Enhancement of Sawdust Grinding Process

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Abstract

An influence of preliminary chemical treatment upon the process of mechanical grinding a raw material was investigated. It has been demonstrated that as the result of sawdust processing by solutions of an acid, alkali or by enzymatic preparations, chemical modification is realized for one of the components of the sawdust lignine-carbohydrate matrix (cellulose, hemicellulose or lignine) and the structure of wood is changed. The influence of enzymatic hydrolysis upon the conversion level and the efficiency of grinding was studied. It has been demonstrated that even insignificant carbohydrate conversion level (1–2 %) is sufficient for the reduction of wood structure strength using the method of preliminary enzymatic destruction of carbohydrates. With the use of a preliminary chemical processing method for sawdust treatment the fraction of 19–25 μm-sized particles after mechanical grinding exhibits an approximately 10-fold increase.

Key words: sawdust grinding, wood flour, enhancement, preliminary chemical treatment

INTRODUCTION

The innovation way of the development of Russia which is accepted as a priority direction of economical development assumes a much more profound processing of natural resources, reduction of raw material export as well as an increase in the fraction of deeper processing products under export. Alongside with oil and gas, wood belongs to such resources, too. One of the directions for increasing the efficiency of wood processing consists in the use of waste products from the wood-processing industry for obtaining wood flour as well as the development of technologies for increasing the yield of wood flour whereby the volumes of small fraction fines would be much higher with the same power inputs.

Wood flour could be used in petroleum industry for increasing oil recovery, in manufacture of composites, polymeric and building materials, solid bio-fuel (pellets) and new constructional materials such as bioplastics [1].

To a small extent the wood flour is formed as a by-product of plywood manufacture. However, wood flour is obtained mainly with grinding sawdust by so-called hammer mills [2]. Fine grinding requires for a high power inputs, therefore searching for methods to increase the efficiency of grinding is of currently central value.

The basic components of wood are presented by carbohydrates and lignine [3, 4]. The features of morphological structure and composition of cellular wall consisting of a cellulose fibre skeleton within the matrix of lignines and hemicelluloses determine the resistivity of phytogenous materials against mechanical destruction [5]. The increase in the intensity of mechanical action due to grinding could result in undesirable consequences such as the destruction of biologically active substances, the resinification of wood components and the reduction of cellulose polymerization level. In this connection one should reduce the intensity of mechanical action at a constant efficiency of grinding.

In this work we propose a method for increasing the efficiency of phytogenous raw material grinding which method consists in consecutive chemical modifying and mechanical grinding of sawdust. As a result of chemical

modification of one of sawdust components the structure of wood natural composites changes and the durability of sawdust decrease.

The purpose of the present work consisted in the investigation of influence of sawdust treatment with acidic, alkaline or enzymatic solutions upon the efficiency of grinding. The studies on the influence of enzymatic treatment conditions, in particular on the activity of cellulase enzymes upon the efficiency of grinding were performed, too.

EXPERIMENTAL

In our experiments we used fir wood sawdust. For enzymatic hydrolysis we used an enzymatic preparation CelloLux-A exhibiting the cellulase activity (SibBioPharm Co., Berdsk city, Russia).

The determination of sawdust grain-size composition was carried out using a sieve analysis method. A weighed sample of the material under investigation was sifted through a sieving stack with top-down decreasing mesh aperture of 80, 125, 200, 300, 400 μm. Further we determined the content of remainder on each sieve in relation to the mass of initial weighed sample. Size distribution of particles was determined within the range of 1–80 μm with the help of a Microsizer 201 A laser particle size analyser (Granat Co., St. Petersburg).

The chemical modification consisted in the removal of extractive substances, enzymatic and acid hydrolysis as well as the treatment with dilute solutions of hydrochloric acid and sodium carbonate. The removal of extractive substances soluble in hot water was carried out at the temperature of 100 °C during 2 h. The extractive substances soluble in the mixture of ethanol and toluene, as well as hemicelluloses were removed using the technique described in the monograph [6].

During enzymatic treatment, sawdust was mixed with a solution of enzyme in the acetate buffer (pH 4.7); the temperature of processing did not exceed 50 °C. The sawdust after the treatment by the enzymatic solution was washed with hot distilled water. The solution was centrifuged and the content of carbohydrates was determined. The concentration of reducing carbohydrates in the solutions was determined according to the reaction of Fe(III) reduction in potassium hexacyanoferrate complex from the absorption at the wavelength $\lambda = 419$ nm, as recalculated for glucose. The conversion level (α) was determined as a ratio between the mass of reducing carbohydrates and the mass of the initial substrate. The grinding of sawdust was performed using a Pulverisette 5 planetary mill (Fritsch GmbH, Germany).

RESULTS AND DISCUSSION

Effect of preliminary chemical treatment on sawdust grinding

We have determined the effect of sawdust chemical modification on the efficiency of grinding them. Data concerning grain-size composition of sawdust obtained with various treatment methods are presented in Table 1.

The analysis of the fraction with particles size <80 μm has demonstrated that for the sawdust after enzymatic processing the percentage 19–25 μm fraction is higher as compared to that for the initial grinded sawdust being of 9.3 and ~1.4 %, respectively. The percentage of 19–25 μm fraction in the bulk of the wood flour

TABLE 1

Grain-size composition of the materials obtained from fir wood sawdust using different methods

Processing method	Mass fraction, %				
	Particle size, μm				
	>400	200–400	125–200	80–125	<80
Raw sawdust, initial fraction	70	23	5	1	1
Grinding of raw sawdust	5	19	16	16	44
Enzymatic hydrolysis	1	5	9	12	73
Treatment with HCl	1	5	10	12	72
Threatment with Na_2CO_3	1	6	10	14	69

obtained by grinding of initial raw sawdust amounts to 0.03 %, whereas the percentage of the same fraction in the sawdust subjected to enzymatic processing, is equal to 0.61 %. Thus, after enzymatic sawdust processing the yield of the aforementioned fraction is observed to increase by a factor of 20. The same increase in the efficiency of grinding is also observed in the case of acidic and alkaline processing of the initial sawdust.

As the result of the chemical treatment, one of the basic components of the wood composite is changed. In the case of enzymatic processing there is a partial hydrolysis of cellulose occurring, which is indicated by data concerning the conversion of carbohydrates. The processing with hydrochloric acid solution results in the removal of hemicelluloses. The concentration of pentoses and hexoses in the solution was determined using an HPLC method. It is demonstrated that such a processing results in the removal of 16–20 % of hemicelluloses.

The treatment with soda solution results in a partial delignification of the sawdust. In each case the removal or partial destruction of certain wood components of results in an infringement of covalent and intermolecular interactions between the components of wood, which, finally, results in the reduction of the strength of these structures as well as a more efficient grinding at identical mechanical power inputs.

Effect of sawdust hydrolysis level on grinding

Table 2 demonstrates data concerning the conversion level of carbohydrates within sawdust at various enzyme concentrations, as well as the results of determining the content of a fraction with the particles size <80 μm in samples, depending on the lignocellulose hydrolysis level.

Under the conditions of enzymatic processing the conversion of lignocellulose is realized within 1–5 % level depending on the concentration the enzymatic solution. The three-fold increase in the conversion level (from 1.7 up to 5.2 %) corresponds to a 30-fold increase in the concentration of the enzymatic solution.

One can see that in order to reduce the strength of a lignocellulose raw material and to increase the efficiency of sawdust grinding it would suffice to gain even a low conversion level for carbohydrates (1.7 %). The conversion level almost does not influence the result of grinding: with increasing this value from 3 up to 5 % the percentage of fine fraction in sawdust samples exhibited no increase. To all appearance, under the treatment conditions the process of hydrolysis does not occur up to rather high conversion level values, since the diffusion of enzyme molecules and reaction products is limited.

CONCLUSION

As the result of chemical modification of one of sawdust components there is a reduction of strength observed for natural wood composites. The method of preliminary chemical processing of wood waste products results in an increase in the yield of wood flour. At the same energy consumption and with the same mills the amount of wood flour fine fraction exhibits a 2- to 4-fold increase.

Effects of enzymatic activity on conversion level and sawdust grinding efficiency are considered. With the use of preliminary enzymatic destruction method, method even a low (1–2 %) carbohydrate conversion level is observed to suffice to reduce the strength of wood structure. The increase in the conversion level of raw

TABLE 2

Effect of sawdust hydrolysis level on grinding

Enzyme concentration, %	Carbohydrate conversion level, %	Fraction percentage with particle size <80 μm, %
0	0	44
0.1	1.7 ± 0.4	54±6
1.0	3.2 ± 0.1	69±8
3.0	5.2	63±7

material up to 5 % does not exert any considerable effect on the efficiency of sawdust grinding.

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