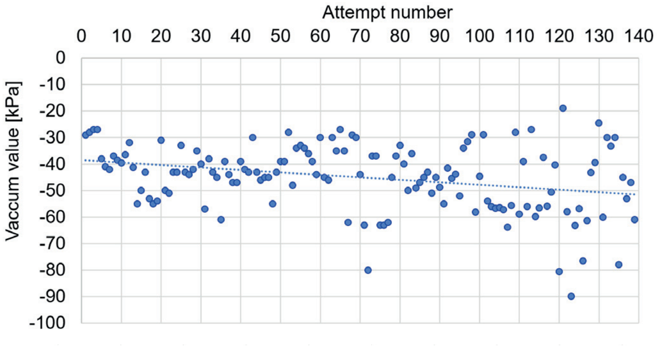

Fig. 10. Vacuum pressure during next attempts

Fig. 11. Suction cup after one day of testing

Summary

The presented research aimed to test the vacuum method of mushroom pulling. The method of applying your simplicity does not allow for application in industrial conditions, however, it provides valuable material and tips for further research and development work. This study is an introduction to the automation of the mushroom pulling process using a robotic arm. Next, mechanical methods of catching the mushroom will be tested, for example using flexible jaws. As noted in this publication, mushrooms very often grow close to each other, which will require manual pulling out of overgrown pieces anyway.

The picking technique also had an impact on the efficiency of the harvest. In the case of the station, it was a vertical movement, and during manual harvesting it is also possible to introduce rotation around the vertical axis and bending. The implementation of a complex movement is planned for the next version of the gripper.

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