

UDC: (602.4:005.936.41-028.76):502.174

## NON-TRADITIONAL RAW MATERIALS FOR BIOTECHNOLOGICAL INDUSTRIES AND SOME ENVIRONMENTAL ASPECTS OF THEIR DISPOSAL

DOI: <https://doi.org/10.15673/fst.v14i1.1652>

### Article history

Received 09.07.2019  
Reviewed 15.09.2019  
Revised 12.10.2019  
Approved 04.02.2020

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### Cite as Vancouver style citation

Kylymenchuk O, Velichko T, Malovanyy M, Umanets A, Hnilichenko A, Lahotska A. Non-traditional raw materials for biotechnological industries and some environmental aspects of their disposal. Food science and technology. 2020;14(1):32-38. DOI: <https://doi.org/10.15673/fst.v14i1.1652>

### Цитування згідно ДСТУ 8302:2015

Non-traditional raw materials for biotechnological industries and some environmental aspects of their disposal / Kylymenchuk O. et al. // Food science and technology. 2020. Vol. 14, Issue 1. P. 32-38. DOI: <https://doi.org/10.15673/fst.v14i1.1652>

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**Abstract.** The work proves how rational it is to use non-traditional, annually renewable wastes of plant raw materials (cuttings of fruit trees, hop stems, and castor bean stems) for further biotechnological processing in order to obtain a valuable protein feed supplement. It has been confirmed that burning these plant wastes adversely affects soil microbiota. The technological properties, chemical and biopolymer composition of the plant waste have been studied. It has been established that the optimum particle sizes for all the three types of the waste under study are 20–35 mm (along the fibres). This degree of grinding provides the best diffusion of the hydrolysing agent in the raw material particles and the extraction of monosaccharides into the solution. Non-traditional plant refuse is high in polysaccharides. The total yield of saccharides in the course of hydrolysis was 52.78–59.11%, depending on the raw material analysed. All types of the plant waste analysed had a high content of polysaccharides and extractive substances. This allows using them as potential raw materials for growth media to cultivate microorganisms in biotechnological industries. Acid degradation of biopolymers of the raw materials analysed has been carried out in the laboratory and confirmed in a production environment. Hydrolysate-based growth media have been obtained in a laboratory environment, and their biological purity has been studied. Yeast strains of the *Candida* genus have been selected, as they are able to grow actively on the hydrolysates of fruit tree cuttings and stems of hop and castor bean. Cultivation of these strains have been carried out in the periodic mode. The negative effect of plant waste incineration on the microbiological status of soil has been investigated. Samples of the soil were taken from the experimental plot before and after burning the plant waste. Microbiological analysis have been done of the total number of mesophilic aerobic, facultative anaerobic, and nitrogen-fixing microorganisms, since they are the only living organisms capable of absorbing molecular nitrogen from the air and incorporating it into the cycle of nitrogenous substances. The total number of microbes is reduced by 45%, and the number of nitrogen-fixing bacteria is halved. The process of their regeneration is rather slow, which will significantly affect the fertility of soil, and its podzolising (ashing) can lead to changes of crops capable of producing high yields on this soil, and will require scientifically based crop rotations.

**Key words:** plant waste, raw materials, biotechnological processing, yeast, protein feed supplement, soil, acidity, disposal.

### Introduction. Formulation of the problem

Among all the problems people have not solved yet the most difficult and urgent one is the lack of feed and food proteins [1,2]. In Ukraine, the demand for the former is far higher than for the latter. This can be explained by

the inadequate structure of sowings of cereal crops which are an important source of proteins, and by the low protein content in the cultivated plants that feeding diets are based on. This protein deficiency is to some extent made up for by using high-protein crops, oil cakes, oilseed meal, fishmeal, and meat and bone meal.

By 2050, humankind will need extra 265 million tons of protein every year. So today, the task of providing the world's population with complete protein requires a novel approach [1,2].

In Ukraine, there is a decrease in fodder yeast production, a lack of vitamins and amino acids, and deficiency in oilseed meal and oil cakes (as large volumes of them are exported), while imported protein supplements are too expensive. All the above has resulted in a severe shortage of feed protein and in the manufacture of animal feed with an imbalanced protein content [1,2]. This, in turn, has become a reason of a decrease in livestock's productivity and number, and, consequently, in the consumption of protein-containing products per capita, which leads to unbalanced diet and tells on the nation's health.

Providing people with environmentally safe food is the priority area of the state's economic activity. That is why new and effective ways should be looked for of how to solve this problem using alternative technologies in different directions. One of these directions is increasing the output of animal husbandry, in particular poultry farming, by means of using high-quality compound feed with a well-balanced content of all nutrients, primarily of proteins.

The shortage of protein feed supplements can be helped by using the biotechnological method of obtaining them. This method does not depend on natural factors and consists in microbial synthesis, that is in cultivating fodder yeast. The rate at which this method is being developed is determined by the demand for feed protein and by the availability of plant raw material residues that can be disposed of by turning them into a growth medium.

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#### **Analysis of recent research and publications**

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The decrease in fodder yeast production in Ukraine observed in the recent decades is due to the country's general economic situation as well as to the lack of sources of raw materials for its manufacture. The main raw material for feed protein is plant waste. Until recently, more than 70% of it was imported from Russia to be used in enterprises currently operating in Ukraine. That is why, to solve the problem of raw material shortage and make up, to some extent, for the feed protein deficiency, alternative sources of plant waste should be looked for.

A raw material used to this end can be fruit tree cuttings (FTC), hop stems (HS), and castor bean stems (CBS). They are not used to feed livestock, are renewable with annual regularity, and accumulate in amounts of up to one million tons every year [3-5].

If the optimum conditions of bioprocessing FTC, HS, and CBS into feed protein are developed, it will help solve not only a technical problem, but a social and economic one as well, because nowadays, these residues hardly ever find any practical application. Almost all of them are ploughed back, or, rather, burnt. This affects the environment severely [6,7].

When plant waste is incinerated, a lot of toxic substances are emitted into the atmosphere: carbon

monoxide, soot, benzopyrene, dioxins, carbon dioxide, nitrogen oxide. They block access of oxygen to the body's tissues, are carcinogenic, can cause bronchospasms, allergy, coughing, asphyxia. Plant waste incineration does not only pollute air, but soil, too. The Ministry of Ecology and Natural Resources of Ukraine never stops warning that burning plant residues results in extinction of certain animal species and death of insects. Besides, it causes changes in the acidity of soils, upsets their microbiological status, and affects the fertility of Ukrainian black soils, which are deteriorating because of their malnutrition and a lack of moisture.

It is known that soil consists of material complexes that are of homogeneous composition and are parts of a system. In soil, four phases are distinguished: solid, liquid, gaseous, and biophase. The latter is a community of microorganisms that populate the soil and contribute to its formation. A complex of living biomass, organic residues of plants, animals, and microorganisms, products of their metabolism, and specific newly-formed dark-coloured humic substances is called humus. It is an essential part of any soil.

However, the humic fraction is diminishing. In the last 130 years, Ukrainian soils have lost 30% of humus that plays a key role in soil's fecundity [6,7].

In view of this, the work is aimed at proving that fruit tree cuttings, hop stems, and castor bean stems, instead of being burnt, can be used as a large-tonnage, annually renewable raw material of plant origin. It can find its application in biotechnological industries to manufacture valuable feed supplements. This raw material has not been an object of research before, and its use will allow obtaining dozens of tons of feed supplements, and reduce environmental pollution. That is why the subject of this paper is topical, of high scientific and practical interest, and economically viable. Using the waste considered in the paper makes it possible to obtain over 250 thousand tons of complete feed protein. This will help the shortage of feed protein, and of food protein, too, as the two problems are directly related.

**The purpose of the work** is to prove that non-traditional raw materials – fruit tree cuttings, hop stems, and castor bean stems – can be biotechnologically processed, and that incineration of this plant waste affects adversely the microbiological status of soil.

To achieve the purpose, the following **objectives** should be solved:

- to study the technological properties, and the chemical and biopolymer composition of plant waste;
- to obtain a hydrolysate-based growth media *in vitro*, and study its biological purity;
- to conduct screening tests of yeast cultures that can grow actively on hydrolysates of FTC, HS, and CBS, and study the dynamics of growing them *in vitro*;
- to study the harmful effects of incinerating plant waste on the microbiological status of soil.

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#### **Research materials and methods**

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Research materials: non-traditional plant waste: FTC, HS, and CBS; soil.

Methods of research: a complex of traditional and

new biochemical and microbiological methods that are described in Table 1.

**Table 1 – Research methods used in the experiments**

| Parameters and research methods              | Principles and specific features of the method   | Source |
|--|--|--------|
| Moisture content                             | By the difference between the mass of the “wet” sample portion and the one dried at 105°C  | [8]    |
| Dry matter                                   | By drying the test portion of the sample down to a constant weight; by refractometry   | [8]    |
| Ash  | By burning the test portion of the sample, followed by charring the mineral residue at 500–600°C   | [8]    |
| Water-soluble and alcohol-soluble substances | By water and alcohol extraction of the sample portion  | [8]    |
| Easily hydrolysable polysaccharides (EHP)    | By the reducing properties of solutions that were obtained as a result of hydrolysing the raw material with aqueous solutions of hydrochloric acid (with the mass concentration 2 %) for 3 hours, with the hydromodulus 40, and at t=100°C, with further multiplication by the coefficient 0.88 (the Kiesel and Semiganovsky method) | [9]    |
| Low-hydrolysable polysaccharides (LHP)       | By the reducing capacity of solutions that were obtained as a result of hydrolysing the residue after extracting EHP with 80% sulphuric acid, with further multiplication by the coefficient 0.9   | [9]    |
| Total nitrogen                               | By the Kjeldahl method   | [8,9]  |
| Potential furfural                           | Spectrometrically: by the bromide-bromate method   | [9]    |
| General and easily eliminable methoxy groups | By the Viebock and Schwappach method   | [9]    |
| Absolutely dry yeast (ADY)                   | By the weight of compressed yeast with moisture subtracted   | –      |
| Hydromodulus                                 | By the ratio of the mass of the solid phase to that of the liquid phase  | –      |
| Bulk density                                 | Was determined in a 1 litre drop-weight grain tester   | [10]   |
| Fineness degree                              | By sifting   | [10]   |
| Active acidity                               | By the potentiometric and indicator methods  | [14]   |
| QMAFAnM                                      | By inoculating on general purpose media and calculating the CFU (colony-forming units, CFU/g)  | [14]   |
| Nitrogen-fixing microorganisms               | By inoculating on an Ashby medium and calculating the total and mucoid colonies  | [15]   |

The raw material was chopped in the laboratory with a pair of pruning shears, with further separating the fine fraction by sifting.

The bulk density ( $d_b$ , kg/m<sup>3</sup>) was calculated by the formula:

$$d_b = P_b/V_b, \quad (1)$$

where  $P_b$  is the weight of the chopped raw material with a certain moisture content, g;

$V_b$  is the volume occupied by the raw material, m<sup>3</sup>.

The hydrolytic breakdown of the raw material was done with an aqueous solution of 0.6% sulphate acid, with the hydromodulus 14, at 130°C for 2 hours.

The growth media was prepared as follows. The raw material’s hydrolysates obtained were neutralised, left to rest for some time, cooled down, and diluted till the weight content of reducing substances was 1.5%. Then, the calculated weight of nutrient salts was added. They contained phosphorus, potassium, calcium, magnesium, and nitrogenous substances, in quantities proportional to their concentrations when cultivated in a production environment [9]. On reaching pH=4.0–4.5, the medium was sterilised.

The cultivation was carried out in flasks on shakers in a laboratory thermostat at 37°C. The

biomass accumulated was controlled periodically.

The soil samples were collected at a depth of 10 cm below the surface of the ground, prior to plant waste incineration and after it. The total quantity of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) and of nitrogen-fixing organisms was determined.

The total number of bacteria was determined by means of ten-fold serial dilutions. From each of the last ones, two parallel inoculations of 1 cm<sup>3</sup> of the sample were made on nutrient agar, and grown for 48 hours at 28–30°C. At the same time, soil samples were taken to determine their moisture content and acidity.

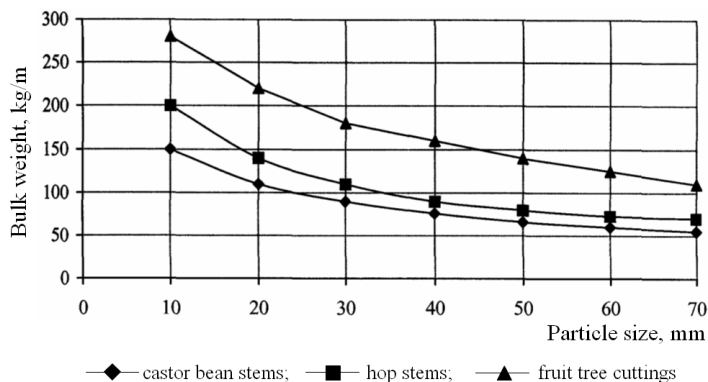
To separate an association of microorganisms that can fix air nitrogen, 25–50 lumps of soil were placed on the surface of the Ashby medium on the Petri dish, which was then put into a thermostat for 5–10 days at 28–30°C. Mucoid colonies of nitrogen-fixing microorganisms formed around the soil lumps. The percentage of the lumps covered with the colonies was determined. The analysis of samples from the same plot of land was repeated a month later.

**Results of the research and their discussion**

**Technological properties of FTC, HS, CBS.** After pruning fruit trees and hop saplings, or after collecting castor bean seed capsules, there is waste material left – branches and stems as long as 0.5–8.0 metres. Residues of fruit tree pruning (with a natural moisture content) normally make up about 5 tons per hectare, those of hop and castor bean 3.0 and 4.5 tons, respectively. They are

resilient, do not easily get compacted, have quite a low bulk density, which does not allow transporting and further processing them. However, the bulk density can be changed by chopping the raw materials.

Fig. 1 shows the results of studying how bulk density depends on the degree of fineness of raw material particles with the moisture content 8–10%.



**Fig. 1. Dependence of bulk density on the degree of fineness of plant waste**

According to the research results, the finer the particles, the higher their bulk density is.

It is a well-known fact that the rate of hydrolytic and enzymatic conversion of the raw material polysaccharides and diffusion of the obtained products into a solution is largely determined by the fineness degree and the particle-size composition of the materials hydrolysed. The bigger the raw material particles, the lower the specific density of the material loaded is, and the slower the penetration of hydrolysing liquid. With big particles, the diffusion of the products formed (monosaccharides) into the ambient liquid is slower. This causes their decomposition into furfural and hydroxymethylfurfural resulting in a decrease of the total yield of saccharides.

That is why we have studied how the degree of raw material fineness effects on the yield of reducing substances (RS). The results have shown that the optimum particle size, for all the three materials under study, is 20–35 mm (along the fibres). This fineness degree ensures the best diffusion of acid into raw material

particles and extraction of monosaccharides into a solution. With this fineness degree, the yield of monosaccharides was 80–85% of the total polysaccharide content, depending on a certain raw material.

**Studies of the chemical composition of non-traditional farming plant waste.** According to the current concepts of how to construct growth media for microorganisms, developing them based on plant waste is a complex and multistage research process. Its basic stage is studying the biochemical composition of the waste, which allows making a conclusion about how practical it is to use certain waste types.

There are numerous works that prove that plant raw materials can be used as a basis to obtain high-quality growth substrates [11].

Studying the chemical composition of the plant waste considered involves finding in it a carbonaceous source for microorganisms and the presence of both promoters and inhibitors of the cultivation process.

The general chemical composition of the waste is presented in Table 2.

**Table 2 – Chemical composition of the plant waste (the weight fraction of the absolutely dry substance (ADS), %)**

| Components   | Fruit tree cuttings      |                        | Hop stems, harvested in 2018 | Castor bean stems, harvested in 2018 |
|--|--------------------------|------------------------|------------------------------|--------------------------------------|
|  | Apple cultivar Mantuaner | Pear cultivar Williams |                              |                                      |
| Water-soluble substances                           | 2.37                     | 1.20                   | 0.75                         | 1.24                                 |
| Substances extracted with an alcohol-ether mixture | 5.15                     | 6.48                   | 1.55                         | 2.31                                 |
| EHP  | 23.64                    | 22.33                  | 18.62                        | 18.53                                |
| LHP  | 33.82                    | 36.78                  | 36.54                        | 34.25                                |
| Total polysaccharides                              | 57.46                    | 59.11                  | 55.16                        | 52.78                                |
| Ash  | 3.14                     | 2.47                   | 4.72                         | 5.93                                 |
| Proteins (N x 6.25)                                | 4.85                     | 5.17                   | 8.50                         | 7.90                                 |
| Lignin   | 26.16                    | 21.60                  | 31.61                        | 30.32                                |
| Potential furfural                                 | 17.38                    | 12.47                  | 16.04                        | 12.40                                |
| General methoxy groups                             | 3.97                     | 2.99                   | 1.94                         | 1.84                                 |
| Easily eliminable methoxy groups                   | 0.24                     | 0.13                   | 0.10                         | 0.09                                 |

Non-traditional plant waste are high in polysaccharides. Total polysaccharide yield of hydrolysis is 52.78–59.11%, depending on the raw material studied. This is by 5–10% lower than the same parameter of leaf wood [12].

In developing the hydrolysis modes in a production environment, an important standard indicator is the ratio between easily hydrolysable polysaccharides (EHP) and low-hydrolysable polysaccharides (LHP). For FTC and HS, this ratio is 1:1.5, for CBS, it is 1:2. This agrees with the ratio of these parameters in raw materials that are traditionally used. The EHP content of FTC is close to that of such farming waste as wheat and rice straw, rye and millet husks, wheat bran, and grain middlings [11].

Like most farming plant waste [11-12], the types considered in the paper have an increased weight content of lignin. All plant waste types contain extractive substances that can both promote and inhibit the growth and development of a microbial cell.

All the raw materials studied were low in easily eliminable, and high in general methoxy groups. This will have no significant effects during their biotechnological processing.

The research of the biochemical composition of non-traditional raw material waste allows concluding that all of them are high in polysaccharides and extractive substances. This makes it possible to use them as potential raw materials for growth media in order to cultivate microorganisms in biotechnological industries.

**Cultivating fodder yeast on hydrolysates of non-traditional raw materials.** Whether the raw materials in question are suitable or not can only be concluded after studying cultivation of microorganisms, namely yeast.

Screening of literary sources has shown that organisms that are protein producers cultivated on plant hydrolysates should meet certain requirements: a minimum generation time; the ability to accumulate protein in an amount of up to 40–70 % of their weight; the ability to assimilate nutrients almost completely in combination with the maximum growth rate; high resistance to furfural, hydroxymethylfurfural, and other harmful substances; the ability to separate easily from the liquid phase of the medium during centrifugation and flotation [13].

For these reasons, the yeast cultures *Candida tropicalis*, *Candida specis*, *Pichia specis*, *Trichosporon cutaneum*, and *Candida skotti* were selected as primary producers for the research. All the yeast cultures meet the above requirements. They have the maximum growth rate which is  $\mu=0.300-0.350 \text{ h}^{-1}$ ; their temperature optimum is 37–38°C, and their pH is 4.0–4.6. They synthesise vitamins resistant to a high furfural, hydroxymethylfurfural, and tannin content. After utilising hexoses and pentoses, they remain productive in accumulating biomass in the presence of inhibiting additives. They are easily separated from the

liquid phase, and do not require sticking to the rules of aseptic.

The process of yeast growth and biomass accumulation during cultivation on hydrolysates in steady-state conditions has been studied. The growth curves had a distinct lag phase I (cells did not grow), a logarithmic phase II (log phase, exponential phase) when the growth rate was maximum, a deceleration phase III (phase of growth declining), and a stationary phase IV observed after 10-12 hours of cultivation. With *Candida tropicalis* cultivated on FTC, HS, and CBS hydrolysates, phase I lasted 4.0–4.5 hours, phase II 4.0–5.0 hours, phase III 1.5–2.0 hours. The stationary phase IV was observed after 9.5–12 hours, depending on the hydrolysate used (Fig. 2).

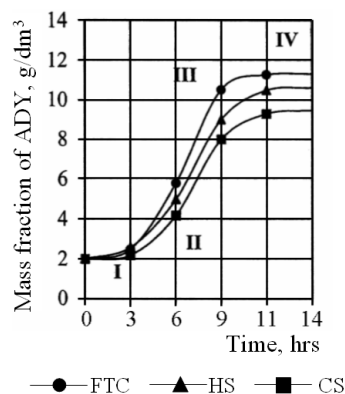


Fig. 2. Dynamics of biomass accumulation by *Candida tropicalis* cultivated on FTC, HS, and CBS hydrolysates

The culture accumulated quite a lot of biomass (9–11 g/dm<sup>3</sup> of absolutely dry yeast – ADY) and assimilated the nutrients of the medium quite completely. The research data plotted make it evident that the *Candida tropicalis* cells grew fastest on the FTC hydrolysates. This can be explained by a higher content of active extractive agents in this medium. So, this yeast culture can be cultivated on FTC, HS, and CBS hydrolysates as a pure culture, which agrees with the data from the literature [13].

**Studying the negative effect of burning plant residues on the microbiological status of soil.** To prove or refute that burning plant residues, besides polluting the atmosphere, violates the microbiological status of soil, we (according to the objectives of this research) studied it before and after these residues were burnt.

Soil fauna contributes greatly to humus formation. According to its size, soil fauna falls into four groups: microfauna, mesofauna, macrofauna, and megafauna. A key role in this process is played by micro and mesofauna, as they actively convert organic substances into humus.

So, in our research, we focused on soil microorganisms, as they are the only living creatures that can assimilate molecular nitrogen from the air and include it into the circulation of nitrogen-containing substances.

Symbiotic nitrogen-fixing microorganisms include those of the genus *Rhizobium* that live on the roots of some plants, in particular legumes – *Rhizobium trifoli*, and *Rhizobium phaseoli*. Among free-living nitrogen fixers are anaerobic bacteria – saprophytes of the genus *Clostridium* (*Clostridium pasteurianum*, *Clostridium buturicum*, *Clostridium acetobutyricum*, *Clostridium pectinovorum*, *Clostridium felsineum*), and aerobic

microorganisms of the genus *Azotobacter* that form specific mucoid colonies on the Ashby medium [14-15].

These were the microorganisms studied by inoculating soil samples on the Ashby medium, followed by calculating the mucoid colonies and determining their percentage of the total MAFA<sub>n</sub>M. The research results are presented in Table 3.

**Table 3 – Soil characteristics before and after the plant waste incineration**

| No | Parameters      | Before incineration | After incineration  | 30 days after incineration |
|----|-----------------|---------------------|---------------------|----------------------------|
| 1  | QMAFAnM, CFU/g  | 185·10 <sup>7</sup> | 102·10 <sup>7</sup> | 109·10 <sup>7</sup>        |
| 2  | Acidity, pH     | 6.0–6.2             | 6.2–6.3             | 7.2–7.5                    |
| 3  | Nitrogen fixers | 55%                 | 25%                 | 30%                        |

According to the research results, at the depth 10 cm below the surface of the ground, the microbiological status of bacteria decreased by 45%, and a month later, was restored but insignificantly. The quantity of nitrogen fixers decreased by half, and they are restored quite slowly. It should be taken into account that the samples were collected in autumn, thus the environmental factors, especially the temperature, did matter.

A month later, the soil got podzolised because ash had penetrated it deep down due to natural precipitation.

cultivating yeast cells on growth media created from the hydrolysates obtained.

2. A pure culture has been selected and cultivated on the growth media based on FTC, HS, and CBS hydrolysates. It has been proved that hydrolysates can be used to cultivate *Candida tropicalis* or other yeast with similar characteristics.

3. The results of growing *Candida tropicalis* on the hydrolysates obtained have shown that FTC, HS, and CBS can be used as potential raw materials for growth media in order to cultivate microorganisms in biotechnological industries.

4. Microbiological analysis of soil before and after burning FTC, HS, and CBS on it has been done. Changes in the quantitative and qualitative parameters of the microbiological composition of soil have been shown. The total number of microbes decreases by 45%, and that of nitrogen fixers decreases by half. They are restored but quite slowly, which significantly affects the fecundity of soil. Its podzolising can result in a change of crops able to yield harvests on this soil, and will require scientifically based crop rotations.

### Conclusion

1. The technological properties, chemical and biopolymer composition of non-traditional plant waste have been studied. The analysis of the chemical composition has revealed that most of the plant waste analysed is high in polysaccharides (52.78–59.11%) and extractive substances (2.30–7.52%), depending on the raw material. All the three raw materials were low in easily eliminable and high in general methoxy groups. This will have but an insignificant effect on

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## НЕТРАДИЦІЙНА СИРОВИНА ДЛЯ БІОТЕХНОЛОГІЧНИХ ВИРОБНИЦТВ ТА ДЕЯКІ ЕКОЛОГІЧНІ АСПЕКТИ ЇЇ УТИЛІЗАЦІЇ

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**Анотація.** У роботі доведено, що нетрадиційні, щорічно відновлювані відходи рослинної сировини – обрізки фруктових дерев, стебла хмелю та рицини доцільно використовувати для подальшої біотехнологічної переробки з метою одержання цінної білкової кормової добавки. Підтверджено негативний вплив від спалювання цих рослинних відходів на мікробіоту ґрунту. Вивчено технологічні властивості, хімічний та біополімерний склад рослинних відходів. Встановлено, що оптимальні розміри часток для усіх трьох видів досліджуваних відходів складають 20–35мм по довжині волокон. Таке подрібнення забезпечує найкращу дифузію гідролізуючого агента всередину часток сировини і вихід моносахаридів у розчин. Нетрадиційні рослинні відходи характеризуються високим вмістом полісахаридів. Загальний вихід сахаридів при гідролізі складає 52.78–59.11% у залежності від виду досліджуваної сировини. У всіх видах рослинних відходів визначено високий вміст полісахаридів, екстрактивних речовин, що дозволить використовувати їх як потенційну сировину для конструювання поживних середовищ з метою культивування мікроорганізмів на біотехнологічних виробництвах. Здійснено кислотну деградацію біополімерів досліджуваної сировини в лабораторних умовах та підтверджено в виробничих. Отримано поживні середовища на основі гідролізатів, вивчено їх біологічну доброякісність. Підібрано штами дріжджових культур роду *Candida*, які здатні активно розмножуватися на гідролізатах обрізків фруктових дерев, стебел хмелю, рицини, і проведено їх культивування у періодичному режимі. Досліджено негативний вплив від спалювання відходів рослин, що досліджувались, на навколишнє середовище, а саме, на мікробіологічний стан ґрунту. Відібрано зразки ґрунту на ділянці до та після спалювання рослинних відходів, проведено мікробіологічні дослідження загальної кількості мезофільно аеробних та факультативно анаеробних мікроорганізмів та азотфіксуючих, оскільки вони є єдиними живими істотами, спроможними засвоювати молекулярний азот повітря і включати його в кругообіг азотистих речовин. Загальна кількість мікробів знижується на 45%, в той час як кількість азотфіксуючих знижується вдвічі.

**Ключові слова:** рослинні відходи, сировина, біотехнологічна переробка, дріжджі, білкова кормова добавка, ґрунт, кислотність, утилізація.

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