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Method of preparing oat straw for biofuel production

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Abstract. As a leading agro-industrial country, Ukraine generates significant amounts of by-products every year, including oat straw, which, given its lignocellulosic composition, is a valuable resource for meeting bioenergy needs. The aim of this work was to investigate the effectiveness of treating oat straw with a mixture of acetic acid and hydrogen peroxide for effective delignification and obtaining a substrate with a high content of polysaccharide component for potential use in the production of second-generation biofuel. Mathematical modelling and regression equation analysis were applied based on experiments with varying hydrogen peroxide concentrations (10-30 vol. %) and treatment

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durations (60-120 min) to determine the optimal compromise between lignin removal and cellulose preservation. It was found that hydrogen peroxide consumption and treatment duration have a predominantly negative effect on substrate yield, while a positive effect is observed for lignin removal. It was shown that the optimal conditions are a hydrogen peroxide content of 30 vol. % in the mixture with a treatment duration of 60 min, which ensures the maximum value of the desirability function and the production of a substrate with a yield of 52.8%, a lignin content of 2.1% and a cellulose content of 66.8%. Experimental verification of these conditions confirmed the reliability of the obtained model: a substrate with a yield of 52.1%, lignin content of 2.3% and cellulose content of 65.9% was obtained. Thus, the work demonstrates the effectiveness of a sound approach to the processing of agro-industrial waste, opening up prospects for the production of second-generation biofuels. The results obtained have scientific and practical significance, as they confirm the effectiveness of optimised delignification of oat straw and create a scientifically sound basis for the development of resource-efficient technologies for the production of second-generation biofuels

Keywords: substrate; lignin; cellulose; waste processing; delignification

Introduction

The urgent need to abandon fossil fuels, linked to resource depletion, climate change and greenhouse gas emissions, is driving the search for alternative energy sources. Biofuel can be considered one of the most promising types of alternative energy, as its use helps to reduce dependence on oil, natural gas and coal, and also reduces the anthropogenic impact on the environment. First-generation biofuels, produced from food crops, are characterised by certain problems, which consist in reducing the amount of food available to people, which can lead to an increase in food prices. Unlike first-generation biofuels, second-generation biofuels are produced from non-food lignocellulosic biomass, agricultural residues and waste, which is a promising solution for creating alternative energy sources. However, technological and economic improvements in its production processes remain a pressing issue, especially in terms of processing lignocellulosic biomass, which is the most accessible type of raw material for producing second-generation bioethanol.

In their work, M. Jayakumar *et al.* (2023) emphasise that bioethanol from lignocellulosic biomass is a key element of energy transformation, as it allows for the combination of resource renewability and CO_2 emission reduction. It is noted that agricultural waste – straw, corn stalks, husks, i.e. materials that do not compete with the food sector – has the greatest potential. N. Novia *et al.* (2025) noted that for the full-scale implementation of second-generation biofuels, it is necessary to improve biomass pre-treatment technologies, which determine the efficiency of further hydrolysis and fermentation. The importance of optimising economic production indicators is also emphasised, as high production costs are the main obstacle to the commercialisation of these processes. The studies by B. Correia *et al.* (2024) indicate that realising the full potential of second-generation biofuels requires overcoming technical, economic and logistical barriers, as well as continuous investment in research, innovation and supportive policy initiatives to ensure their sustainable and widespread implementation.

S. Roy & S.P. Chundawat (2023) studied the use of ionic liquids for biomass delignification, proving that these compounds provide a high degree of lignin dissolution (up to 95%). At the same time, such reagents are expensive and require further regeneration, which limits their industrial application. Another group of authors, R.S. Abolore *et al.* (2024), showed that the use of organic solvents could be an environmentally acceptable alternative. The study demonstrated the possibility of effective delignification (removal of more than 90% of lignin) under relatively mild processing conditions (temperature 80-100°C) without the formation of toxic by-products. In their work, S. Das *et al.* (2024) analysed in detail the physicochemical properties of lignocellulosic biomass and proposed a concept of multistage conversion taking into account thermomechanical and chemical processes. The authors showed that pre-treatment is a crucial stage that ensures the availability of cellulose for further hydrolysis. Ukrainian researchers have also paid considerable attention to this area. Thus, the authors of the work A. Dankevych *et al.* (2023) emphasised that Ukraine has one of the largest potentials in Europe for agricultural waste, which can provide more than 10 million tonnes of fuel equivalent annually. The authors proposed using cereal straw as a stable source of raw material for the production of second-generation bioethanol.

Despite significant scientific achievements, the studies leave open the question of finding affordable, safe and environmentally friendly pre-treatment methods suitable for large-scale implementation. The conditions for the delignification of specific types of biomass, in particular oat straw, using an acetic acid-hydrogen peroxide system remain insufficiently studied. The influence of process parameters (time, reagent concentration) on the degree of lignin removal and the quality of the substrate obtained for further fermentation also needs to be clarified. The aim of this study was to investigate the effectiveness of treating oat straw with a mixture of acetic acid and hydrogen peroxide in order to establish the conditions for effective delignification and obtain a substrate for further bioethanol production. Particular attention was paid to determining the effect of hydrogen peroxide consumption and treatment time.

Materials and Methods

In laboratory conditions at the Department of Ecology and Technology of Plant Polymers of Igor Sikorsky KPI, research was conducted on the isolation of the polysaccharide component from oat straw by delignifying it with a mixture of acetic acid and hydrogen peroxide under various conditions. Oat straw collected in 2024 in the fields of the Chernihiv region was used as lignocellulosic raw material in the study. The straw was first sorted by hand, separating the leaves and nodes, after which only the internodes were selected for further work. The selected fragments were crushed to a length of 1.5-2 cm to ensure uniformity during the subsequent processing stages. The prepared biomass was stored in sealed plastic bags at room temperature. The chemical composition of oat straw was as follows: cellulose content – 36.7%, lignin – 18.1%, substances extractable with hot water, 1% NaOH solution and alcohol-benzene mixture – 11.6%, 37.3% and 3.2%, respectively, ash content – 6.2% (according to the results of laboratory analysis conducted in accordance with the methods of V.A. Barbash *et al*. (2003), which are generally accepted for determining the chemical composition of plant raw materials). The weight of the raw material in each experiment was 15 g of absolutely dry raw material. The hydromodule was 10:1 and ensured complete wetting of the raw material with a reaction mixture based on acetic acid and hydrogen peroxide.

Oat straw was treated with different ratios of acetic acid to hydrogen peroxide, ranging from 90:10 to 70:30 vol. % respectively. The treatment duration was 60-120 minutes. The treatment time was selected based on previous experience, since it is in this range of treatment duration for different types of raw materials that intensive lignin removal occurs, but with varying efficiency (Barbash *et al*., 2022). The pre-prepared biomass was poured into a reaction mixture and heated in heat-resistant glass flasks in a boiling water bath using reflux condensers to minimise the loss of liquid phase components. After completion of the treatment process, the solid phase – the cellulose product – was separated by filtration, thoroughly washed with water to a neutral pH and dried in air to a residual moisture content of 6%.

The effectiveness of the treatment was evaluated based on the yield of the cellulose product (y_1), its residual lignin content (y_2), cellulose content (y_3) and ash residue (y_4). The effectiveness of the treatment was assessed visually, based on the substrate yield and its chemical composition. Each of the experiments was conducted three times, based on which the average values were calculated. This approach minimised the relative measurement error, which is critical for the reliable construction of a mathematical model of the process. The experimental results were processed using the least squares method to construct a mathematical model of the process. To describe the relationship between the technological parameters and the output characteristics of the cellulose product, a second-order polynomial was used:

$$y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 + b_4x_1^2 + b_5x_2^2, \quad (1)$$

where y_i – dependent variable (cellulose substrate indicator); x_1, x_2 – independent variables (hydrogen peroxide content in the mixture and treatment duration); b_0-b_5 – regression coefficients that quantitatively characterise the contribution of each corresponding member to the formation of the model. Regression equations were used to visualise the effect of oat straw treatment conditions on substrate properties by constructing 3D models in MATLAB. The substrate production process was optimised using a multi-criteria evaluation method based on Harrington's generalised desirability function. For this purpose, each substrate parameter (y_i) was converted into a dimensionless desirability scale (d_i) with values ranging from 0 ("very poor") to 1 ("very good"). Next, the generalised desirability function was calculated as the geometric mean of individual indicators, reflecting the overall quality of the substrate. To determine the optimal parameters of oxidative treatment, one-sided Harrington desirability profiles were used, and the search for the optimum was carried out by scanning the generalised function with high accuracy (step 0.001), which allowed establishing the optimal conditions of the process.

Results and Discussion

Pre-treatment processes play a key role in preparing biomass for the extraction of the polysaccharide component and the subsequent production of biofuel from it. The efficiency of this process largely depends on the ratio of reagents and the duration of treatment, which lead to structural changes in plant raw materials, resulting in an increase in the yield of cellulose and hemicellulose for subsequent maximum bioethanol yield. Figure 1 shows the effect of treatment duration on the appearance of oat straw substrate when exposed to a mixture of acetic acid and hydrogen peroxide for different periods of time.

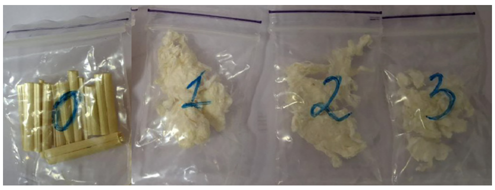

Figure 1. Visual changes in the structure of lignocellulosic substrate based on oat straw
Note: 0 – initial straw; 1 – substrate after treatment of oat straw with a mixture of acetic acid : hydrogen peroxide (70:30 vol. %) for 60 min; 2 – substrate after treatment of oat straw with a mixture of acetic acid : hydrogen peroxide (70:30 vol. %) for 90 min; 3 – substrate after treatment of oat straw with a mixture of acetic acid and hydrogen peroxide (70:30 vol. %) for 120 min
Source: developed by the authors

Destruction of the lignocellulose complex structure was observed, resulting in fibrous products. The structure and colour of the obtained substrate samples clearly demonstrated the destructive effect of the reaction mixture components, in particular the oxidative effect on the aromatic component – lignin, which acts as a binding component and is part of the structural component of the cell wall, the removal of which led to the destruction of the cell wall (Bao *et al.*, 2025). The oxidation and dissolution of lignin led to the enrichment of the obtained products with cellulose, which is a fibrous component of the cell wall. Visual assessment of the substrate samples led to the conclusion that the lignin removal process was sufficiently effective after 60 minutes and that further increases in the duration of treatment had no significant effect on the appearance of the cellulose materials. The change in colour from yellowish for the raw material to white for the obtained samples also indirectly indicates the removal of the aromatic component. A similar effect was observed in cases of delignification of deciduous and coniferous wood in a study by C. Kundu *et al.* (2021). However, in the case of wood processing, it took twice as long to achieve the bleached product effect. This was due to differences in the structure of wood and non-wood plant raw materials, as the former had a denser structure.

Visual assessment of the samples gave a general idea of the processing process, but further detailed analysis of the yield of the processed products and their chemical composition made it possible to substantiate the effect of the reaction mixture on the structure of the raw material and to conclude on the effectiveness of delignification. Treatment of oat straw with a mixture of acetic acid and hydrogen peroxide at a reagent ratio of 70:30 vol. % for 60 min resulted in a substrate yield of 52.1%. The lignin and cellulose content under these conditions was 2.4% and 66.0%, respectively. A further increase in the treatment time to 120 minutes led to a decrease in product yield and lignin content to 46.2% and 1.2%, respectively. Under these conditions, the cellulose content increased and reached 72.9%. Extending the treatment time had a slight positive effect on the mineral content, in particular, the ash content decreased from 2.8% to 2.5%.

In general, the decrease in yield was the result of the removal of non-cellulose components from the plant raw material under the influence of peracetic acid, which was formed in the reaction mixture during heating (Tian *et al.*, 2021). During processing, peracetic acid acts as an effective oxidant capable of breaking down the ether and carbon-carbon bonds between the structural units of lignin, leading to the destruction of its polymer structure, dissolution and diffusion into the liquid phase. Increasing the duration of treatment naturally intensified the oxidative reactions, ensuring the gradual destruction of a larger number of aromatic fragments and contributing to an increase in the degree of delignification. Thus, prolonged exposure to an oxidative environment affected the overall yield of the cellulose product. Similar patterns were noted by other researchers, in particular in the work of Z. Lin *et al.* (2023), which states that during the treatment of poplar chips, prolonging the reaction time contributed to deeper lignin removal. A similar pattern in the change in yield and chemical composition was observed during the treatment of straw with a mixture of acetic acid and hydrogen peroxide at a reagent ratio of 90:10 vol. %. However, due to the lower content of hydrogen peroxide, the efficiency of the process was slightly different. In particular, when the treatment time was increased in the range of 60-120 minutes, the yield of the substrate, its lignin, cellulose and ash content varied within the range of 70.8-63.6%, 2.7-2.5%, 53.9-58.2% and 2.7-2.1%, respectively.

Comparing the efficiency of raw material processing at different ratios of components in the reaction mixture, a positive effect of increasing the hydrogen peroxide content was clearly observed. Thus, in the case of a reagent ratio of 70:30 vol. %, more peracetic acid was generated, which acted as a selective delignifying agent. The results obtained are consistent with the data presented in the work of R. Ma *et al.* (2021), where it was also noted that an increase in the concentration of hydrogen peroxide contributes to a more efficient formation of peracetic acid and, accordingly, an increase in the degree of delignification while maintaining the high integrity of cellulose fibres. As a result of mathematical processing of experimental data, regression equations were obtained that adequately describe the process of chemical treatment of oat straw stalks with a mixture of acetic acid and hydrogen peroxide. For substrate yield:

$$y_1 = 105.65 - 3.61x_1 - 0.124x_2 + 0.046x_1^2 + \\ + 0.0002x_1\,x_2 + 0.0003x_2^2.$$

For residual lignin content:

$$y_2 = 4.32 - 0.11x_1 - 0.022x_2 + 0.002x_1^2 - \\ - 0.0002x_1\,x_2 + 0.002x_2^2.$$

For cellulose content:

$$y_3 = 83.01 + 3.23x_1 + 0.07x_2 - 0.049x_1^2 - \\ - 0.0006x_1\,x_2 - 0.0007x_2^2.$$

For ash content:

$$y_4 = 4.07\text{-}0.15x_1 - 0.0003x_2 + 0.002x_1^2 + \\ + 0.00004x_1\,x_2 - 0.00003x_2^2.$$

The analysis of the models allows to quantitatively assess the impact of two key factors – hydrogen peroxide consumption (x_1) and treatment duration (x_2) – on the quality characteristics of the substrate. Each of the four equations describes a nonlinear relationship that reflects the complex interaction between the process parameters and its results. Hydrogen peroxide consumption and treatment duration show a predominantly negative linear effect on substrate yield and lignin content. This indicates that more intensive treatment, although effective for lignin removal, inevitably leads to some degradation of valuable material. However, positive coefficients for quadratic terms indicate that the rate of this degradation is not constant but slows down over time. On the other hand, reducing the residual lignin content is the main goal of the treatment, and the equation confirms that both factors contribute to this. It is noteworthy that the interaction coefficient ($x_1 x_2$) for this indicator is negative, indicating a synergistic effect: a simultaneous increase in peroxide consumption and treatment duration gives a better result in lignin removal than the general separate application. The ash content proved to be the least sensitive to changes in treatment duration, as confirmed by a very low coefficient. This means that the decisive factor for its control is the concentration of hydrogen peroxide, which has a significantly greater influence.

Based on the obtained regression equations, three-dimensional response surfaces were constructed, which clearly demonstrate the nature of changes in substrate properties depending on the process conditions. The constructed models reflect the relationship between the studied factors and the main technological indicators, which allows them to be used for forecasting and optimising the process. Figure 2 shows 3D models of the effect of processing conditions on the properties of the substrate based on oat straw.

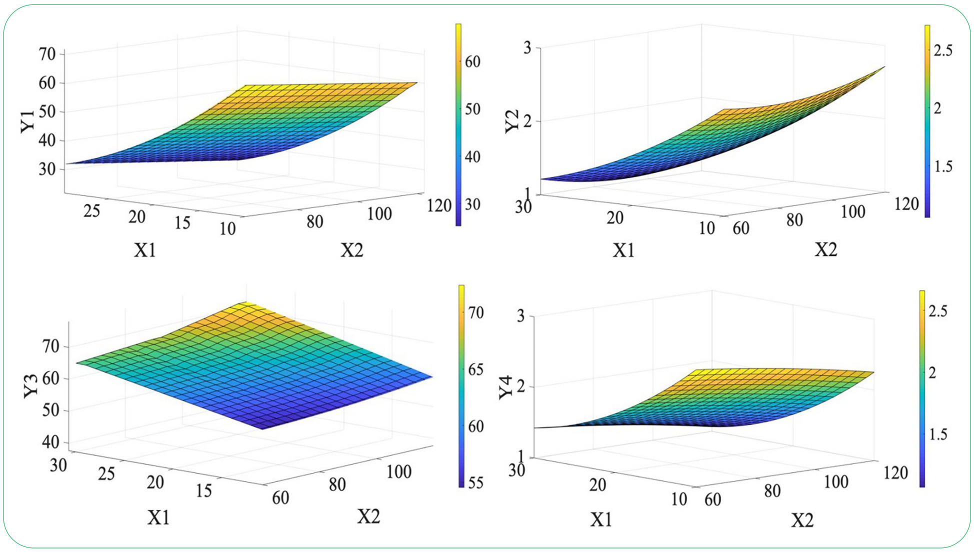

Figure 2. 3D models of the effect of processing conditions on the properties of oat straw-based substrate
Source: developed by the authors

The models presented allow for a quantitative assessment of the impact of key technological parameters – treatment duration and reagent consumption – on solid residue yield and delignification efficiency. The calculated results showed that at an acetic acid : hydrogen peroxide ratio of 70:30 vol. % with an increase in duration from 60 to 120 min, a gradual decrease in yield by 10% was observed. This effect was associated with the destruction and removal of various biomass components, in particular lignin, hemicellulose, and partially extractive substances that were easily subjected to oxidative-hydrolytic processes. At the same time, the reduction in lignin was intense and was due to the selective action of peracetic acid, which acts as an oxidising agent capable of breaking aromatic bonds in the lignin structure.

The delignifying effect of peracetic acid is also mentioned in the works of other researchers who studied the delignification of wood chips and confirmed the selective delignifying effect. In particular, in the case of poplar chips treatment in the study by P. Wen *et al.* (2025), maximum lignin removal with minimal degradation of cellulose and hemicellulose was demonstrated. The authors P.-O. Westin *et al.* (2021) obtained a holocellulose complex from wood chips using a single-stage peracetic acid delignification method. In the work of M.K. Esmaeil *et al.* (2019), the possibility of delignification of sugar cane bagasse was investigated, and a cellulose product with a yield of about 50% was obtained. In the case of wheat straw processing by D.U. Pascoli *et al.* (2022), high-quality cellulose suitable for the production of nanocellulose was obtained. In all cases, the efficiency of the process depended on the conditions of its implementation. In the case of wood, slightly harsher processing conditions are required than when using non-wood plant raw materials, such as cereal straw. Wood raw materials (eucalyptus, poplar, spruce chips) are characterised by a higher lignin content with a more condensed aromatic structure. In such materials, the delignification process was slower, requiring higher temperatures or longer processing times. In contrast, non-wood raw materials had a lower lignin content but a higher hemicellulose content, and their cell walls were more porous and less dense. This allowed acetic acid to penetrate the fibrous structure more easily, promoting faster lignin breakdown even under mild conditions.

The results also showed that, along with the removal of lignin, the cellulose content in the obtained products increased, reaching up to 73%. This is not due to the formation of additional cellulose, but to the enrichment of its relative content in the product as a result of the removal of accompanying components (lignin, partially hemicellulose). In all cases of peracetic acid use, part of the hemicellulose component was preserved (Geng *et al*., 2018). Thus, the selective effect of the oxidative reagent on the aromatic component has been confirmed. An increase in cellulose content during changes in the concentration-time regime has also been observed by other researchers, in particular N. Muna *et al*. (2019) during the processing of fibrous mass based on coconut shells. As for the removal of mineral components, the treatment also contributed to the partial removal of mineral components, but did not lead to the complete removal of ash substances, which can be considered a disadvantage. However, when using the obtained products as substrates for the production of second-generation liquid biofuels, this does not significantly affect the efficiency of the biochemical conversion process.

Thus, in order to achieve the desired result – maximum removal of lignin with minimum loss of cellulose and substrate yield – it was necessary not only to increase the intensity of the process, but also to optimise it. The use of multi-criteria optimisation was extremely important for the effective processing of oat straw and the extraction of a substrate with a high polysaccharide content from it. This made it possible to achieve the specified indicators for the cellulose product. In this case, the main task was to maximise lignin removal while minimising substrate and cellulose yield losses. To solve this problem, multi-criteria optimisation was performed, in particular, using Harrington's generalised desirability function, which is a reliable tool for finding the optimum of various processes. The calculations showed that the optimal parameters for extracting substrate from oat straw were a hydrogen peroxide content of 30 vol. % in the mixture and a processing time of 60 minutes. It was for these processing parameter values that the generalised Harrington desirability function had its maximum value of 0.797. The optimisation results were presented in Table 1.

Table 1. Desirability scale and optimisation results

Indicator y_i	Desirability scale		Optimal value
	Ideal option (very good)	Unacceptable option (very poor)	
y_1	70.8	46.2	52.8
y_2	1.2	2.8	2.1
y_3	72.9	53.9	66.8
y_4	2.2	2.8	2.7

Source: developed by the authors

Experimental studies conducted under the established optimal parameters confirmed the effectiveness of the optimisation of the delignification process. The results obtained show that, with the optimal ratio of reagents and treatment duration, it was possible to achieve a high yield of cellulose product with minimal losses of the polysaccharide part of the biomass. As a result, a substrate with a yield of 52.1% was obtained, characterised by a low lignin content of 2.3%, a high cellulose content of 65.9% and a low ash content of 2.8%. These indicators indicate deep delignification of oat straw and a significant increase in the purity of the cellulose fraction, which is an important prerequisite for further effective enzymatic hydrolysis and biotechnological conversion to bioethanol. In general, the approach used has opened up new opportunities for the valorisation of large-tonnage plant waste from the agro-industrial complex with the production of new valuable products.

The conversion of lignocellulosic biomass is a key process in the development of sustainable biofuels (Woźniak *et al*., 2025). It involves breaking down the complex structure of plant materials. Effective conversion requires overcoming the natural resistance of plant biopolymers, in particular through pre-treatment methods. Pre-treatment is important for disrupting the rigid structure of lignocellulosic biomass, making cellulose and hemicellulose available for further processing (Hu *et al*., 2022; Limeneh *et al*., 2025). Treatment methods include mechanical, thermal, acid, alkaline, and novel methods based on green solvents such as ionic liquids, deep eutectic solvents, steam explosion, etc. Combining pretreatment methods can increase its efficiency, as shown in the works of S. Baksi *et al*. (2023) and L.G. Nair *et al*. (2023). However, for the scalability of second-generation biofuel production processes, it is necessary to develop affordable and cost-effective pretreatment methods that allow for the utilisation of processing by-products (Amini *et al*., 2021). Such methods include organosolvent treatment using a mixture of glacial acetic acid and hydrogen peroxide, as discussed by Z. Lin *et al*. (2023) and W. Ying *et al*. (2023). This treatment can remove up to 97% of lignin from lignocellulosic biomass, significantly improving the availability of cellulose for enzymatic hydrolysis and subsequent fermentation. This method ensures a high cellulose content in the substrate (up to 87%), which is crucial for maximising sugar yield, as shown in a study by T.K. Bedru *et al*. (2025). It is also important that the process takes place under relatively mild conditions, which reduces energy consumption and minimises the formation of fermentation inhibitors (Ummalyma *et al*., 2024).

Ukraine is one of Europe's leading agro-industrial countries, producing significant volumes of grain crops and by-products of their cultivation every year (Talavyria *et al*., 2025). Oat production in Ukraine is estimated at hundreds of thousands of tonnes annually. This means that, along with the grain, a large amount of straw is produced, most of which has no profitable use. However, this biomass is a valuable renewable resource and a potential raw material for bioenergy needs (Błaszczyk *et al*., 2023). The study showed that oat straw is a promising raw material for the production of second-generation bioethanol, as it is characterised by a high content of cellulose components, availability and belongs to renewable types of lignocellulosic biomass. The use of this type of agricultural waste in bioenergy technologies contributes to the more efficient use of agricultural resources and a reduction in organic residues, which is an important factor in the context of developing a circular bioeconomy and reducing greenhouse gas emissions.

Conclusions

Experimental studies have shown that treating oat straw with a mixture of acetic acid and hydrogen peroxide ensures effective delignification of biomass and the formation of a fibrous substrate enriched with cellulose. During the reaction, peracetic acid is formed, which acts as a selective oxidising agent and promotes the breakdown of lignin structures without significant destruction of the carbohydrate part. It has been proven that increasing the hydrogen peroxide content in the reaction mixture enhances the delignification effect, but excessive treatment time can lead to partial degradation of hemicellulose and a decrease in solid residue yield. In particular, at an acetic acid : hydrogen peroxide ratio of 70:30 vol. %, with an increase in the reaction time from 60 to 120 minutes, a decrease in yield of approximately 10% is observed, indicating the destruction of part of the carbohydrate complex. This pattern indicates the need for an optimal combination of technological parameters that ensure a rational compromise between the efficiency of delignification and the preservation of the quantitative yield of the substrate.

Mathematical processing of experimental data allowed to build regression models and 3D response surfaces that quantitatively reflect the effect of hydrogen peroxide consumption and treatment duration on substrate yield, lignin, cellulose and mineral component content. The models demonstrate a negative linear effect of treatment intensity on substrate yield and residual lignin, while quadratic and interactive terms show a synergistic effect between factors. Ash components were found to be less sensitive to changes in conditions. To solve this problem, a multi-criteria optimisation method was applied using Harrington's generalised desirability function, which made it possible to find the optimal compromise between conflicting indicators. The optimal conditions were determined to be a hydrogen peroxide content of 30 vol. % and a treatment duration of 60 min.

Experimental verification of the modelling results confirmed the adequacy of the constructed regression equations. Under the specified optimal parameters, a substrate with a yield of 52.1%, lignin content of 2.3%, cellulose content of 65.9% and ash content of 2.8% was obtained. These indicators demonstrate the high efficiency of the acetic acid-hydrogen peroxide organosolvent system as a reagent medium for the preliminary treatment of oat straw. The results obtained have both theoretical and practical significance, as they expand scientific understanding of the peculiarities of delignification processes. The proposed technology can be used as a basis for further research in the direction of scaling up the process, optimising energy costs and integrating it into second-generation bioethanol production lines. Further research will focus on optimising the processes of hexose sugar extraction and their conversion to bioethanol.

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Conflict of Interest

None.

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Спосіб підготовки вівсяної соломи для одержання біопалива

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Анотація. Україна як провідна агропромислова держава щорічно генерує значні обсяги побічних продуктів, зокрема вівсяну солому, яка з огляду на лігноцелюлозний склад є цінним ресурсом для забезпечення потреб біоенергетики. Метою цієї роботи було дослідити ефективність обробки вівсяної соломи сумішшю оцтової кислоти та пероксиду водню для ефективної делігніфікації та одержання субстрату з високим вмістом полісахаридної складової для потенційного використання для одержання біопалива другого покоління. Застосовано математичне моделювання й аналіз регресійних рівнянь на основі експериментів із варіюванням концентрації пероксиду водню (10-30 об. %) і тривалості обробки (60-120 хв) для визначення оптимального компромісу між видаленням лігніну й збереженням целюлози. Встановлено, що витрати пероксиду водню та тривалість обробки мають переважно негативний вплив на вихід субстрату, тоді як для видалення лігніну спостерігається позитивний ефект. Показано, що оптимальними умовами є вміст пероксиду водню у суміші 30 об. % при тривалості обробки 60 хв, що забезпечує максимальне значення функції бажаності та одержання субстрату з виходом 52,8 %, вмістом лігніну 2,1 % та целюлози 66,8 %. Експериментальна перевірка цих умов підтвердила достовірність отриманої моделі: одержано субстрат з виходом 52,1 %, вмістом лігніну 2,3 % та целюлози 65,9 %. Таким чином, робота демонструє ефективність обґрунтованого підходу до переробки агропромислових відходів, відкриваючи перспективи для виробництва біопалива другого покоління. Отримані результати мають наукове й прикладне значення, оскільки підтверджують ефективність оптимізованої делігніфікації вівсяної соломи та створюють науково обґрунтовану основу для розроблення ресурсоефективних технологій виробництва біопалива другого покоління

Ключові слова: субстрат; лігнін; целюлоза; переробка відходів; делігніфікація