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Sustainability of *Agaricus blazei* Murrill Mushrooms in Classical and Semi-Mechanized Growing System, through Economic Efficiency, Using Different Culture Substrates

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Abstract: Mushroom cultivation is a source of organic, sustainable food that is growing rapidly to become a profitable sector of agriculture. Nutritional supplements and natural medicines are provided by many mushroom products, including the *Agaricus blazei* Murrill mushroom. In recent years, the classical culture system has begun to be used more in less-developed countries, providing an additional gain for locals. The content of the article is based on the deductive research method, starting from theory to practice. This paper aimed at the economic efficiency of the *Agaricus blazei* Murrill mushroom crop using four substrate recipes and two protein additives, following the economic efficiency of the crops and the composition of production costs for the classic semi-mechanized production system. According to prepared technological sheets, the principal component analysis of the main economic indicators highlighted the experimental variant V5 (Synthetic substrate, with 3% wheat bran protein addition) with the highest labor productivity, obtaining 6.48 kg md^{-1}, the equivalent of 194.3 RON md^{-1}, and a profit rate of 80.42% compared to the V10 variant (reed substrate without protein addition), where the profit rate was only 26.16%. The addition of 3% wheat bran protein to the synthetic culture substrate (V5) brings an increase in global production with 45 RON sqm^{-1} compared to the variant without protein addition (V4). The research carried out is of practical use, especially for small producers using classical mushroom cultivation technology, and can be extended to other harvested mushroom species.

Keywords: *Agaricus blazei* Murrill; economic efficiency; production costs; labor productivity

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1. Introduction

1.1. The Importance of Mushroom Growing

Climate change now and in the future is driving scientists to find new sources of food for a growing population. Obtaining edible mushrooms all year round in intensive mushroom farms is an alternative to these goals. In addition to their food value, *Agaricus blazei* Murrill mushrooms are also a profitable crop with a high yield per unit of area used on premises set up for this purpose. The advantages of mushroom cultivation are many, including economic, occupational, medicinal, and the conversion of ligno-cellulosic waste [1].

From a nutritional point of view, mushrooms are a highly nutritious food, containing essential amino acids in their complex protein structure, and some species also have really therapeutic and medicinal virtues [2].

Agaricus blazei Murrill mushroom cultivation is not only a source of protein-rich food but can also contribute to the production of effective medicinal products [3,4].

Nowadays, nutritional supplements and herbal medicines are also provided by many mushroom-based products, cultivated and medicinal basidiomycetes. Extensive studies carried out all around the world have demonstrated the beneficial effects of producing dietary supplements from nutritious fungal biomass obtained by cultivating edible basidiomycetes of the species *Cordyceps sinensis*, *Agaricus blazei*, *Grifola frondosa*, *Ganoderma lucidum*, *Letinus edodes*, *Pleurotus ostreatus*, *Schizophyllum commune*, and *Trametes versicolor* for use in the prevention and treatment of multiple human ailments [5,6].

There is also increasing research into cultivating and improving mushroom yields by improvising growing substrates and equipment used to process mushrooms. Mushrooms have been processed into various products to increase their consumption, providing health and nutritional benefits to mankind [7].

Agaricus blazei Murrill mushroom cultivation is an environmentally friendly, sustainable food source that is rapidly growing to become a profitable sector of agriculture. In high-resource environments, technological advances have enabled farmers to maximize mushroom production and quality while reducing input costs and resources. Mushrooms have a species-specific cultivation technology, in some simpler and in others more complex [8].

Apart from being a food and even a therapeutic product (Figure 1), mushroom cultivation also has some economic advantages. By preserving, mushrooms do not change their organoleptic parameters, and dehydration considerably extends the shelf life.

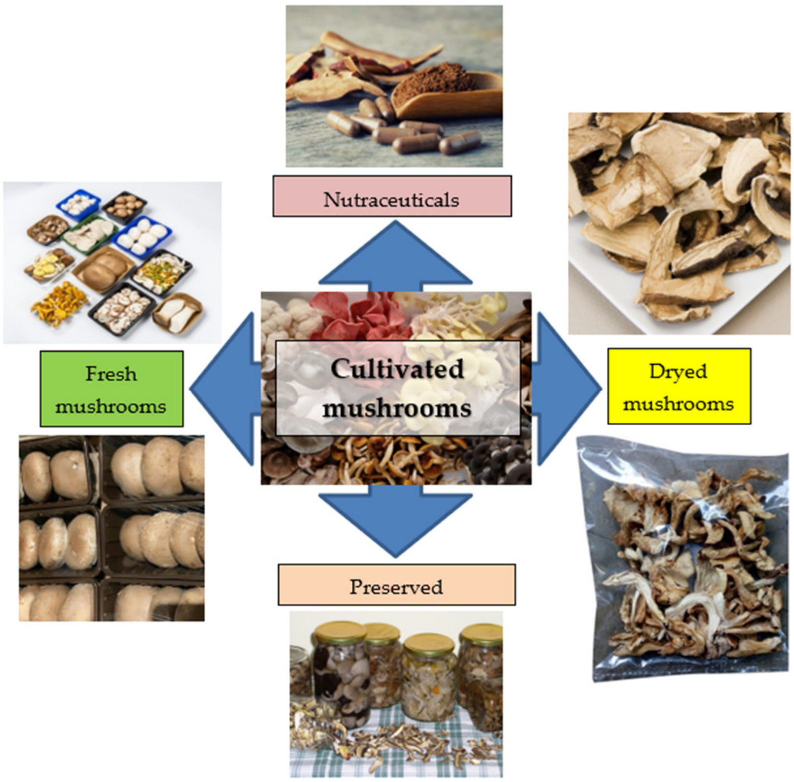

Figure 1. Exploiting ways of harvested mushrooms.

Agaricus blazei Murrill mushroom cultivation, as well as other mushroom crops, allows, in the case of classical technology, the use of different spaces (cellars, old buildings, abandoned mine galleries, tunnels, old stables—unsuitable for other purposes) with maximum yield, it does not require agricultural land and can be carried out both with classical technology, with 1–2 cycles per year, and with intensive technology, with 5–6 cultivation cycles per year, constituting a real industry with predicted production and carried out without major risks [9].

Thanks to these advantages, mushroom cultivation has grown 9 times in the last 35 years in the USA, 9.2 times in France, 5.8 times in England, and the most, 350 times in the Netherlands, but also in recent years, the classical cultivation system has started to be used more in less-developed countries, where different ligno-cellulosic materials are available in rural areas that can be used to cultivate different mushroom species, providing an additional income to the local people. Furthermore, the world mushroom production in 2020 registered 42,972,893 tons, 1,270,241 tons at the European level, and in Romania, 14,320 tons, which represents only 0.029% of European production and 0.0334% of world production [10], so small producers need to be supported in developing local mushroom business.

Mushrooms, both cultivated and wild, are sold at relatively high prices, both edible and especially those used for pharmaceutical extracts, ensuring high economic efficiency. For example, the market price of *Agaricus blazei* mushrooms is exaggerated, sometimes reaching more than €60 kg^{-1} of fresh mushrooms [11].

As one of the mushrooms with therapeutic effects, *Agaricus blazei* Murrill has quickly become one of the most popular cultivated medicinal mushrooms [12].

1.2. Economic Efficiency

The analysis of the degree of development of an economic entity, of its capacity for growth and survival, requires the definition and precise measurement of economic efficiency. From this perspective, an important role is played by the concept of economic efficiency, which links the resources allocated to carrying out an activity (actions) to the results obtained from these activities (actions). The theoretical and practical problems of economic efficiency have concerned and continue to concern the field of economic science, with different approaches to this concept depending on the branches and sectors of activity. The literature devotes numerous definitions to economic efficiency, differing only in the form of expression, while in essence, most definitions are the same.

In the dictionary of Romanian political economy, efficiency is defined as an expression of the ratio between the useful effect or result obtained and the expenditure made to obtain it [13]. According to the Oxford Dictionary of Economics [14], efficiency means obtaining the maximum possible results with a predetermined number of resources or obtaining predetermined results with minimum consumption of resources. The concept of economic efficiency has penetrated and developed in economic science, particularly in the 20th century [15].

The notion of economic efficiency is also linked to the name of Vilfredo Pareto (1848–1923), an Italian economist, who defined efficiency as: "an equilibrium ratio between the optimum of consumption and the optimum of production". In other words, Pareto's famous principle (or 80/20 rule) says that 80% of the effects are generated by 20% of the causes [16].

In the reverse sense, economic efficiency is determined as the ratio between the size of the effects and the size of the efforts or the inverse ratio, i.e.,

E = Results achieved/Resources consumed (which must be maximum), or

E = Resources consumed/Results obtained (which must be minimum) [17,18].

In the first case, it is necessary to obtain a maximum effect with a minimum of effort, in which case the ratio must be super unitary to express the efficiency of the activity. In the second case, the aim is to obtain the proposed effect with as little effort as possible, in which case the ratio must be subunit [19].

Any increase in output relative to input (of any kind) means an increase in efficiency [20]. Input (resources or effort), in the literature, is expressed in the totality of expenditures of material, financial, and human nature. In an increasingly competitive society, it is essential to distinguish between efficiency and effectiveness.

Thus, in general terms, efficiency refers to the relationship between input and output, while effectiveness refers to the relationship between input and goal (output) (Figure 2).

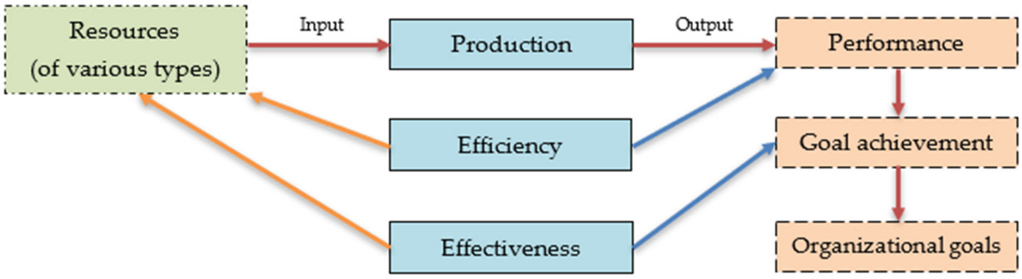

Figure 2. Efficiency versus Effectiveness [20].

The literature also talks about the notion of "performance", which is presented as a relative measure because it is determined by comparison with other measures (set objectives, results obtained by competitors, etc.), while the result appears as an absolute notion. The notion of performance has an abstract character, and its definition is often made by referring to other concepts, such as efficiency, effectiveness, economy, and value [21]. Thus, in the general view of some researchers, effectiveness is represented by the ratio between the result obtained and the objective to be achieved.

If in the analysis of effectiveness, the problem is to emphasize the goal dimension and neglect the effort dimension, in the case of the economy, the situation is the opposite, with the emphasis only on cost reduction. In this respect, it should be noted that efficiency and effectiveness are also interconnected with the notion of "economy" or "cost-effectiveness" (Figure 3).

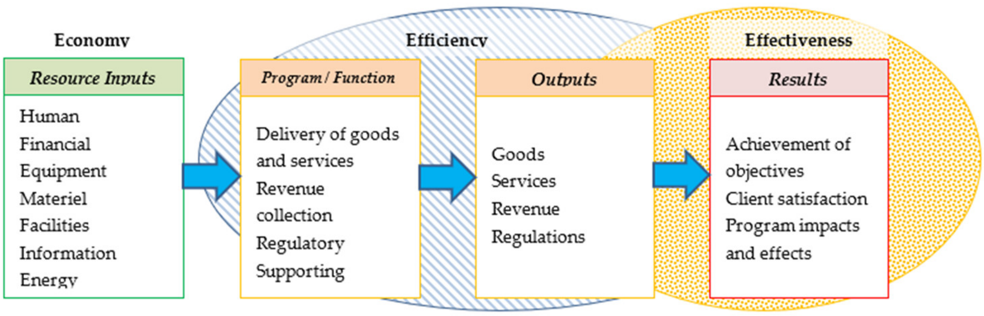

Figure 3. Interlinking economy, efficiency and effectiveness [22].

In other words, the content of the category of "economicity" consists in obtaining savings in the performance of economic activity or process. From this point of view, the approach to economy as an economic category is of particular importance in the present day, when resources of all kinds are increasingly limited and expensive.

One of the most important forms of economic efficiency is labor productivity. Numerous arguments support and reinforce this claim. The link between productivity, performance, and profitability is best captured by the 3Ps Model, which is described very well by Tangen [23].

According to this model, labor productivity reflects the actual result achieved and the actual efficiency with which labor has been spent in a provided production process. The level of labor productivity, in its quantitative form, is expressed by the ratio of the results (effects) obtained in a productive process to the effort (expenditure) made in that process. As can be seen from Figure 4, productivity is the core of the model, profitability is also seen as a relationship between output and input, but this is a monetary relationship in which price factor influences are included.

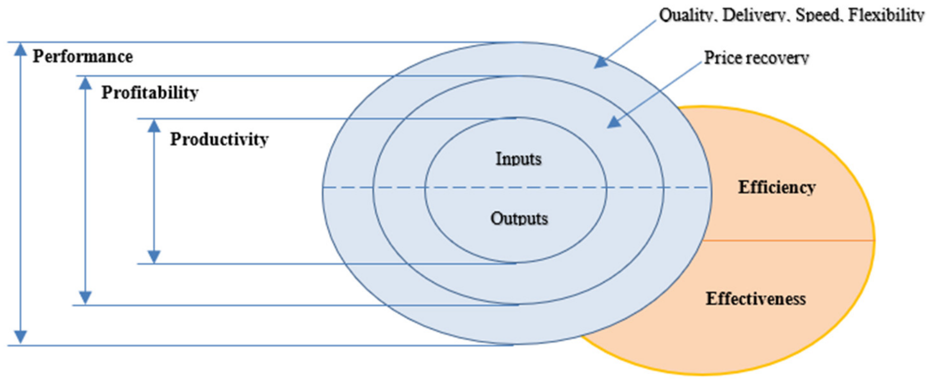

Figure 4. The 3Ps Model (Productivity, Profitability, Performance) [23].

Performance is the umbrella term for excellence, including productivity and profitability (profitability), as well as other factors such as product quality, delivery, speed, and flexibility. Furthermore, included here are the notions of efficiency, which shows how well the resources used are used, and effectiveness, which is the degree to which the desired results are achieved.

In view of these considerations, this article aimed at the economic efficiency of a classical *Agaricus blazei* Murrill crop, using four recipes of culture substrate, as described by Rozsa et al. [24], with practical applicability, especially in less-developed countries with favorable material resources for the establishment of mushroom crops, such as Romania.

2. Materials and Methods

2.1. Biological Material Used in the Experiment

The biological material used in the experiment was strain M7700 of the fungus *Agaricus blazei* Murrill, described by Rozsa et al. [24].

2.2. Experimental Factors

In order to study the economic efficiency of the *Agaricus blazei* Murrill culture in a semi-intensive and semi-mechanized system, a bifactorial experiment was organized, similar to that described by Rozsa et al. [24], using the composting facility presented by them. In the experiment, we used four substrate recipes with three different protein additions presented and described by Rozsa et al. [24], following the culture of the *Agaricus blazei* Murrill mushroom, in a semi-intensive, semi-mechanized system, on the 12 experimental variants resulting (Table 1), in terms of their economic efficiency.

Table 1. Experimental variants of experience.

Experimental Variant	Type of Substrate
V1	Classical substrate, without protein addition
V2	Classical substrate, with 3% wheat bran protein addition
V3	Classical substrate, with 3% corn flour protein addition
V4	Synthetic substrate, without protein addition
V5	Synthetic substrate, with 3% wheat bran protein addition
V6	Synthetic substrate, with 3% corn flour protein addition
V7	Mixed substrate, without protein addition
V8	Mixed substrate, with 3% wheat bran protein addition
V9	Mixed substrate, with 3% corn flour protein addition
V10	Reed + horse manure substrate, without protein addition
V11	Reed + horse manure substrate, with 3% wheat bran protein addition
V12	Reed + horse manure substrate, with 3% corn flour protein addition

2.3. Applied Crop Technology

Semi-intensive and semi-mechanized cultivation system was applied, with the following technological works: pre-soaking, aerobic composting, turning I, II, III, and IV, disinfection of the culture space, the introduction of the substrate into the culture chambers, spawning, preparation of the covering layer, disinfection of the casing, ruffling of casing, maintenance of the culture during incubation, maintenance of the culture during the formation of fruiting primordia, fruiting—harvesting of mushrooms in 3 flushes, maintenance of the culture during harvesting, removal of a used substrate, and cleaning of the culture chambers. More details on research facilities and design are presented in the Supplementary material, Figures S1–S12.

The experiment was carried out in the entity SC CIUPERCARIA SRL, Cluj County, Romania, where compost recipes were made according to the experimental variants considered and in accordance with the literature in this field. The weight of compost was 1 ton for 10 sqm for one crop cycle.

2.4. Research Methods

The content of the article is based on the deductive research method, starting from theory to practice. Other scientific research methods were used, such as the case study method, the observation method, the comparison method, and the economic analysis method.

The planning of the technical-economic activity of mushroom cultivation requires the prior preparation of documents, among which the technological sheet (estimate) plays a decisive role. The technological sheet (work estimate) is the main document, the main source of information for planning and financing production. The economic data were collected from the supporting accounting documents related to each category of expenses.

Thus, 12 technology sheets (part 1—technical part A (Table A1) and B (Table A2)—and part 2—economic part (Table A3)—have been prepared, each one drawing up a general estimate of works and direct and production costs for each experimental variant, calculating the live labor requirement (dm/sqm), its cost, mechanical labor costs, material requirements and cost.

The technical and economic aspects of the project are clearly shown in this technology sheet. Thus, the first part, relating to technical aspects, records all the work carried out on the crop in question, grouped separately according to the method of execution into mechanized and manual work, in chronological order (Tables A1 and A2).

The labor requirements, expressed in man-days (MD), are determined according to the relationship:

$$MD = V/N \times n$$

where V = the volume of work, N = work norm and n = number of workers in team.

The calculation of the labor requirements (LR) is made based on the number of man-days (MD) calculated and the duration of the work to be performed:

$$LR = MD/t = V/N \times t \times n$$

where t = duration of the work

The labor requirement expressed in man-days (MD) is the basis for calculating labor costs, and the labor requirement calculated in the number of workers helps to organize the work processes. For manual expenditure, labor costs are also recorded, and for mechanized expenditure, expenditure to the service-providing unit [25].

Labor requirements were calculated using work norms, and costs were determined according to the complexity category of each job and the current rate Table 2.

Table 2. Complexity category of used jobs.

Job Category	Value *
I	50 RON day^{-1} (10 € day^{-1})
II	60 RON day^{-1} (12 € day^{-1})
III	80 RON day^{-1} (16 € day^{-1})
IV	100 RON day^{-1} (20 € day^{-1})
V	130 RON day^{-1} (26 € day^{-1})

* The rates presented for each category of work in Romania were taken from Merce et al. [25].

The second part of the technology sheet contains the economic aspects, in which the categories of expenditure by item (material costs, labor costs) are highlighted, i.e., direct expenditure, to which is added a share of indirect production costs (approximately 8% of the direct costs), thus making it possible to establish the total production costs for the crop in the experimental version concerned. By using the aggregated data from the two parts of the technology sheet, key economic indicators such as unit cost, unit price, gross unit profit, and labor productivity were established (Table A3).

For the economic efficiency analysis, the average physical yields of three replications per variant and the overall yields based on the evolution of the market price were taken into account. Production costs (direct and indirect costs) and their structure at current price levels were determined.

The selling prices of *Agaricus blazei* Murrill mushrooms in the pharmaceutical industry averaged 30 lei kg^{-1} of fresh mushrooms. Other direct costs were added to the expenditure: the 2.25% labor insurance contribution in Romania, which is deducted from the total gross wage fund and has to be paid by the employer. It is the company's contribution due to the state budget [26].

To the cost of materials was added the value of the water used, an additional 10% supply costs, and 1% other material costs. To the total amount of direct costs was added the 8% share of indirect costs. In order to assess the results correctly, economic efficiency indicators were established for each experimental variant.

All determinations were performed in triplicate, and the results are reported as mean values ± standard deviation (SD). Differences between means were analyzed with DUNCAN test. Differences were considered significant for p-values < 0.05.

3. Results and Discussion

To make the results easier to present and interpret, the technology works and their related data, which can be found in the technology sheets (technology sheet—part I), have been divided into four stages (Table 3).

Table 3. Stages followed and related technological works.

Stage	Related Technological Works
Stage I (Substrate preparation and seeding)	Compost component Pre-soak placement Aerobic composting placement Turn I, II, III, IV Disinfection of the cultivation place Insertion of the substrate in the cultivation chamber Spawning
Stage II (Preparation for fruiting)	Casing preparation Disinfection of casing mixture Ruffling of casing Incubation culture maintenance The maintenance of culture in the formation of primordia

Table 3. *Cont.*

Stage	Related Technological Works
Stage III (Harvesting)	Harvesting—3 flushes Substrate maintenance at harvest
Stage IV (Post-harvest work)	Disposal of used substrate Cleaning the culture chambers

To correctly assess the effect of the technical measures investigated, a study of the economic efficiency of growing *Agaricus blazei* Murrill mushrooms (Appendix B Figure A1) in the experimental variants was carried out. The profitability of the crop, as is well known, depends on the level and quality of production, the possibilities of exploitation, and the production costs, which must be as low as possible.

Any cultivation method or technical measure proposed to raise production levels must also be economically justified; otherwise, their application in production is inefficient and unreliable.

Cultivation methods, such as other agro-technical measures and the degree of mechanization, influence both the level of production and the costs of mushroom cultivation, and, consequently, the degree of profitability.

The technological works related to mushroom cultivation are divided, as shown in the Technological Sheet—part 1—into mechanized and manual works, which are identical in terms of expenses and man-days required for all 12 experimental variants and are presented in the Appendix A (Table A1, order no. 1–7).

Material consumption differs, however, depending on the components of each substrate type, and these are shown in Table 4, less the quantities of disinfectants and mycelium.

Table 4. Material consumption and related costs for each experimental variant.

Experimental Variant	Recipe Components			Amendment (V1–V3)/Urea (V4–V12)			Calcium Sulphate			Disinfectants			Mycelium			Total Material Value
	NC	UP	TV	NC	UP	TV	NC	UP	TV	NC	UP	TV	NC	UP	TV	(RON)
V1	0.5	200	100	14	10	140	25	5	125	2	50	100	20	50	1000	1465 ± 6.93 [b]
V2	0.5	220	110	14	10	140	25	5	125	2	50	100	20	50	1000	1475 ± 8.08 [ab]
V3	0.5	250	125	14	10	140	25	5	125	2	50	100	20	50	1000	1490 ± 8.66 [a]
V4	0.5	200	100	7	10	70	20	5	100	2	50	100	20	50	1000	1370 ± 6.35 [defg]
V5	0.5	240	120	7	10	70	20	5	100	2	50	100	20	50	1000	1390 ± 7.51 [cd]
V6	0.5	260	130	7	10	70	20	5	100	2	50	100	20	50	1000	1400 ± 8.08 [c]
V7	0.5	255	128	2	10	20	24	5	120	2	50	100	20	50	1000	1368 ± 5.77 [efg]
V8	0.5	230	115	2	10	20	24	5	120	2	50	100	20	50	1000	1355 ± 6.93 [g]
V9	0.5	240	120	2	10	20	24	5	120	2	50	100	20	50	1000	1360 ± 7.51 [fg]
V10	0.5	270	135	2	10	20	24	5	120	2	50	100	20	50	1000	1370 ± 6.35 [defg]
V11	0.5	280	140	2	10	20	24	5	120	2	50	100	20	50	1000	1380 ± 5.77 [cdef]
V12	0.5	290	145	2	10	20	24	5	120	2	50	100	20	50	1000	1385 ± 6.93 [cde]

NC—Normed consumption—UP—Unit price (RON)—TV—Total value (RON). The values are expressed as mean values ± standard deviations of all measurements. [a–g] A *Duncan* test was used to compare the mean differences registered among variants; data within the same column sharing different superscripts are significantly different ($p < 0.05$); data within the same column sharing the same superscripts are not significantly different ($p > 0.05$).

Following the data presented in Table 4 concerning the material consumption and related costs for each experimental variant, it can be seen, in the case of the classic compost with all three variants (V1, V2, V3), the material expenses concerning the compost recipe are different, because the compost composition there are in addition wheat bran (V2), as well as maize flour (V3).

For this reason, the price of compost is different. Then, compared to the other compost recipes, in the case of the classic version, we have superphosphate and ammonium sulfate (amendments) in the composition.

In the case of synthetic compost, these amendments are not in the composition, and they are replaced by urea. Here again, prices differ for each variant, depending on the components added, apart from wheat straw and poultry manure, wheat bran (V5), and maize meal (V6).

In the case of mixed compost, a higher compost price is found for V7, the variant not supplemented with wheat bran (V8) or malt flour (V9).

In the case of the original compost, its composition is different from the previous variants, with the addition of ground cane, which is why the compost prices in all three variants (V10, V11, V12) are higher compared to the other variants.

The rest of the material costs are identical for all experimental variants.

Stage I—substrate preparation and seeding, the technological works involve a series of expenses with mechanized works, such as compost component, pre-soak placement, aerobic composting placement, turn I, II, III, and IV, disinfection of the cultivation place, insertion of the substrate in the cultivation chamber and spawning. The composition of these costs is shown in Table A1, points 1–7, and is similar for all experimental variants since all these experimental variants were carried out under similar conditions, thus ensuring the subsequent repeatability of the experiment.

Stage II—preparation for fruiting, the technological works such as preparation of the covering layer and disinfection of the covering mixture, require mechanized labor expenses and some material expenses (black peat needed for the covering layer, disinfection with viricide), which are identical for all 12 experimental variants. Similarly, the manual labor expenses for crop scooping and maintenance are identical for all 12 experimental variants, and the data are presented in Table A1, points 8–12.

Stage III—harvesting, technological works are represented by three waves of harvesting and crop maintenance during harvesting. In this stage, we have only manual labor costs because mushroom harvesting is only performed manually, as the mushroom species *Agaricus blazei* Murrill is marketed mainly in the pharmaceutical industry, which requires a high quality of mushrooms. Cost data from this stage are provided in Table A1, points 13–14.

Stage IV—post-harvest work covers the technological work after harvesting the mushrooms, i.e., the removal of the spent substrate and the cleaning of culture chambers.

The removal of the used substrate is performed mechanically; therefore, we have expenditure on mechanized work, and for the cleaning of the culture chambers, we have expenditure on consumables (disinfectants). These expenses are identical for all experimental variants and are shown in Table A1, points 13–14.

The technology sheet—part 2—contains economic data on material costs and labor costs, as well as the calculation of economic indicators of efficiency of economic activity, such as profit, profit rate, and productivity. All the data in the technology sheet—part 2—are taken from the primary data entered in the technology sheet part 1.

Table 5 shows the data related to these categories of economic indicators for all 12 experimental variants, expressed in RON.

Table 5. Composition of the total production cost of each experimental variant expressed in RON.

Order No.	Elements of Expense	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
I. Material expenses													
1.	Materials from own sources	0	0	0	0	0	0	0	0	0	0	0	0
2.	Purchased materials	166.5	167.5	169	157	159	190	156.8	155.5	156	157.5	158	158.5
3.	Supply costs (10%)	16.65	16.75	16.9	15.7	15.9	19	15.68	15.55	15.6	15.75	15.8	15.85
4.	Expenses with mechanized works	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	4.05
5.	The cost of watering (water)	5	5	5	5	5	5	5	5	5	5	5	5
6.	Depreciation of fixed assets	0	0	0	0	0	0	0	0	0	0	0	0
7.	Agricultural income tax	0	0	0	0	0	0	0	0	0	0	0	0
8.	Electricity	15	15	15	15	15	15	15	15	15	15	15	15

Table 5. *Cont.*

Order No.	Elements of Expense	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
9.	Solid fuel	10	10	10	10	10	10	10	10	10	10	10	10
10.	Other taxes and fees	0	0	0	0	0	0	0	0	0	0	0	0
11.	Other material expenses (1%)	3	3	3	2	2	3	2	2	2	2	2	2
I. TOTAL material expenses		256	257	259	246	248	282	245	244	245	246	247	210
II. Expenses with labor													
1.	Manual labour costs	390	390	390	390	390	390	390	390	390	390	390	390
2.	Insurance contribution for work (2.25%)	9	9	9	9	9	9	9	9	9	9	9	9
II. TOTAL labour expenses		399	399	399	399	399	399	399	399	399	399	399	399
III. TOTAL direct expenses (I + II)		655	656	658	645	647	681	644	643	643	645	646	609
IV. Indirect expenses (8%)		52	52	53	52	52	54	52	51	51	52	52	49
V. Interest on loans (IL)		0	0	0	0	0	0	0	0	0	0	0	0
VI. TOTAL production costs (PC)		708	709	711	696	698	736	696	694	695	697	697	658
The value of secondary production (VSP)		0	0	0	0	0	0	0	0	0	0	0	0
VII. Main production costs (MPC)		708 ± 2.31 [b]	709 ± 5.2 [b]	711 ± 3.46 [b]	696 ± 2.89 [c]	698 ± 3.46 [c]	736 ± 2.31 [a]	696 ± 3.46 [c]	694 ± 2.89 [c]	695 ± 2.89 [c]	697 ± 4.04 [c]	697 ± 5.2 [c]	658 ± 2.89 [d]

The values are expressed as mean values ± standard deviations of all measurements. [a–d] A Duncan test was used to compare the mean differences registered among variants; data within the same column sharing different superscripts are significantly different ($p < 0.05$); data within the same column sharing the same superscripts are not significantly different ($p > 0.05$).

In this case, crop production technology is understood as the set of technically and economically sound agro-phytotechnical, agrochemical, and phytosanitary works designed to ensure, under provided conditions, the highest possible yields per unit area and high economic efficiency [25].

Given the state of the component elements of the technology, it can present varying degrees of intensity, an attribute that ultimately materializes in the average yield per unit area and cost per unit product.

A certain level of production is required for a profitable mushroom crop, which is estimated at 30–40 kg sqm^{-1} [27]. When viewed from this point of view, it can be seen that for all 12 variants analyzed, and the average yield falls within this range (30.7 kg sqm^{-1} for V12 and 42 kg sqm^{-1} for V5). The exception is V10, which is slightly below this limit (29.3 kg sqm^{-1}). It can also be seen that the highest average yield, exceeding 40 kg sqm^{-1}, is found for the variants with synthetic compost (V4, V5, V6).

A higher volume of work requires harvesting, but especially conditioning of mushrooms for immediate use or storage. In this case, the income is influenced by the level of production and the quality of the mushrooms [28].

The literature refers to the manual labor requirements of mushroom growing, depending on the degree of mechanization of the work [29]. For example, mushrooms can be harvested for industrialization using a mushroom harvesting machine, but for fresh consumption or for use in the pharmaceutical industry, harvesting is performed by hand [30].

In intensive farming systems and with the use of modern, high-performance mechanical means, the need for mechanical labor, even if the workload is higher, can be reduced by complex mechanization so that the need for man hours is 100 in the case of complex mechanization and 125 in the case of average mechanization for one ton of compost [31].

Production costs (Table 5) are greatly affected by various taxes, social contributions, which the farmer pays, as well as indirect costs. Cost is a particularly important economic indicator in the behavior of the consumer as well as the producer, who, before undertaking something, asks the apparently simple question: how much does it cost? In this sense, the cost is a criterion and a tool for comparison in the choice of consumption and production variations [32].

The economic analysis of expenditure recorded at the level of an economic entity can highlight how efficiently the available resources are connected to the economic objectives pursued, which is why expenditure analysis is an economic efficiency analysis [33].

Following the composition of the production cost, it can be observed (Figure 5) that of the total costs, labor costs rank first, with values ranging from 54.22% to 60.61% of the total costs, and depending on the experimental variant analyzed, the minimum being recorded at variant V6 and the maximum at variant V12.

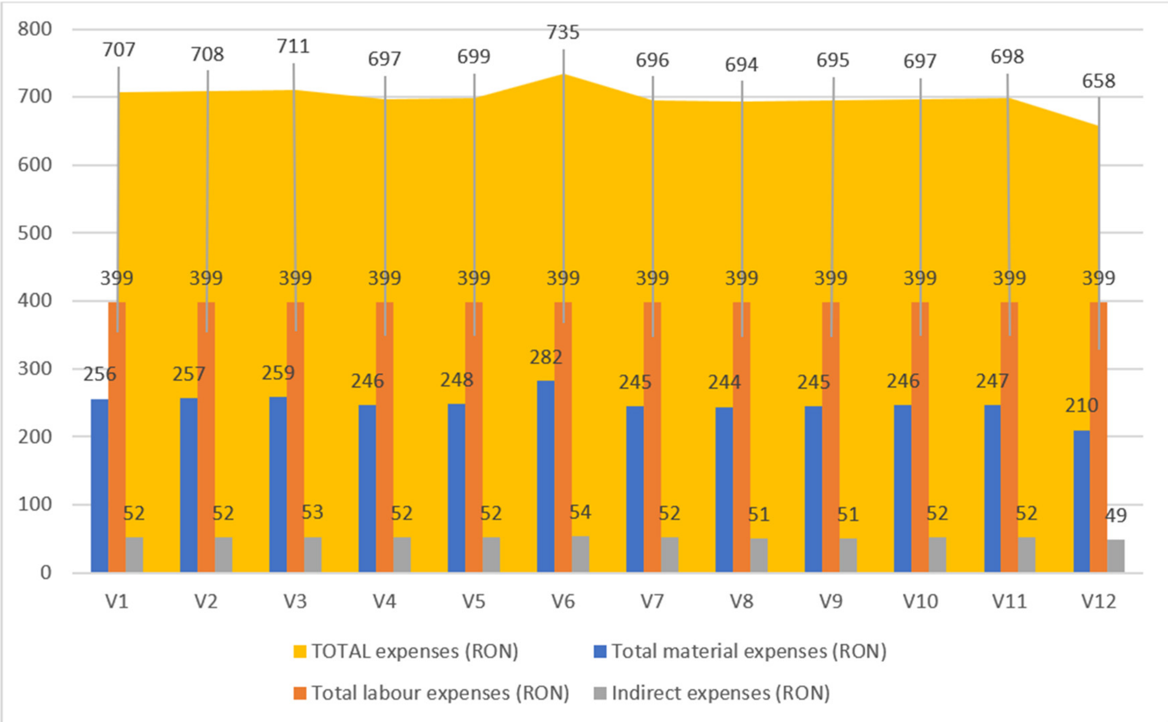

Figure 5. Production cost expenditure (RON).

Material costs then follow with values ranging from 31.98% to 38.37% of total costs, the minimum being recorded in the V12 variant and the maximum in the V6 variant. Indirect costs in this study represent 7.41% of direct costs (material costs + labor costs).

By comparing the data from the 12 technology sheets, it can be established which variant is the most efficient from both a technical and economic point of view. It can be seen that the variant with the lowest production cost (the most efficient in terms of expenditure) is variant V12 (Table 5).

Depending on the way the effect and effort were expressed, a number of indicators were calculated to show the level of labor productivity. Thus, taking into account the way the effect is measured, labor productivity can be calculated in physical units and value units. In the first case, the economic effect is expressed using natural or natural-conventional units. Labor productivity is usually measured in terms of the amount of labor time spent to produce a provided product or the number of products produced by a person in a unit of time [25].

Based on data on physical output (Figure 6) and overall output, labor requirements, and production costs, using an average recovery price of 30 lei kg^{-1} (RP), labor productivity (LP1, LP2), profit (P), and profit rate (PR) were determined for each experimental variant (Table 6).

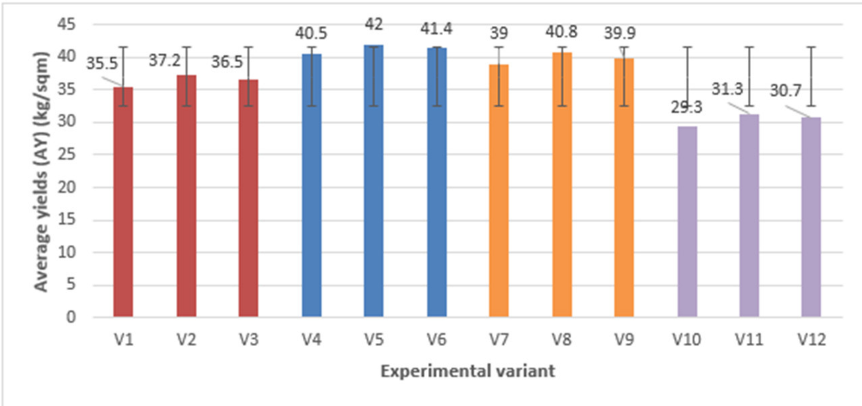

Figure 6. Average yield (AY) obtained for each experimental variant, with standard deviation (SD 0.06–0.35).

Table 6. The value of economic efficiency and productivity of variations in culture experiments using *Agaricus blazei* Murrill mushrooms.

Experimental Variant	Global Production (GP) (RON sqm^{-1})	Total Costs (TC) (RON sqm^{-1})	Unit Cost (UC) (RON kg^{-1})	Profit (P) (RON kg^{-1})	Labor Productivity (LP1) (kg md^{-1})	Labor Productivity (LP2) (RON md^{-1})	Profit Rate (PR) (%)
V1	1065 ± 8.66 ^{h}	708 ± 2.31 ^{b}	19.93 ± 0.14 ^{d}	10.07 ± 0.14 ^{g}	5.47 ± 0.04 ^{h}	164.2 ± 1.33 ^{h}	50.53 ± 1.06 ^{g}
V2	1116 ± 3.46 ^{f}	709 ± 5.2 ^{b}	19.05 ± 0.12 ^{f}	10.95 ± 0.12 ^{e}	5.73 ± 0.02 ^{f}	172.0 ± 0.53 ^{f}	57.47 ± 0.99 ^{f}
V3	1095 ± 5.2 ^{g}	711 ± 3.46 ^{b}	19.47 ± 0.16 ^{e}	10.53 ± 0.16 ^{f}	5.63 ± 0.03 ^{g}	168.8 ± 0.8 ^{g}	54.11 ± 1.28 ^{f}
V4	1215 ± 8.66 ^{c}	696 ± 2.89 ^{c}	17.19 ± 0.17 ^{i}	12.81 ± 0.17 ^{b}	6.24 ± 0.04 ^{c}	187.3 ± 1.33 ^{c}	74.54 ± 1.75 ^{bc}
V5	1260 ± 10.39 ^{a}	698 ± 3.46 ^{c}	16.63 ± 0.19 ^{j}	13.37 ± 0.19 ^{a}	6.48 ± 0.05 ^{a}	194.3 ± 1.6 ^{a}	80.42 ± 2.07 ^{a}
V6	1242 ± 6.93 ^{b}	736 ± 2.31 ^{a}	17.77 ± 0.14 ^{gh}	12.23 ± 0.14 ^{cd}	6.38 ± 0.04 ^{b}	191.50 ± 1.07 ^{b}	68.82 ± 1.29 ^{de}
V7	1170 ± 5.2 ^{e}	696 ± 3.46 ^{c}	17.84 ± 0.15 ^{g}	12.16 ± 0.15 ^{d}	6.01 ± 0.03 ^{e}	180.4 ± 0.8 ^{e}	68.15 ± 1.37 ^{e}
V8	1224 ± 6.93 ^{c}	694 ± 2.89 ^{c}	17.02 ± 0.15 ^{ij}	12.98 ± 0.15 ^{ab}	6.29 ± 0.04 ^{c}	188.7 ± 1.07 ^{c}	76.29 ± 1.5 ^{b}
V9	1197 ± 1.73 ^{d}	695 ± 2.89 ^{c}	17.42 ± 0.1 ^{hi}	12.58 ± 0.1 ^{bc}	6.15 ± 0.01 ^{d}	184.5 ± 0.27 ^{d}	72.25 ± 0.97 ^{cd}
V10	897 ± 5.2 ^{k}	697 ± 4.04 ^{c}	23.78 ± 0.14 ^{a}	6.22 ± 0.14 ^{j}	4.52 ± 0.03 ^{k}	135.5 ± 0.8 ^{k}	26.16 ± 0.73 ^{j}
V11	939 ± 3.46 ^{i}	607 ± 5.2 ^{c}	22.28 ± 0.08 ^{b}	7.72 ± 0.08 ^{i}	4.83 ± 0.02 ^{i}	144.8 ± 0.53 ^{i}	34.66 ± 0.51 ^{i}
V12	921 ± 6.93 ^{j}	658 ± 2.89 ^{d}	21.44 ± 0.22 ^{c}	8.56 ± 0.22 ^{h}	4.73 ± 0.04 ^{j}	142.0 ± 1.07 ^{j}	39.94 ± 1.45 ^{h}

Notes: GP = AY x RP; TC = MPC; UC = TC/AY; P = RP–UC; LP1 = AY/MDx10; LP2 = GP/MDx10; PR = P/UCx100; (MD = 64.869). Labour productivity (LP1 = Average yield/Man days-needed, is multiplied by 10, since the cultivated area with mushrooms is 10 sqm. The values are expressed as mean values ± standard deviations of all measurements. $^{a–k}$ A *Duncan* test was used to compare the mean differences registered among variants; data within the same column sharing different superscripts are significantly different ($p < 0.05$); data within the same column sharing the same superscripts are not significantly different ($p > 0.05$).

Principal component analysis (PCA) of the main economic indicators was performed on all experimental variants and on all variables (Unit Production Cost (UPC) RON kg^{-1}, Gross Unit Profit (GUP) RON kg^{-1}, Profit Rate (PR) %, Labor Productivity (LP1) kg MD^{-1}, Labor Productivity (LP2) RON MD^{-1}, Production costs in product equivalent (PCPE) kg sqm^{-1}), to investigate the structure and regularity of the relationships between variables and cases. The first two principal components (PC) explained 99.10% of the total variation in the data.

The correlations between the original variables and the principal components obtained are shown in Figure 7A,B.

Figure 7A shows the principal component plane score plot, which shows the similarity between the types of substrate recipes used. The position of the analyzed cases relative to each other highlights similar costs for some experimental variants, and in Figure 7B, each of the variables is represented by a vector. The direction and lengths of the vectors indicate to what extent the provided variables affect the principal components. In our study, most of the input variables are located near the circle, which means that the information in these variables is transferred by the principal components. The PCA analysis revealed the experimental variant V5 with the highest labor productivity and showed a strong positive correlation between the experimental variants on the classical substrate (V1–V3) and Unit Production Cost (UPC). A strong negative correlation was also observed between the experimental variants on the mixed substrate (V7–V9) and GUP.

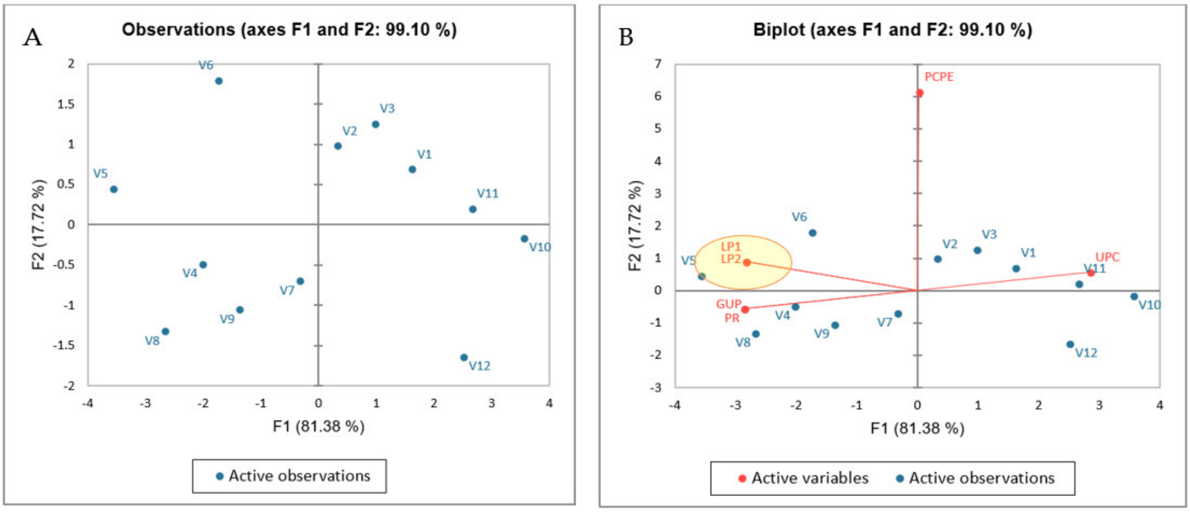

Figure 7. Principal component analysis (PCA) of the main economic indicators.

According to the principal component analysis (PCA) data, it can also be seen from Figure 8 that the highest labor productivity is recorded in the experimental variant V5, synthetic compost, which achieved 194.3 lei per Labor Day, equivalent to 6.48 kg of fresh mushrooms. It can also be observed that the highest labor productivity is also recorded in the other two experimental variants on the synthetic substrate (V4 and V6).

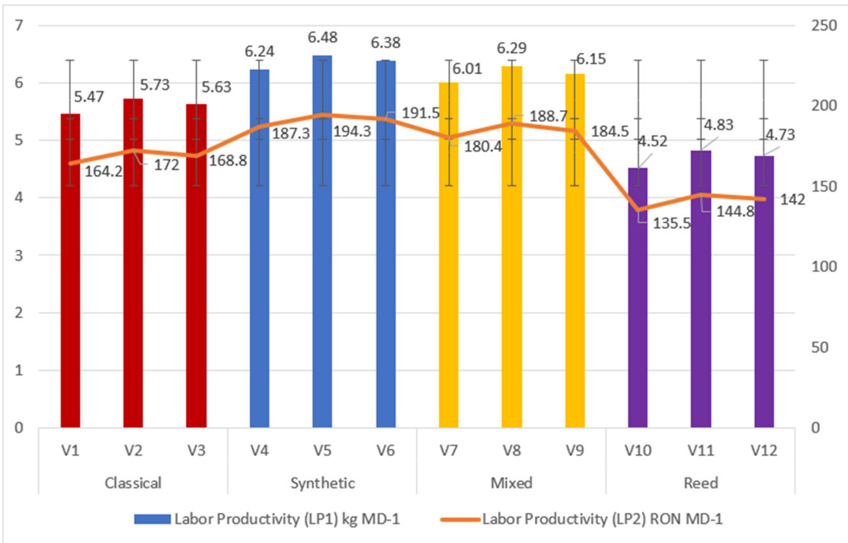

Figure 8. Experimental variants productivity with standard deviation (SD LP1 0.01–0.05; SD LP2 0.27–1.6).

The economic efficiency of mushroom cultivation can also be seen in terms of the first profit obtained at the end of a provided management period (month, quarter, semester, or year).

Profit can be expressed in absolute or relative amounts. In absolute terms, the size of the profit is the profit margin, i.e., the cash profit obtained by the firm after deducting all expenses from the revenue recorded during a provided management period [34].

The relative size of the profit is measured by the profit rate, which expresses the percentage ratio between the profit mass and a reference indicator (in our case, total production costs).

If the structure of production and the quality of goods remain unchanged, the rate of profit will be directly proportional to the volume of production [35,36]. Taking all these aspects into account, in the case of the mushroom crop *Agaricus blazei* Murrill, it can be seen (Table 6) that the most profitable variant, V5 (an experimental variant on the synthetic substrate), is the most profitable; the profit rate, in this case, being 80.42%, compared to variant V10 (an experimental variant on the original substrate), which has the lowest profit rate of 26.16%.

This can be explained by the fact that in the case of variant V5, as in the case of the other variants on the synthetic substrate (V4 and V6), there has been a saving of material components by substituting natural resources with synthetic ones, which are much cheaper, but without affecting the quality of production. This reduces the unit cost and consequently increases the profit rate [37]. In the case of variant V5, each spent RON generated a profit of 8.04 RON (the most profitable variant), and in the case of variant V10, each spent RON generated a profit of only 2.61 RON (the least profitable variant).

4. Conclusions

From the above, it can be stated that the *Agaricus blazei* Murrill mushroom cultivation has special economic importance. In addition to their nutritional value, mushrooms are also a profitable crop, which ensures a high production. In the case of the experimental variants, with the four types of substrates, the variant on synthetic substrate V5, from the economic point of view, is considered the most profitable variant, with the highest labor productivity, 194.3 RON per day of work, the equivalent of 6.48 kg of fresh mushrooms, being followed by variants V4 and V6 (also on a synthetic substrate).

The yield expressed in kilograms of mushrooms harvested per square meter depends on the cultivation system, the microclimate conditions ensured, as well as the culture substrate used, and it can be seen in our case that the highest average production is also made in the case of synthetic substrate variants (V5, but also V4 and V6), the average production for all three variants being over 40 kg sqm^{-1}. Furthermore, the experimental version V5 stands out, with the highest production measuring 42 kg sqm^{-1}, registering a profit rate of 80.42%, compared to the V10 variant, which records the lowest profit rate of only 26.16%.

The supplementation of *Agaricus blazei* Murrill mushroom substrate with 3% protein addition can bring an increase in global production between 42–54 RON sqm^{-1}.

A shortcoming could be the sale of fresh produce. If the sale is not guaranteed based on established contracts in advance with traders (chain stores, supermarkets, etc.). However, even under these conditions, the fresh unsold mushrooms can be dried and subsequently capitalized for other purposes, such as food supplements, the pharmaceutical industry, etc.

Moreover, if the compost is produced on the farm (as in our case), the profit can double. Thus, if in one year two or four to five cycles of cultivation are achieved, a yield of 30–80 kg/square meter/year results.

In the current crisis, when the price of cereals is constantly changing, mushroom cultivation could be a major form of consumption and capitalization, especially for small farmers, as it is considered a sustainable crop.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14106166/s1, Figure S1: Phase I—compost components presoaking (watering), Figure S2: Composting tank, internal view, Figure S3: Placing the compost in culture spaces, in 1 m^2 frames, Figure S4: 765.xl Fancom control system for mushroom growing microclimate conditions control, Figure S5: The substrate aspect after ruffling, Figure S6: The substrate aspect after ruffling, Figure S7: The casing layer surface before ruffling, Figure S8: Mycelium reached the surface of the cover layer, Figure S9: Pinhead formation, Figure S10: The *Agaricus blazei* Murrill mushrooms before harvesting, Figure S11: Harvested *Agaricus blazei* Murrill mushrooms with the partially unfolded velum, Figure S12: *Agaricus blazei* Murrill mushrooms spent substrate.

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Appendix A

Table A1. Technology sheet—part I A—the technical part: mechanical/manual work.

Order No.	Tehnological Works in Cronological Order	Unit	Mechanical Work			Manual Work				
			Volume of Work	Cost (RON/ Unit)	Expenses with Mechanical Work (RON)	Volume of Work	Work Standard	The Complexity Group of the Work	Requirement of Days—Man (DM)	Expennses on Labour (RON)
0	1	2	3	4	5	6	7	8	9	10
1	Compost component	t	1	100	100	0.06	15	IV/2	0.008	1
2	Pre-soak placement	t	1	50	50	0.06	15	IV/2	0.008	1
3	Aerobic composting placement	t	1.0	100	100	0.06	15	IV/2	0.008	1
4	Turn I, II, III, IV	t	1	-	-	2	50	IV/2	0.080	8
5	Disinfection of the cultivation place	m^2	1	50	50	0.06	15	IV/2	0.008	1
6	Insertion of the substrate in the cultivation chamber	m^2	10	-	-	2	50	III/1	0.040	3
7	Spawning	m^2	10	-	-	2	50	III/3	0.120	10
8	Casing preparation	m^3	1	50	50	0.15	10.6	IV/1	0.014	1
9	Disinfection of casing mixture	m^3	1.0	5	5	0.06	15	IV/1	0.004	0
10	Ruffling of casing	m^2	10	-	-	0.5	0.12	II/1	4.167	250
11	Incubation culture maintenance	m^2	10	-	-	0.5	0.12	II/1	4.167	250
12	The maintenance of culture in the formation of primordia	m^2	10	-	-	0.5	0.6	II/1	0.833	50
13	Harvesting—3 waves	m^2	10	-	-	20	1.1	II/3	54.545	3273
14	Substrate maintenance at harvest	m^2	10	-	-	0.5	0.6	II/1	0.833	50

Table A1. *Cont.*

Order No.	Tehnological Works in Cronological Order	Unit	Mechanical Work			Manual Work				
			Volume of Work	Cost (RON/ Unit)	Expenses with Mechanical Work (RON)	Volume of Work	Work Standard	The Complexity Group of the Work	Requirement of Days—Man (DM)	Expennses on Labour (RON)
15	Disposal of used substrate	t	1	50	50	0.5	40	IV/2	0.025	3
16	Cleaning the culture chambers	m^2	10	-	-	0.06	15	I/2	0.008	0
	TOTAL (RON)				405				64.869	3901
	Total (euro)				82					790

Table A2. Technology sheet—part I B—the technical part: material consumption.

Order No.	Technological Works in Chronological Order	Material Consumption				
		Sort of Material	UM	Normed Consumption	Price (RON)	Total (RON)
0	1	11	12	13	14	15
1	Compost component	Recipe components	t	0.5	200	100
2	Pre-soak placement	-	-	-	-	-
3	Aerobic composting placement	Amendments	kg	14	10	140
4	Turn I, II, III, IV	Calcium sulphate	kg	25	5	125
5	Disinfection of the cultivation place	Disinfectants	kg	2	50	100
6	Insertion of the substrate in the cultivation chamber	-	-	-	-	-
7	Spawning	Mycelium	kg	20	50	1000
8	Casing preparation	Black peat	t	1	50	50
9	Disinfection of casing mixture	Virocid Disinfectant	l	1	50	50
10	Ruffling of casing	-	-	-	-	-
11	Incubation culture maintenance	-	-	-	-	-
12	The maintenance of culture in the formation of primordia	-	-	-	-	-
13	Harvesting—3 waves	-	-	-	-	-
14	Substrate maintenance at harvest	-	-	-	-	-
15	Disposal of used substrate	-	-	-	-	-
16	Cleaning the culture chambers	Disinfectants	kg	2	50	100
	TOTAL (RON)					1665
	Total (euro)					337

Appendix B

Figure A1. *Agaricus blazei* Murrill mushroom culture. Original photo.

Table A3. Technology sheet—part II—the economic part.

Order No.	Elements of Expense	RON	%
I. Material expenses			
1.	Materials from own sources	0	0.00
2.	Purchased materials	166.5	23.53
3.	Supply costs (10%)	16.65	2.35
4.	Expenses with mechanized works	40.5	5.72
5.	The cost of watering (water)	5	0.71
6.	Depreciation of fixed assets	0	0.00
7.	Agricultural income tax	0	0.00
8.	Electricity	15	2.12
9.	Solid fuel	10	1.41
10.	Other taxes and fees	0	0.00
11.	Other material expenses (1%)	3	0.36
I. TOTAL material expenses		256	36.21
	II. Expenses with labour		
1.	Manual labour costs	390	55.14
2.	Insurance contribution for work (2.25%)	9	1.24
II. TOTAL labour expenses		399	56.38
III. TOTAL direct expenses (I + II)		655	92.59
IV. Indirect expenses (8%)		52	7.41
V. Interest on loans (IL)		0	0.00
VI. TOTAL production costs (PC)		708	100.00
The value of secondary production (VSP)		0	0.00
VII. Main production costs (MPC)		708	100.00
	Economic indicators		
1.	Unit cost of production (UCP)	RON/kg	19.93
2.	Selling price (SP)	RON/kg	30.00
3.	Gross unit profit (GUP)	RON/kg	10.07
4.	Profit rate (PR)	%	50.53
5.	Work productivity (WP)	kg/DM	5.47
		RON/DM	164.2
6.	Production costs in product equivalent	kg/m^2	23.58

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