Application of Lignin Sorbents for Correction of Carbohydrate-Lipid Profile of Diabetic Patient's Blood Serum

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Abstract: Novel cost-effective sorbents based on hydrolytic lignin of cotton husk have been synthesized by two-step process including condensation of lignin with epichlorhydrin oligomer and subsequent amination of formed chloroderivative with polyamines. The results show the efficiency of lignin sorbents for the removal of water and lipid soluble toxic metabolites from blood serum of diabetic retinopathy patients. Due to high sorption activity of synthesized sorbents in relation to glucose and lipids, including triglycerides, cholesterol and its most atherogenic fractions (LDL-C, VLDL-C) their concentration reduced from pathological levels to physiological norm or the levels of optimum compensated diabetes. Considerable hypolipidemic and hypoglycemic effects of synthesized sorbents in comparison with enterosorbent Polyphepan have potential for prevention and treatment of diabetes. Sorption correction of pathological process decrease risk of diabetic retinopathy progression and can delay irreversible vision loss among working-age adults.

Keywords: Lignin sorbents, blood serum, sorption correction, detoxication, diabetic retinopathy, diabetes.

1. INTRODUCTION

The diabetic retinopathy (DR) is one of the most frequent and prognostically adverse manifestations of microangiopathy, which often leads to severe visual loss in working-age patients [1-3]. The leading role in its formation is played by metabolic disorders. Lipid dysmetabolism and prolonged hyperglycemia are the risk factors promoting DR development [3,4]. Pathological content of glucose in blood leads to a non-enzymatic glycosylation of proteins and proteinaceous components being a part of glycoproteids, lipoproteins, etc. That causes failures of many enzymatic reactions occurring in human body. Hyperglycemia is correlated with the high level of lipids and induce changes of cells structural components and retinal capillary basement membrane. That leads to functional disorders in blood vessels, including in retinal microvessels. The thickening and decreasing of an elastance of retina membrane increases probability of retinal hole and vitreous hemorrhage which provide blindness or hypovision.

At present, there are no effective methods of DR drug treatment. Therefore development of visual functions maintaining methods for prioritizing and managing diabetic patients with ophthalmologic pathology in the early stages of this disease is extremely important [4]. Monitoring and correction of glycemic and lipid profile are key element in the multifactorial approach to preventing and slowing the progression of DR in patients with diabetes [1,2].

Among well-known methods of metabolic disorders correction one of the most effective is enterosorption used alone or in combination with several therapies, including traditional pharmaceutical approach based on application of lipid- or sugar-lowering medications [5-9]. In this case increasing of treatment effectiveness is accompanied with reducing of drug dosage having, as we know, some side effects.

Currently, broad spectrum of enterosorbents are developed and used in clinical practice and research, but the range of the medical sorbents used for treatment of diabetes and its vascular complications is limited. The first studies have demonstrated efficient clinical application of carbon enterosorbents based on activated charcoal [6,10-15], nitrogen-containing granular activated carbons (SKN, SKN-SH) [16] and carbon-fiber materials [17] for correction of diabetic dysmetabolism. Their hypoglycemic, antitrigliceridemic, hypocholesteremic and hypotensive effects have been observed. Sorbents provide the accelerated compensation of diabetes at lowered dosage of insulin and oral antidiabetic drugs. Besides, they reduce clinical manifestations of diabetic angiopathy [17], improve synthetic liver function [12] and activity of cardiovascular system [11,15-17]. In particular, they have positive impact on the contractive activity of a myocardium reduced at diabetes [15,16] and state of coexisting digestive system diseases [17].

However, carbon enterosorbents are traumatic for a gastrointestinal mucosa and their prolonged application

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are not recommended at gastric erosion, stomach ulcer and enterorrhagia [6]. Moreover, these sorbents have some side-effects, such as obstipation, diarrhea, a hypovitaminosis, decreasing of absorption of nutrients and hormones from gastrointestinal tract.

Another promising enterosorbents for diabetes treatment is represented by silicon-containing sorbents (organosilicon polymers, aerosol and clay) [7-9,17-23]. Many experimental and clinical studies were carried out with enterosorbent Enterosgel which is a polymethylsiloxane based hydrogel [17-24]. Human clinical trials of Enterosgel for treatment of diabetes and dyslipidemia [19] were in good correlation with preclinical experiments on the rats with streptozotocin-induced diabetes [20]. Enterosgel normalizes lipid profile, parameters of pro-oxidant-antioxidant homeostasis in liver tissue and its histological structure. It has positive effect on left ventricular systolic and diastolic function and leads to decrease of ventricular extrasystole in patients with diabetes complicated with acute coronary syndrome [21]. Sorbent also improves biochemical parameters of blood of diabetic patients with ischemic heart disease and non-alcoholic steatohepatitis [22,23] and patients with hypercholesterolemia and hypertriglyceridemia [24].

Compared with activated carbons most commonly used as enterosorbents, Enterosgel exhibits lower capacity towards the pathogenic compounds with molecular weight below 1,500 Da, but it is a much more potent adsorbent than activated carbons for the removal of high molecular compounds such as proteins and bacterial endotoxins [17].

In recent years natural plant-based enterosorbents are developed and used in clinical practice for prevention and therapy of diabetes and other diseases [6-9,25-40]. Such sorbents exert positive long-term effect on the function of the gastrointestinal tract. Other major advantages of these types of sorbents are their low-cost, availability and renewability. Among phytogenic enterosorbents special attention is paid to medical lignins, which have high sorption activity due to their fine porous structure and a set of different functional sorption active groups, capable to eliminate various types of toxic agents [6-9,25-40].

Results of a comparative research of detoxication properties of lignins extracted from different plants with other enterosorbents indicated that lignins have a much higher adsorption capacity than charcoals, chitine, chitosan, cellulose, hemicellulose and pectin in relation to glucose, creatinine, urea, ammonia, bile acids, xenobiotics, heavy metals ions, radioactive isotopes, fractions of average and low-molecular metabolites, gonadal sex steroids, microbes, allergens and promote their accelerated removal from an organism [26-40]. Due to these properties lignin sorbents were recommended for treatment of patients with gastrointestinal [26,31] and skin diseases [26], hepatitis, pancreatitis [32], peritonitis [26], pneumonia [33], bronchial asthma [34], common intoxication and also for prophylaxis and treatment of young growth of farm animals [26]. They possess not only enterosorption, detoxication, antioxidative, but also hypocholesterolemic [35], anti-arteriosclerotic [36] hypoglycemic and hypolipidemic [36-38] effects. In vivo experiments on hyperlipidemia induced rats have shown that lignin is more effective sorbent than microcrystalline cellulose and synthetic enterosorbents and can be used as dietary supplement for hyperlipidemia treatment. High sorption ability of lignin in relation to lipids allows to use it for treatment of an atherosclerosis, hyperlipidemia as well as diabetes [39,40].

In vivo comparative studies of carbon and plant sorbents efficiency for therapy of type 1 and type 2 diabetes testify the greatest effectiveness of enterosorption with natural plant polymers, such as lignin, microcrystalline cellulose and pectin than charcoal sorbent [39]. According to results of human clinical trials, lignin enterosorbent promotes decreasing of insulin resistance and stabilization of carbohydrate metabolism at type 1 diabetic patients with hyperinsulinemia.

Thus, application of enterosorption by lignin sorbents in complex therapy of type 1 and type 2 diabetic patients at decompensation and subcompensation stages leads to short-term improvement of clinical outcomes. It is found that enterosorption is most effective for diabetic patients with gastroenteropathy, obesity and purulent infective complications [40]. Sorption treatment of patients with diabetes complicated by purulent process provides positive dynamics of the local inflammatory process and promotes accelerated wound healing [40].

Currently, there are more than ten medical lignin preparations in the pharmaceutical market of EEU countries. They are manufactured by hydrolysis and alkaline treatment of wood and sold as *Polyphepan, Polyphepan plus, Polyphan, Filtrum-STI, Lignosorbum, Entegnin, Entegnin-N, Filtrum-Safary, Lactofiltrum, Lactofiltrum ECO Polyphepanum veterinary*. Among them six preparations of hydrolytic lignin (HL) such as *Polyphepan, Polyphepan plus, Polyphan, Filtrum-STI, Lignosorbum*, *Entegnin and Entegnin-N* are used as dietary supplement and pharmaceutical for diabetes treatment. They are produced in different dosage forms: powders, granules, pastes, tablets, sachet and chewing pastilles in composition with various technological additives and aids improving their medicinal properties [41-45].

To expand plant raw materials source for lignin sorbents obtaining and increase the resultant products range, new medical lignins based on cereals [46], nutshell, grape seeds, husk of the buckwheat and the sunflower [47], cotton husk [48-50] and sawdust [51] have been developed. Their physical and chemical, toxicological and pharmacological properties have been studied [46,48-51]. New ways of extraction [46,47,52-54], modification of lignins [48,49,55], and also standardization [27,56] and decontamination [57] of preparations to achieve their required microbiological purity have been proposed.

It is found that chemical functionalization of lignin is a good strategy to develop enterosorbents with improved sorption properties. Results of our previous researches indicated that aminolignins synthesized by *o*-alkylation and amination of HL of cotton husk exhibit considerable hypolipidemic and hypoglycemic effects in comparison with Russian enterosorbent Polyphepan [49]. Toxicological studies of sorbent testify its nontoxicity and possibility of use in preclinical and clinical trials [50]. In vivo experiments on alloxan-induced diabetic rats have demonstrated suitability of sorbent for correction of diabetes dysmetabolism and prevention of this disease.

The aim of the present study is evaluation of hypolipidemic and hypoglycemic activity of novel enterosorbents based on HL of cotton husk on blood serum of DR patients. Carrying out such research is important for the development of the domestic pharmaceutical market by expansion of assortment of competitive domestic pharmaceuticals, efficient for prevention and treatment of diabetes and its vascular complications, such as DR which is the most common cause of vision loss among the diabetic patients.

2. MATERIALS AND METHODS

2.1. Materials

HL of cotton husk is a large-scale by-product of Shymkent hydrolysis plant, which specialized on production of protein-rich fodder yeast by biochemical processing of xylose. Xylose is obtained by hydrolysis of polysaccharides extracted from crops. Only lignin remains as insoluble nonhydrolyzable residue after all processing steps. HL of cotton husk distinguished by its composition from other HL isolated from agricultural wastes processed on the plant (maize cob, rice and sunflower husk). It is more enriched with methoxy, phenolic, carboxyl and carbonyl groups in comparison with HL from other plants (Table **1**) [58]. Moreover, it is characterized by lowered content of residual hardly hydrolyzed polysaccharides and extractive, resinous and mineral compounds, which are not chemically bind with cellular wall of vegetative tissue. Due to higher functionalization of cotton husk lignin macromolecules, it is used to further chemical modification for preparation of polyfunctional nitrogen-containing sorbents.

Content of cellulose and lignin in HL was determined by Kyurshner and sulphuric methods [59]. Extractive compounds were extracted with an alcohol-benzene solution (1/2, v/v), alcohol and distilled water as described in [59]. Their mass gain in HL was calculated by the formula:

$$(m_o - m) \cdot 100/m_o,$$

where m and m_o are the masses of treated and initial samples respectively.

Ash content was determined according to the procedure [59]. Quantitative analysis for the methoxy

Table 1: The Composition of Extracted Hydrolytic Lignins of Shymkent Hydrolysis Plant [58]

Lignin from different plants	Chemical composition, %					Functional composition, %			
	Lignin	Polysaccharide	Extractive compounds	Resinous compounds	Ash	OCH_3	COOH	C=O	OH_{phen}
Maize cob	60.7	16.2	10.8	9.8	2.1	5.8	0.76	5.0	1.12
Cotton husk	72.0	14.5	10.6	7.8	3.2	8.7	1.27	5.8	2.3
Sunflower husk	61.8	14.8	9.6	12.2	2.6	8.0	0.92	5.2	1.08
Rice husk	66.2	12.2	12.8	9.2	18.9	8.6	0.98	5.4	1.09

groups was carried out by modified Tseyzel-Fibek-Shvappakh method, alcohol groups – by phthalation, carbonyl groups – by oximation, carboxyl and phenolic groups – by chemisorption method [60].

The oligomer of epichlorohydrin was synthesized by homopolymerization of epichlorohydrin in the presence of acid-activated bentonite clay from Monrak, Kazakhstan (H^+–M-14). Synthesis was carried out according to the following procedure. 83.7 mL of monomer was put into a 250 mL three-necked flask equipped with a mechanical stirrer, thermometer and reflux condenser. 1.0g of bentonite clay as catalyst was mixed with monomer and vigorously stirred for 2 hours at 60°C. An oligomer was purified by triple reprecipitation from benzene in ethanol and dried in a vacuum oven at 25ºC. An oligomer yield reached 80% and the content of chlorine in it was equal to 32.61%.

Polyethyleneimine (PEI) with molecular weight $(30\text{-}40)\cdot 10^3$ and polyethylenepolyamine (PEPA) with molecular weight 265 were obtained from Fluka AG and Nizhnii-Tagil plant (Russia) respectively. Polyamines were stored over granulated KOH and used without further purification. All other chemicals were of analytical grade and used as received.

2.2. Preparation of Lignin Sorbents

Nitrogen-containing lignin sorbents were synthesized by condensation of HL of cotton husk with epichlorhydrin oligomer and subsequent amination of lignin chloroderivative with PEI (HL-PEI) and PEPA (HL-PEPA). Condensation of HL with epichlorhydrin oligomer was carried out according to the following procedure. 1.0 g of extracted HL was added into a 250 mL three-necked flask equipped with a mechanical stirrer, thermometer and reflux condenser. 6.0 mL of 50% benzene solution of epichlorhydrin oligomer was mixed with HL and vigorously stirred for 1.5 hours at 60°C. An intermediate product was separated from the solution and extracted with benzene in a Soxhlet apparatus after 5-6 hours and dried in a vacuum oven at 25°C. The content of chlorine in semiproduct was equal to 9.95% at mass gain 30.6%. The mass gain of the HL was calculated by the formula:

$$(m - m_o) \cdot 100/m_o ,$$

where m and m_o are masses of modified and initial samples respectively.

To synthesize the aminelignins 1.0 g of HL chloroderivative was aminated by 5 mL of 30% dimethylformamide solution of polyamines in a three-necked flask and subsequently solidified in porcelain crucibles in a muffle oven at 80°C for 10 hours. The amination process was carried out at 80°C during 1 hour. After the reaction completed, the final nitrogen-containing sorbents were treated with 5% HCl and then 5% NaOH aqueous solutions for 24 hours. After each treatment samples were washed with distilled water and dried in a vacuum oven at 50°C.

2.3. Characterization of Sorbents

The static exchange capacity (SEC) of sorbents was determined with the use of 0.1 M HCl solution by keeping a 1.0 g of the samples in the OH^- form in 100 mL of the acid solution for 24 hours [61]. After establishing of equilibrium an aliquot of the filtrates (25 ml) was titrated with 0.1 M NaOH solution in the presence of methylene blue indicator. The SEC was calculated by the formula:

$$SEC_{HCl} = (100 - 4V)/10\ m,$$

where 100 is the volume of 0.1 M HCl solution, mL, V is the volume of 0.1 M NaOH solution spent for titration of the aliquot of the acid solution, mL, and m is mass of the sorbent, g.

The apparent dissociation constant pK of sorbents ionic groups was determined from the potentiometric titration data and was calculated by the Henderson–Hasselbalch equation from the $pH=f\{\log[\alpha/(1-\alpha)]\}$ plot by extrapolation of the linear function to $\log [\alpha/(1-\alpha)] = 0$ ($\alpha = 0.5$) [61].

Specific volume (V_S) of sorbents was estimated by keeping aminated samples in distilled water for 24 hours and calculated by the formula:

$$V_S = V_{SW} /m,$$

where V_{SW} is the volume of swelled sample, mL, and m is mass of dry polymer, g.

Characteristics of lignin sorbents are shown in Table **2**.

2.4. Blood Serum Detoxication Procedure

Synthesized lignin sorbents were used for purification of pathological blood serum of DR patients. In vitro blood serum correction procedure was carried out with a mass ratio of 1:10 in cells thermostated at 25°C for 1 hour. The total amount of bilirubin and cholesterol was determined quantitatively by measuring

Table 2: The Characteristics of Lignin Sorbents

Sample	Element composition, %				Functional composition, %			SEC in 0,1N HCl,mequ/g		pK	V_S, mL/g	Yield, %
	C	H	O	$\frac{N_{elem}}{N_{titrable}}$	OCH_3	$OH_{alcohol}$	CO	HCl	NaCl			
HL-PEI	54.70	7.96	25.70	$\frac{11.64}{9.94}$	5.46	5.00	1.68	6.5	0.6	6.20	5.25	90.3
HL-PEPA	56.38	7.54	25.71	$\frac{10.37}{7.81}$	5.32	5.30	1.49	5.18	0.4	5.65	4.75	90.9
	Semi-empirical formulas of lignin phenylpropanoic unit											
HL-PEI	$C_9H_{14,69}O_{2,30}N_{1,71}(OCH_3)_{0,36}\ (OH)_{0,53}(O_{CO})_{0,11}$											
HL-PEPA	$C_9H_{13,37}O_{2,2}N_{1,47}(OCH_3)_{0,34}\ (OH)_{0,56}(O_{CO})_{0,095}$											

the optical density of the initial and equilibrated solutions on a UV-Visible Spectrophotometer (Specord 210plus, Germany) at 590 and 510 nm respectively. The bilirubin concentration was established using diagnostic sets of reagents (Lachema, Czech Republic). The determination was based on interaction of the azo-bond of bilirubin with diazotized sulfanilic acid to form a colored solution of an azo dye that was measured photometrically [62].

Spectrophotometric determination of the total cholesterol and high-density lipoprotein cholesterol (HDL-C) level in serum was based on enzymatic reaction with cholesterolesterase [62] and carried out using a Vital-Europe diagnostic set of reagents (Vital Diagnostics SPb, Russia).

The content of HDL-C was determined in a supernatant after sedimentation of low and very low density lipoprotein cholesterol (LDL-C and VLDL-C) and calculated by the formula:

$$C_{Chol/HDL\text{-}C} = E_o/5.17\cdot E,$$

where E_o and E are the extinctions of the sample and standard measured relative to a control sample.

The calculation of VLDL-C and LDL-C concentration used the Friedvald formula [63]:

$$C_{VLDL\text{-}C} = C_{TG}/2.2$$

$$C_{LDL\text{-}C} = C_{Chol} - C_{VLDL\text{-}C} - C_{HDL\text{-}C}$$

The concentration of triglycerides (TG) was measured as described in [64]. The glucose content in serum was established by glucooxidase method [62].

3. RESULTS AND DISCUSSION

Diabetes is correlated with a high risk of acute and late vascular complications, such as DR, cardiovascular disease, nephropathy, neuropathy, diabetic foot and etc. [65]. Managing diabetic patients by stable compensation of dyslipidemia, glycemia, hypercholesterolemia as well-recognized and modifiable risk factors, is current strategy for prevention and appropriate therapy of micro- and macrovascular complications associated with diabetes.

In this work sorption correction of carbohydrate-lipid profile of blood serum of DR patients have been carried out by using novel nitrogen-containing lignin sorbents in comparison with enterosorbent Polyphepan based on unmodified soft wood lignin. The purpose of the sorbents application is reducing the total cholesterol level and correction of pathological ratio of cholesterol in HDL, LDL and VLDL.

Well-known that sorption removal of atherogenic fractions of cholesterol (LDL and VLDL) is accompanied with difficulties caused by their high molecular mass and sizes considerably exceeding than other proteins of plasma (Table **3**) [66]. As seen in Table **4**, carbohydrate-lipid profile of DR patients is characterized by elevated glucose, TG levels and total cholesterol level, including its most atherogenic fractions such as LDL-C and VLDL-C, and decreased angioprotected HDL-C levels. Concentration of these metabolites is above the standard level by factors of 1.23, 2.09, 1.67, 2.02 and 4.60 respectively. Concentration of HDL-C was below more than twice.

After sorption on amine-containing sorbents the total cholesterol level in serum decreased to 22.48–28.61% and reached to 5.31 – 5.11 mmol/L, that corresponds to the level of optimum compensated diabetes (<4.8–6.0 mmol/L). Enterosorbent Polyphepan on the basis of unmodified wood lignin extracted only 12.41% of cholesterol and its concentration reached to 6.0 mmol/L. Low sorption activity of untreated high porous natural material,

Table 3: Composition and Characteristics of Human Lipoproteins [66]

Lipoproteins	Composition, %				Size, nm	Density, g/mL
	Protein	TG	Cholesterol	Phospholipids		
Chylomicrons	1	89	6	4	100–1000	0.900
VLDL	10	53	19	18	30–70	0.900
LDL	21	11	45	23	15–25	1.018
HLDL	50	2	18	30	7.5–10	1.131

Table 4: Carbohydrate-Lipid Profile of Blood Serum of DR Patients Before and After Contact with Lignin Sorbents

Blood serum components	Physiological norm	Lipid profile of PDR* patients	Criteria of diabetes compensation	Initial level	Biochemical composition of blood serum after contact with sorbents/ extraction degree, %		
					HL-PEI	HL-PEPA	Polyphepan
Total Cholesterol, mmol/L	4.1 ± 0.08	5.4 ± 0.21	< 4.8 – 6.0	6.85	5.31 22.48	5.11 25.40	6.00 12.41
LDL-C, mmol/L	2.4± 0.24	3.6 ± 0.15	< 3.0 – 4.0	4.85	4.11 15.26	4.00 17.53	4.65 4.12
VLDL-C, mmol/L	0.31 ± 0.09	0.62 ± 0.07	–	1.43	0.86 39.86	0.72 49.65	0.95 33.57
HDL-C, mmol/L	1.6 ± 0.3	1.1 ± 0.07	>1.0 – 1.2	0.58	0,34 41.38	0,39 32.76	0,41 29.31
TG, mmol/L	1.5 ± 0.23	2.8 ± 0.18	< 1.7 – 2.2	3.14	1,89 39.81	1.59 49.36	2.08 33.76
Bilirubin, mkmol/L	< 20.5	–	–	12.15	5.60 53.91	4.01 67.00	11,9 2.06
Glucose, mmol/L	< 4.2–6.1	–	4.4 – 6.7	7.5	5,35 28.67	5,50 26.67	6,70 10.67
Total protein, g/L	< 52–91	–	–	73	73 0.0	73 0.0	72,5 0.68

*proliferative diabetic retinopathy.

apparently, is causes by absence of sorption active amine groups.

The analysis of biochemical indicators of blood serum before and after sorption demonstrates that sorption ability of sorbents in relation to lipids depends on polyamines nature in their structure (Table **4**). Adsorption efficiency of atherogenic fractions of cholesterol depended on the basic properties of used sorbents and increased in the following order: Polyphepan < HL-PEI < HL-PEPA. On sorbent with PEPA groups average concentration of LDL-C decreased to the upper normal level of optimum compensated diabetes (<3.0–4.0 mmol/L). Polyphepan possessed significantly lower sorption activity for LDL-C. Its concentration slightly decreased from 4.85 to 4.65 mmol/L. Adsorption degree reached to 4.12%. As seen from the presented data significant amount of extracted cholesterol is transport LDL-C and VLDL-C, and the other part is angioprotective HDL-C.

High sorption ability of HL-PEPA-sorbent is probably caused by its high affinity to protein apoB, which represents most of the protein content in LDL-C and VLDL-C, than ApoA, which is the principal apolipoprotein in HDL-C [67]. According to the modern approach, HDLP is the protein removing cholesterol from cell. Therefore, it is anti-risk factor of atherosclerosis development. On the contrary, ApoB is protein delivering cholesterol into cell that is risk factor for atherosclerosis. Lignin sorbent with PEPA groups can cause delaying development of atherosclerotic process due to preferred extraction of LDL-C and insignificant absorption of HDL-C.

Delipidization of serum proceeded not only by removal of atherogenic fractions of cholesterol, but also by adsorption of large amounts of TG. The degree of extraction reached to 39.81, 49.36 and 33.76% with using PEI, PEPA containing sorbents and Polyphepan respectively. TG concentration significantly decreased 1.66 (HL-PEI), 1.97 (HL-PEPA) and 1.51 (Polyphepan) times than initial levels. Established TG concentration (1.89, 1.59 and 2.08 mmol/L) corresponded to the level of optimum compensated diabetes (HL-PEI, Polyphepan) and physiological norm (HL-PEPA). As seen, Polyphepan possessed lowest level of TG adsorption in comparison with amine-lignin sorbents.

One of the important results of sorption was the ability of synthesized sorbents to remove superfluous amount of glucose. As a result of effective uptake of glucose its content decreased from pathological levels (7.50 mmol/L) to physiological norm (< 4.2 – 6.1 mmol/L). After contact with Polyphepan concentration of glucose reduced to 10.67% and reached to 6.7mmol/L. It is testify about low detoxicaion activity of untreated HL in relation to glucose.

Thus, synthesized sorbents based on hydrolytic lignin of cotton husk – a large-scale waste of hydrolytic industry of Qazaqstan possess considerable hypolipidemic and hypoglycemic effects in comparison with Polyphepan. The availability and high concentration of sorption active groups capable of effectively removing pathogens and toxic substances makes them promising materials as enterosorbents for detoxification of body fluids. Adequate blood glucose and lipid control reaching by sorption correction of blood serum allows decreasing microvascular complications associated with diabetes.

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