Technological Basis of Conversion of Plant Wastes to Into Food Products

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Abstract. The presented work investigated to the possibility of using plant waste generated as a result of various production processes in the biotechnology industry to obtain food and feed products. It was determined that the waste contained sufficient components suitable for biological conversion and could be recycled to obtain food and feed products. For this reason, it is convenient to carry out the process under solid-phase fermentation conditions and use strains of xylotrophic macromycetes, such as *Pleurotus ostreatus* and *Cerrena unicolor*, which cause white rot in natural conditions, as biological agents.

Keywords: plant waste, chemical composition, bioconversion, food and feed products.

1 Introduction

As is known, every year in various production sectors, primarily in the agricultural sector, materials are generated in sufficient quantities that do not belong to the intended product and are not suitable for use in the form in which they are generated. These wastes have been attracting considerable attention for some time from the perspective of a raw material base for biotechnology[1].

It should be noted that the agricultural sector has a significant share in the economy of the Republic of Azerbaijan, and therefore the generation of plant waste is also characteristic of the country, and the amount of plant waste generated is measured in thousands of tons[2-3]. However, as in many countries around the world, the attitude towards this waste in Azerbaijan is the same, as most of it is burned or dumped into the environment in an irregular manner[2]. In a number of countries, a certain part of this type of waste is recycled, resulting in food and feed products[4]. The fact that the plant waste used in this direction constitutes a small part of the total waste, and the fact that most of it causes environmental pollution is one of the problems that still needs to be

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solved. The recycling of these wastes into production is of scientific and practical importance both in terms of expanding the raw material base of biotechnology through unconventional substrates and in terms of preventing environmental pollution. The situation in the field of organizing a production process based on the biological conversion of waste into food and feed products is not very encouraging, and therefore there is a special need for research in this direction.

For this reason, the goal has been set to investigate the possibility of using plant waste generated in the agricultural sector in Azerbaijan to increase the raw material resources of the biotechnology industry and to produce food and feed products.

2 Material and methods

For any biotechnological process, including bioconversion, as well as its microbiological and enzymological conversion types, the presence of 3 components is a prerequisite: substrate, biological agent or primary or secondary metabolite derived from it, and conditions for the process to occur[5]. Each of these has a different impact on the process, and therefore it is important to take each of them into account and determine their optimal indicators that ensure the effectiveness of the process. Thus, it is a reality that everyone accepts today that these factors should be taken into account in any biotechnological processes carried out to obtain products for various purposes, and this has been also taken into account in our research.

In the studies, plant waste such as broadleaf tree chips, aboveground parts of cotton, wheat bran, wheat straw, sunflower seed husks, sugar beet waste, grape prunings, and others were used when selecting the substrate. Plant waste was air-dried and crushed (0.4-0.6 cm) to use. All substrates were mixed with plain water in a 1:1 ratio and sterilized for 1 hour at a pressure of 1 atm. Cultivation was carried out for various periods at 26-28^{0}C[6]. Intensive cultivation of *P.ostreatus* mushroom was also carried out according to the known method[7].

It was collected from the 5-day biomass formed during the cultivation of this or that fungus in a liquid glucose peptone nutrient medium[6], which was used as a seed material during microbiological conversion.

The chemical composition of the studied substrates, some physicochemical structural elements, and the bioconversion process were carried out in accordance with known methods and approaches[8-9], as well as those used in the work of some authors[1, 6, 10].

Macroscopic fungi causing white rot were used in the study provided by the Laboratory of Microbiological Biotechnology of the Institute of Microbiology of the Ministry of Science and Education of the Republic of Azerbaijan. The use of white rot fungi in natural conditions includes both oxidases and hydrolases in their enzyme system[1, 6, 11].

The experiments were repeated 4-6 times during the research, and all the results were statistically processed[12].

3 Results and Discussion

From the obtained results became clear that, although the wastes differed in terms of the quantitative characteristics of their constituent components, in all of them the specific weight of difficultly hydrolyzable polymers (more precisely, under this name the sum of the crystalline part of lignin and cellulose is considered) was greater than that of easily hydrolyzable polymers (under this name the sum of the amorphous part of cellulose and hemicellulose and other polymers is considered)(tab.1).

Table 1. Chemical composition of used waste.

Waste	Amount of constituent elements (%)					
	Difficult to hydrolyze	Easily hydrolyzed	Soluble sugars	Protein	Lipid	Ash.
Broadleaf tree debris	57,6	28,4	1,5	2,2	1,0	2,2
Cotton swab	50,5	32,1	1,2	1,9	0,7	2,0
Wheat bran	32,8	46,5	2,7	4,4	1,8	1,7
Wheat straw	39,0	29,7	1,1	2,7	1,1	1,9
Sunflower seed husk	42,4	30,5	1,2	4,3	2,5	2,1
Grape pruning shears	42,5	34,3	1,6	3,5	1,3	2,0
Sugar beet waste	30,7	28,6	2,4	3,1	1,9	2,1

It is not correct to make an unambiguous statement about the suitability of waste for bioconversion depending on its chemical composition, and therefore the practical utilization of many wastes is not widely implemented. The main reason for this is the extreme complexity of the components of plant waste, such as lignin, cellulose, hemicellulose, as well as pectin, which is found only in plants (the space and the supramolecular structures they form between themselves). In addition, the surface area of polymer-containing waste, primarily the structural areas of the cellulose it contains, which are favorable for the action of enzymes, also plays a role and can significantly affect the efficiency of the process. Taking these into account, it was considered appropriate to characterize the waste used in the studies from this aspectMore specifically, the cellulose in the waste was also evaluated for its crystallization coefficient (CC) and enzyme-accessible surface area (EASA). It has become clear that wastes differ from each other in terms of these indicators. Thus, the crystallization coefficient of waste generated during the use of woody plants ranges from 0.54-0.59, while this indicator varies between 0.37-0.44 for potato and cotton plant waste. As for the other indicator, namely the EASA, its indicator was 0.18-0.21 M^2/g in woody plants, and 0.26-0.30 M^2/g in others.

Since the mentioned substrates contain sufficient substrates suitable for biological conversion and are mainly composed of difficultly hydrolyzable substances, it was considered appropriate to use species of xylotrophic macromycetes(*Armillaria mellea, Bjerkandera adusta, Trametes versicolor, Pleurotus ostreatus*, *Cerrena unicolor* etc.) that cause white rot in natural conditions as biological agents. Thus, based on the analysis of literature data, as well as the results of our studies, it became clear that fungi that meet this characteristic have the ability to synthesize enzymes that catalyze the degradation of all polymers contained in complex polymer-containing substrates, among which strains belonging to species such as *Pleurotus ostreatus* and *Cerrena unicolor* are characterized by higher activity, which makes them suitable for further studies as biological agents. This can also be seen in the process of conversion of sunflower seed husks in the example of the mushroom *P.ostreatus* SQ-23(tabl. 2). As can be seen, the amount of cellulose and lignin in the waste decreases significantly (32-34%), while the amount of protein increases (2.3 times) over a period of 10 days. Analysis of the obtained product determined that it was more suitable for use as feed. When the mushroom is cultivated in the mentioned substrate under other conditions (intensive cultivation) for up to 46 days, 3 waves of fruiting body formation occur, resulting in up to 1 kg of fruiting body (by wet weight) per kg of substrate (by dry weight). Biochemical analysis of the obtained fruit body showed that it is a valuable nutrient.

It should be noted that the formation of fruiting bodies by the mentioned mushroom is characteristic of producers that are currently considered promising.

It has been determined that when using the mushroom *C. unicolor*, the presence of polymers in the waste is significant, the amount of protein, and the degree of cellulose and lignin degradation are relatively high, and its use is suitable for the production of feed products.

Table 2. Bioconversion of sunflower seed husk by *P.ostreatus* SQ-23 mushroom

Mushrooms species	Weight loss	Degradation degree (%)		Protein collection (%)
		Cellulose	Lignin	
A.mellea	19,7	28,7	25,8	6,2
B.adusta	24,1	32,3	33,5	7,7
C.unicolar	26,4	34,5	35,6	8,3
G.applanatum	20,9	31,3	30,4	7,1
G.lucidum	21,2	33,4	31,5	7,5
P.tigrinus	21,7	34,5	35,4	8,0
P.ostreatus	24,6	36,3	36,5	8,3
P.squamosus	20,2	28,7	28,2	7,3

The conversion of selected substrates with biological agents was comparatively carried out under both solid (SFF) and liquid (LFF) fermentation conditions, and SFF was shown to be more favorable in this regard. Thus, under these conditions, the degradation

of the polymer components of the substrates used was more profound, the amount of biomass obtained was greater, and their enrichment with proteins, lipids, and other biologically active substances was also characterized by higher indicators.
In general, it should be noted that xylotrophic macromycetes, since they live only in woody plants, are more active in a solid-state environment, which can be characterized as an adaptive trait they have acquired as a result of evolution.
There are a number of plant wastes generated in the agricultural sector of the Republic of Azerbaijan, which are mainly thrown into the environment in an irregular manner, causing ecological problems. As a result of our research, the substrate, biological agent and conditions for their conversion into feed and food products have been identified.

4 Conclusion

This study investigates the feasibility of converting agricultural plant waste into valuable food and feed products using biotechnological methods. Various types of plant waste were analyzed and found to contain sufficient lignocellulosic components suitable for biological conversion. Xylotrophic macromycetes, particularly *Pleurotus ostreatus* and *Cerrena unicolor*, were identified as effective biological agents due to their strong enzymatic capacity to degrade complex polymers such as cellulose and lignin. Comparative analysis showed that solid-phase fermentation is more efficient than liquid fermentation, leading to greater substrate degradation, increased biomass production, and enhanced protein enrichment. The results demonstrate that plant waste can be effectively recycled into nutritionally valuable products, offering a sustainable approach to waste management while expanding the raw material base for the biotechnology industry.

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