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ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
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В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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UTILIZING COAL MINING WASTE FOR FEED PRODUCTION: EXPLORING THE POTENTIAL OF HUMATES IN POULTRY NUTRITION

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Abstract. This manuscript explores the innovative utilization of coal mining waste, specifically focusing on the potential of humates derived from this byproduct for enhancing livestock nutrition. Coal mining waste, predominantly comprising humic substances, presents an untapped resource rich in minerals and biologically active compounds that can be transformed into valuable feed additives. The study was conducted using advanced analytical techniques to characterize the chemical and physical properties of humates extracted from coal mining waste. Scanning Electron Microscopy (SEM) provided insights into the microstructure, confirming the presence of mineral constituents like quartz, kaolinite, and muscovite which dominate the waste material. This microstructural insight suggests a dense, crystalline matrix beneficial for dietary applications. X-Ray Diffraction (XRD) analysis further substantiated the SEM findings, quantifying the mineral phases and offering a detailed composition profile of the humates. This phase analysis was essential for understanding the mineral content which can influence the nutritional value of the feed additives. Infrared (IR) spectroscopy was employed to determine the functional groups and molecular interactions within the humates. The IR spectra revealed the presence of various organic and inorganic compounds, highlighting the complex nature of the humates that includes beneficial elements such as nitrogen, calcium, and phosphorus. The study's findings underscore the potential of humates as a feed additive, improving feed efficiency and animal health. These substances have been shown to enhance nutrient absorption, stimulate digestive processes, and provide detoxification benefits, effectively adsorbing harmful substances like heavy metals and pesticides. Moreover, humates form a protective barrier in the gastrointestinal tract, which aids in safeguarding against infections and toxins. Overall, this research demonstrates that coal mining waste can be repurposed into a high-value additive for livestock feed, contributing to sustainable agricultural practices and waste management. The application of such waste not only helps in reducing environmental burden but also adds economic value to the mining and agricultural industries.

Keywords: humates, coal mining waste, livestock nutrition, feed additives, sustainable agriculture

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КӨМІР ӨНДІРУ ҚАЛДЫҚТАРЫН АЗЫҚ ӨНДІРУ ҮШІН ПАЙДАЛАНУ: ҚҰС ТАҒАМЫНДАҒЫ ГУМАТТАРДЫҢ ӘЛЕУЕТІН ЗЕРТТЕУ

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Аннотация. Бұл мақалада құстардың коректенуін жақсарту үшін жанама өнімнен алынған гуматтардың әлеуетіне ерекше назар аудара отырып, көмір өндіру қалдықтарын инновациялық пайдалану қарастырылады. Құрамында негізінен гумусты заттар бар көмір өндіру қалдықтары құнды азық қоспаларға айналатын минералдар мен биологиялық белсенді қосылыстарға бай пайдаланылмаған ресурс болып табылады. Зерттеу көмір өндіру қалдықтарынан бөлінетін гумматтардың химиялық және физикалық қасиеттерін сипаттау үшін озық аналитикалық әдістерді қолдану арқылы жүргізілді. Сканерлеуші электронды микроскопия (SEM) микроқұрылымды түсінуге мүмкіндік берді, бұл қалдықтарда басым болатын кварц, каолинит және мусковит сияқты минералды компоненттердің болуын растады. Бұл микроқұрылымды зерттеу тығыз кристалды матрица диеталық тамақтану үшін пайдалы екенін көрсетеді. Рентген сәулелерінің дифракциясы (XRD)минералдық фазаларды сандық бағалау және гумматтардың егжей-тегжейлі композициялық профилін қамтамасыз ету арқылы SEM нәтижелерін одан әрі растады. Бұл фазалық талдау азық қоспалардың тағамдық құндылығына әсер етуі мүмкін минералды құрамды түсіну үшін қажет болды. Гуматтардағы функционалдық топтар мен молекулалық өзара әрекеттесулерді анықтау үшін инфрақызыл (ИК) спектроскопия қолданылды. Инфрақызыл спектрлер әртүрлі органикалық және бейорганикалық қосылыстардың болуын анықтады, гуматтардың күрделі табиғатын, соның ішінде азот, кальций және фосфор сияқты пайдалы элементтерді көрсетеді. Зерттеу нәтижелері жемшөп тиімділігі мен құстардың денсаулығын жақсарту үшін азық қоспасы ретінде гуматтар әлеуетін көрсетеді. Бұл заттардың қоректік заттардың сіңуін жақсартатыны, ас қорыту процестерін ынталандыратыны және ауыр металдар мен пестицидтер сияқты зиянды заттарды тиімді сіңіру арқылы детоксикацияға ықпал ететіні дәлелденген. Сонымен қатар, гуматтар асқазан-ішек жолында қорғаныс тосқауылын құрайды, бұл денені инфекциялар мен токсиндерден қорғауға көмектеседі. Тұтастай алғанда, бұл зерттеу көмір өндіру қалдықтарын тұрақты ауыл шаруашылығы мен қалдықтарды басқаруға ықпал ететін құнды құс азық қоспасына өңдеуге болатынын көрсетеді. Мұндай қалдықтарды пайдалану қоршаған ортаға түсетін ауыртпалықты азайтуға көмектесіп қана қоймай, тау-кен және ауыл шаруашылығы салаларына экономикалық құндылық қосады.

Түйін сөздер: гуматтар, көмір өндіру қалдықтары, құс азығы, азық қоспалары, тұрақты ауыл шаруашылығы

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ИСПОЛЬЗОВАНИЕ ОТХОДОВ УГЛЕДОБЫЧИ ДЛЯ ПРОИЗВОДСТВА КОРМОВ: ИЗУЧЕНИЕ ПОТЕНЦИАЛА ГУМАТОВ В ПИТАНИИ ПТИЦЫ

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Аннотация. В статье рассматривается инновационное использование отходов угледобычи с особым упором на потенциал гуматов, получаемых из этого побочного продукта, для улучшения питания птиц. Отходы угледобычи, содержащие преимущественно гуминовые вещества, представляют собой неиспользованный ресурс, богатый минералами и биологически активными соединениями, которые могут быть преобразованы в ценные кормовые добавки. Исследование было проведено с использованием передовых аналитических методов для характеристики химических и физических свойств гуматов, выделяемых из отходов угледобычи. Сканирующая электронная микроскопия (СЭМ) позволила получить представление о микроструктуре, подтвердив наличие минеральных компонентов, таких как кварц, каолинит и мусковит, которые преобладают в отходах. Это исследование микроструктуры позволяет предположить, что плотная кристаллическая матрица полезна для диетического питания. Рентгеноструктурный анализ (РСА) дополнительно подтвердил результаты СЭМ, количественно определив минеральные фазы и предоставив подробный профиль состава гуматов. Этот фазовый анализ был необходим для понимания содержания минеральных веществ, которые могут влиять на питательную ценность кормовых добавок. Для определения функциональных групп и молекулярных взаимодействий в гуматах была использована инфракрасная (ИК) спектроскопия. Инфракрасные спектры выявили присутствие различных органических и неорганических соединений, что подчеркивает сложную природу гуматов, включающих такие полезные элементы, как азот, кальций и фосфор. Результаты исследования подчеркивают потенциал гуматов в качестве кормовой добавки, улучшающей эффективность кормов и здоровье птиц. Доказано, что эти вещества улучшают усвоение питательных веществ, стимулируют пищеварительные процессы и способствуют детоксикации, эффективно адсорбируя вредные вещества, такие как тяжелые металлы и пестициды. Кроме того, гуматы образуют защитный барьер в желудочно-кишечном тракте, который помогает защитить организм от инфекций и токсинов. В целом, это исследование показывает, что отходы угледобычи могут быть переработаны в ценную добавку для кормления птиц, что способствует устойчивому ведению сельского хозяйства и управлению отходами. Использование таких отходов не только помогает снизить нагрузку на окружающую среду, но и повышает экономическую ценность горнодобывающей и сельскохозяйственной промышленности.

Ключевые слова: гуматы, отходы угледобычи, питание птиц, кормовые добавки, устойчивое сельское хозяйство

Introduction

Organic materials in soil are subject to constant change, influenced by numerous factors. Two main reasons for these changes are mineralization and humification. From the perspective of zootechnical and veterinary sciences, particularly interesting are the reactions that lead to the formation of complex compounds with significant potential in feed production. Only a fraction of organic substances undergoes such transformations, which are more complex than the mineralization process. Humification is based on the decomposition and synthesis of organic compounds, as well as the polymerization and condensation of the resulting products. This process is complex and not fully understood, primarily resulting in the formation of humic and fulvic acids (Abd El-Hack, 2015).

Humus comprises insoluble humic substances in water at any pH value, characterized by large molecular sizes. The oxygen content in humus is the lowest, while nitrogen makes up about 5–6 %. The mobility of these substances in soil is limited due to their high molecular weight, which makes the negative charge on their surfaces insufficient for peptization at high pH levels. Humic acids are polymers consisting of cyclic phenolic or nitrogen-containing aromatic cores linked to sugars, peptides, amino acids, and other aliphatic compounds. Their complex, compact, unstable, and amorphous structure contributes to their chemical and biological degradation resistance (Abdel-Mageed, 2012). Recent studies have revealed that humic acids, previously considered high-molecular-weight polymers, are actually composed of low-molecular-weight compounds, forming a loosely structured aggregate rather than a regular polymeric chain. This discovery highlights the potential of humic acids and humates in chelation, despite the complexity of extracting chelate compounds from them.

This understanding of the structure of humic acids suggests that they do not form consistent, repeating monomeric chains, but rather are assemblies of various molecules interconnected in a somewhat disordered fashion. This revelation opens up new possibilities for using humic substances, particularly in the area of chelation. Chelating agents are compounds that can form multiple bonds with a single metal ion, and the discovery of the irregular and complex structure of humic acids implies that they can form diverse and potentially useful chelating complexes. Despite the challenges associated with their complex nature, the application of humic acids in agriculture, environmental remediation, and even in pharmaceuticals, as natural detoxifying agents or organic fertilizers, presents a promising field for future research and development. The exploration of these applications could lead to more sustainable and efficient uses of natural resources, aligning with environmental protection goals and the promotion of sustainable agricultural practices (Arafat, 2015).

Currently, the use of ecologically clean and safe materials in agriculture is of great relevance. One promising direction is the use of humic substances. These are high-molecular-weight compounds of natural origin that form through the oxidation of carbon or the transformation of dead biomass. Humic substances have a chaotic structure, typically dark brown in color, and are amorphous structures that can dissolve or swell in water. These compounds do not have a uniform chemical formula, but their basic structures are known to consist of aromatic rings and functional groups (such as hydroxyl, carboxyl, carbonyl, alkyl, and methoxyl groups). In addition to aromatic rings, these substances may also contain polypeptide and polysaccharide fragments. Even simpler compounds like fulvic acids possess a complex chemical structure.

Beyond their structural complexity, humic substances play a significant role in enhancing soil fertility and plant growth. Their ability to interact with minerals and nutrients in the soil can improve nutrient availability and uptake by plants. This interaction helps in the formation of stable soil aggregates, which improves soil structure, water retention, and aeration. Additionally, humic substances can act as natural chelators, binding to heavy metals and reducing their bioavailability, thus mitigating soil pollution. Their diverse functionalities make them valuable for sustainable agricultural practices, promoting healthier plant growth and restoring soil health without relying on synthetic chemicals. The exploration of humic substances is thus aligned with efforts to achieve more environmentally friendly and sustainable farming methodologies. Due to the challenges in quantitatively characterizing the structure of humic acid molecules using traditional methods, researchers have developed a classification system based on solubility in bases and acids. Thus, humic substances are divided into three categories: humins, which are insoluble in both acids and bases; humic acids, which are insoluble in acids but soluble in bases; and fulvic acids, which are soluble in both acids and bases. Humic acids are fractions of humic substances that dissolve in alkaline conditions, are partially soluble in water, and remain insoluble in acidic environments. The classification can vary depending on the pH and ionic interactions (Arafat et al., 2015). Due to their amphiphilic nature, humic acids form micelle-like structures in neutral and acidic environments, known as pseudo-micelles. This property is utilized in water purification systems and to enhance the water solubility of hydrophobic compounds. These pseudo-micelles enhance the efficiency of humic acids in various applications by increasing the interaction surface between humic acids and other molecules or ions in solution. This ability makes humic acids valuable in environmental cleanup, as they can effectively bind and remove contaminants from water. Furthermore, their complexing capabilities are instrumental in agriculture for delivering nutrients efficiently to plant roots, thereby improving plant health and growth. The adaptability of humic acids to different pH levels and their ionic nature allow them to be tailored for specific uses, optimizing their effectiveness in soil amendment and pollution control strategies. This versatility and the eco-friendly nature of humic substances make them an appealing option for sustainable practices in agriculture and environmental management.

Humic acids contain a variety of functional groups, the proportions of which can vary depending on their source, extraction and production methods, as well as the climatic and environmental conditions during their formation. Primarily, the functional groups in humic acids include phenols and carboxylic acids. These characteristics enable humic acids to enhance plant growth and form complex structures with heavy and transitional metals, effectively removing these metals from organisms and forming chelate compounds. Additionally, their antiviral and anti-inflammatory activities have been documented. The presence of phenols, carboxylic acids, and quinones in the structure of humic acids is associated with their antioxidant, fungicidal, and bactericidal properties. The chemical composition of humic substances can change based on geographic origin, age, climate, and biological conditions, which complicates precise identification. Literature sources widely agree on the chemical composition of humic acids derived from various sources. Typically, substances based on humic acids contain about 50 % carbon, 35 % oxygen, and 5 % hydrogen, with the remaining percentage attributed to nitrogen and sulfur (Arafat et al., 2017). The highest carbon content, reaching 60–65 %, is found in materials such as bituminous and brown coal. The ability of humic acids to bind cationic metals and complexes makes them valuable across various sectors. Thus, they facilitate the transfer of micronutrients from soil to plants and from feed additives to the bodies of agricultural animals. Additionally, humic acids help reduce the levels of heavy metals in soils, waters, and living organisms.

The primary source of humic acids is brown coal, which in Kazakhstan is estimated to have reserves of 34 billion tons. Compared to other sources of humic acids, brown coal has a distinct chemical composition that includes various micronutrients suitable for use in the production of animal feed additives. The main methods for extracting humic substances involve alkaline extraction using ammonia solutions or potassium/sodium hydroxides. These processes convert humic substances into water-soluble salts, namely biologically active potassium or sodium humates. This method is practically waste-free, which is why it is widely used in many countries.

In recent years, various feed additives have been widely used to supplement the dietary deficiencies of nutrients in agricultural and domestic animals. These include mineral supplements (macro and microelements), protein and fat supplements, vitamins, biostimulants, complex natural compounds (sapropel, peat, humates), and synthetic products (enzymes, hormones, antibiotics, adaptogens, antioxidants). The exploration of new ways to enhance the productivity of livestock through feed additives has led to an increase in research on the use of natural feed resources with immunomodulatory properties. Studies have shown that these additives have high ecological safety and possess unique capabilities to improve metabolic processes and increase cellular energy, which beneficially impacts living organisms.

Materials and Methods

To achieve the main objectives of the research, various experimental, physicochemical, and analytical analysis methods were employed: chemical analysis, photocolorimetry, potentiometry, IR spectroscopy, and analysis using an INCAEnergy (Oxford Instruments) X-ray energy dispersive microanalyzer installed on an ISM-6490LV (IED) scanning electron microscope, among others.

Potentiometric titration was carried out at a temperature of 298±0.1 K using an LPM-60 laboratory pH meter equipped with a DL-01 sensor. The measuring system included a glass electrode ESL II-0.4, and a calomel electrode was used as the reference electrode.

The chemical analysis of the raw materials and the products obtained was conducted in accordance with the regulatory requirements of the known MEST standards.

Method for determining total phosphates: 1–2 grams of the sample are weighed with an accuracy of 0.0002 grams using analytical scales, transferred to a 250 ml volumetric flask, and treated with 50 ml of 20 % hydrochloric acid (HCl) solution. The mixture is then gently boiled for 30 minutes. When the volume of the solution has reduced to approximately 50 ml, water is added. After cooling, the solution is diluted to the mark with distilled water, thoroughly mixed, and filtered, discarding the initial filtrate. 1 ml of filtrate is taken with a pipette and transferred to a 100 ml volumetric flask, filled up to 50 ml with water. Then, 25 ml of a prepared solution for phosphates is added and the volume is brought up to the mark with water, followed by thorough mixing. After 10–15 minutes, the optical density compared to a control solution is measured. The control solution is prepared simultaneously with the sample, taking 100 ml of the phosphate solution into a volumetric flask and diluting to the mark with distilled water. The control solution is used for the determination of all forms of P_2O_5 and is prepared once.

Method for determining available phosphates: 1–2 grams of the sample are weighed with an accuracy of 0.0002 grams using analytical scales. The sample is then dispersed in 150 ml of 0.2 mol/dm³ Trilon B solution preheated to 93±3°C in a beaker, transferred to a 500 ml volumetric flask, sealed, and placed on a shaker for 20–30 minutes. The volume of the solution is adjusted to the mark with water and mixed. The solution is then filtered through «white band» filter paper, discarding the initial filtrate.

Using a pipette, 1 ml of the filtrate is collected and added to a 100 ml volumetric flask. To this solution, 2 ml of 20 % hydrochloric acid and 10–15 ml of water are added, and the mixture is boiled for 10 minutes. After cooling, the solution is diluted to 50 ml with water. Then, 25 ml of a phosphate solution is added, and the volume is brought up to the mark with distilled water and mixed thoroughly. After 20–25 minutes, the optical density is measured relative to a comparison solution.

Method for determining the phosphorus content in feed additives. The method is based on mineralizing the sample through dry or wet ashing to form salts of orthophosphoric acid, and then detecting phosphorus in the form of yellow-colored complex formed with vanadate and molybdate ions in an acidic medium, using a photometric method.

Extraction of humates (according to MEST 9517–76). Approximately 1 gram of powdered coal production residue is placed in a 250 cm³ conical flask, over which 100 ml of sodium pyrophosphate solution is poured, and the flask is then placed on a shaker for 60 minutes. The resulting suspension is centrifuged for 15 minutes, collected into a 1-liter flask, and decanted. The dissolved residue is washed twice with 100 ml of sodium hydroxide solution. After each wash, the suspension is centrifuged, and the wash solution is collected in Flask B.

The settled sludge is collected in Flask A, to which 100 ml of sodium hydroxide solution is added, and then heated in a boiling water bath for 2 hours. After cooling to room temperature, the contents of Flask A are centrifuged for 15 minutes, the solution is decanted and collected in Flask B. The insoluble residue is washed twice more with 100 ml of sodium hydroxide solution. After each wash, the suspension is centrifuged, and the wash solution is collected in Flask B.

Modern scanning electron microscope equipment (JSM6490 LV brand) was utilized for microstructural and elemental-weight analysis of raw materials and finished products. Additionally, IR spectral analysis was conducted on a SHIMADZU IR PRESTIGE-21 Fourier-transform infrared spectrometer with a Miracle full internal reflection (ATR) accessory from Pike Technologies.

X-ray phase analysis was carried out on a D8 Advance (Bruker) device to identify inorganic compounds within the studied samples. Data processing from the obtained diffractograms and calculation of interplanar distances were performed using the EVA software. Deciphering the samples' codes and phase identification were conducted using the Search/match program, with the PDF-2 powder diffractometry database.

Drying and grinding of the samples were performed using an MSHL-1 laboratory mill. For the extraction of humates and the production of feed additives, a laboratory reactor with a paddle mixer was used under laboratory conditions. Additionally, a laboratory vacuum filter was employed for the filtration process.

Results and Discussion

Elemental-chemical and microstructural analyses were conducted on samples obtained from this heap. The surfaces of the samples were examined at a 40x magnification in the spectrum. The results of the study are presented in Figures 1–2 below.

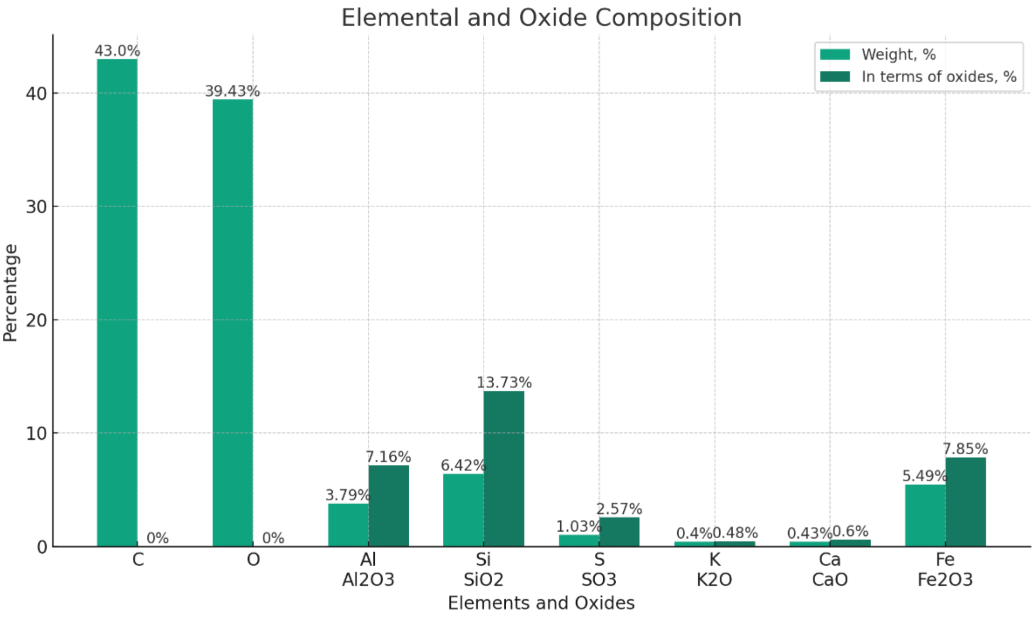


Figure 1. Elemental-weight composition of coal production residue

The table summarizes the elemental and oxide compositions of coal production residue. Carbon (C) and oxygen (O) dominate the residue, comprising 43.00 % and 39.43 % respectively, with no associated oxides listed for these elements. Aluminum (Al) makes up 3.79 % of the residue, which corresponds to 7.16 % when expressed as aluminum oxide (Al_2O_3). Silicon (Si) is present at 6.42 %, and its oxide form, silicon dioxide (SiO2), accounts for 13.73 %. Sulfur (S) contributes 1.03 %, translating into sulfur trioxide (SO_3) at 2.57 %. Potassium (K) is at a lower concentration of 0.40 %, with its oxide, potassium oxide (K_2O), representing 0.48 %. Calcium (Ca) is slightly higher at 0.43 %, which corresponds to calcium oxide (CaO) at 0.60 %. Iron (Fe) is significantly present at 5.49 %, with iron(III) oxide (Fe_2O_3) making up 7.85 %. These values indicate the transformation of elemental compositions into their respective oxide forms, highlighting the predominance of heavier elements like silicon and iron in their oxide states within the residue.

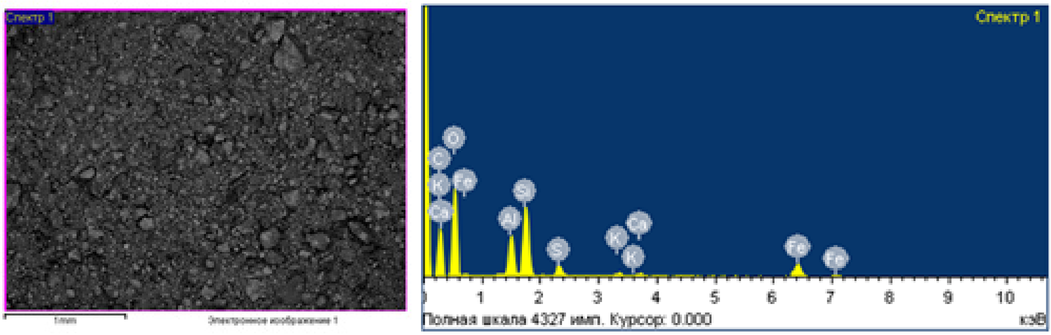


Figure 2. Microstructure and diffraction peaks of elements in coal production residue

According to the data provided above, the main component of the coal production residue is the element carbon, with substances like sulfur, aluminum, and silicon oxides also present. There are also smaller amounts of potassium and calcium compounds. The microstructure of the analyzed sample shows minerals of sulfur, iron, and calcium compounds as distinct clusters, while the presence of small hexagonal crystals indicates the presence of calcium aluminates. The silicon compounds in the sample are characterized by fine, particulate structures.

The Scanning Electron Microscopy (SEM) image analysis of the coal production residue provides a detailed look at the microstructure and elemental composition. The dominant presence of carbon is visible as a fundamental matrix within the residue, forming a substantial portion of the overall structure. This matrix is interspersed with various mineral clusters and inclusions, primarily constituted by sulfur, iron, and calcium compounds.

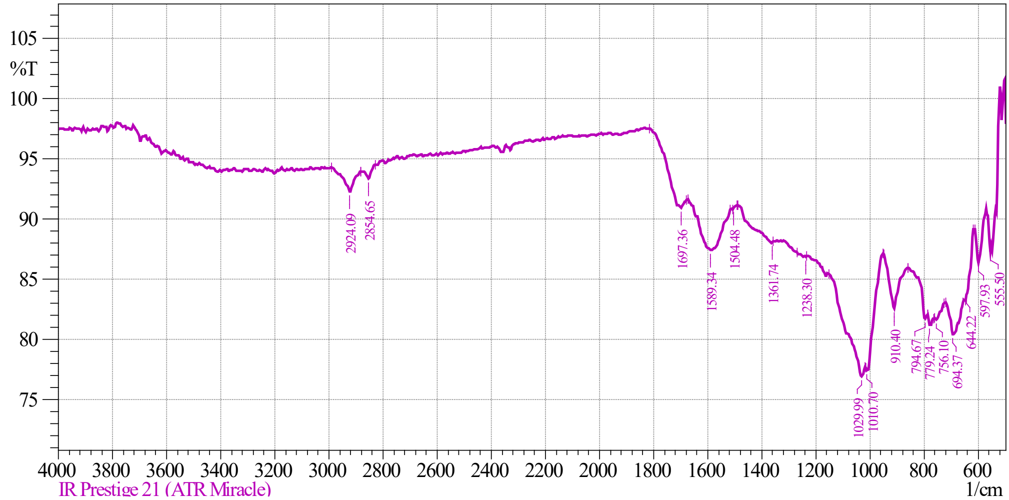
The sulfur compounds likely manifest as scattered aggregates throughout the sample, potentially contributing to the overall texture and porosity of the residue. Iron compounds are typically more dense and might appear as darker, more defined clusters or particles within the SEM image, reflecting their heavier atomic weight and distinct physical properties compared to other elements.

Calcium compounds are particularly interesting as they form small, hexagonal crystal structures, indicative of calcium aluminates. These hexagonal shapes suggest a crystalline phase within the residue, which could influence the mechanical properties such as hardness and structural integrity of the residue.

Moreover, the presence of silicon compounds is noted by their finer, particulate form, likely contributing to the residue's overall surface area and reactive properties (Arif, 2016). These fine silicon compounds could be involved in various interactions with other elements in the residue, potentially affecting its chemical reactivity and usefulness in applications like soil amendment or industrial processes.

Overall, the SEM analysis reveals a complex interplay of carbon with other mineralogical elements, each contributing unique properties that define the physical and chemical characteristics of the coal production residue. This detailed microstructural insight is crucial for understanding the potential applications and environmental impacts of such residues.

The infrared spectral analysis of the coal production residue was conducted using the modern Shimadzu IR Prestige-21 Fourier-transform infrared spectrometer. The results of the study are presented in Figure 3 below.



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	555,50	87,320	3,204	570,93	540,07	1,610	0,269
2	597,93	86,390	3,257	613,36	574,79	2,111	0,317
3	644,22	83,190	0,746	648,08	617,22	2,034	0,092
4	694,37	80,421	2,647	721,38	655,80	5,771	0,488
5	759,10	81,668	0,230	759,38	725,23	2,942	0,033
6	779,24	81,211	0,717	786,96	763,81	2,056	0,043
7	794,67	81,701	0,746	860,25	786,96	5,389	-0,173
8	910,40	82,571	4,018	948,98	860,25	6,375	0,782
9	1010,70	77,444	0,798	1014,56	952,84	5,143	0,099
10	1029,99	76,948	1,394	1153,43	1018,41	12,500	0,452
11	1238,30	86,867	0,109	1269,16	1234,44	2,106	0,020
12	1361,74	88,043	0,198	1489,05	1357,89	6,502	0,241
13	1504,48	90,824	0,075	1508,33	1492,90	0,630	0,000
14	1589,34	87,409	3,778	1674,21	1516,05	7,906	1,583
15	1697,36	90,939	1,460	1816,94	1678,07	3,745	0,380
16	2854,65	93,339	0,902	2881,65	2827,64	1,472	0,080
17	2924,09	92,271	1,826	2989,66	2881,65	3,198	0,364

Figure 3. The infrared spectral analysis of the coal production residue

The detailed interpretation of the IR-spectra from the analysis of coal production residue reveals a variety of absorbance peaks, each corresponding to different chemical bonds and structures within the sample. The peaks at 555.50 cm^{-1}, 597.93 cm^{-1}, and 644.22 cm^{-1}, with corrected intensities of 3.204, 3.257, and 0.746 respectively, indicate the presence of complex inorganic compounds, possibly involving metal-oxygen bonds, reflecting the mineral components of the residue. The peaks at 694.37 cm^{-1} and 759.10 cm^{-1}, with relatively higher corrected intensities of 2.647 and 0.230, could be indicative of bending vibrations in silica or other silicate materials, which aligns with the silicon content observed in the sample. The sequence from 779.24 cm^{-1} to 1029.99 cm^{-1} includes several moderate peaks suggesting various functional groups, possibly involving sulfur or phosphorus oxides, as suggested by the presence of sulfur in the elemental analysis (Arpášová, 2016).

Significantly, the peaks at 1238.30 cm^{-1} and 1361.74 cm^{-1}, with very low corrected intensities, could represent the presence of organic compounds such as aliphatic amines or ethers. The sharp peaks at 1504.48 cm^{-1} and 1589.34 cm^{-1} with corrected areas of practically nil and 1.583 indicate the presence of aromatic compounds, possibly from residual coal substances. Moreover, the peaks at 1697.36 cm^{-1}, 2854.65 cm^{-1}, and 2924.09 cm^{-1}, with corrected intensities of 1.460, 0.902, and 1.826, are typically associated with carbonyl groups and the C-H stretching vibrations in aliphatic hydrocarbons, hinting at the presence of fatty acids or other long-chain hydrocarbons (Cetin, 2016).

Overall, the IR spectra suggest a complex mix of inorganic and organic components, highlighting the diverse nature of the chemical makeup of coal production residues, which includes both aromatic and aliphatic organic substances alongside various mineral-derived compounds. This complexity underlines the potential for various industrial and environmental applications or challenges associated with such residues.

The results of the X-ray phase analysis of coal production residue are presented in Figure 4.

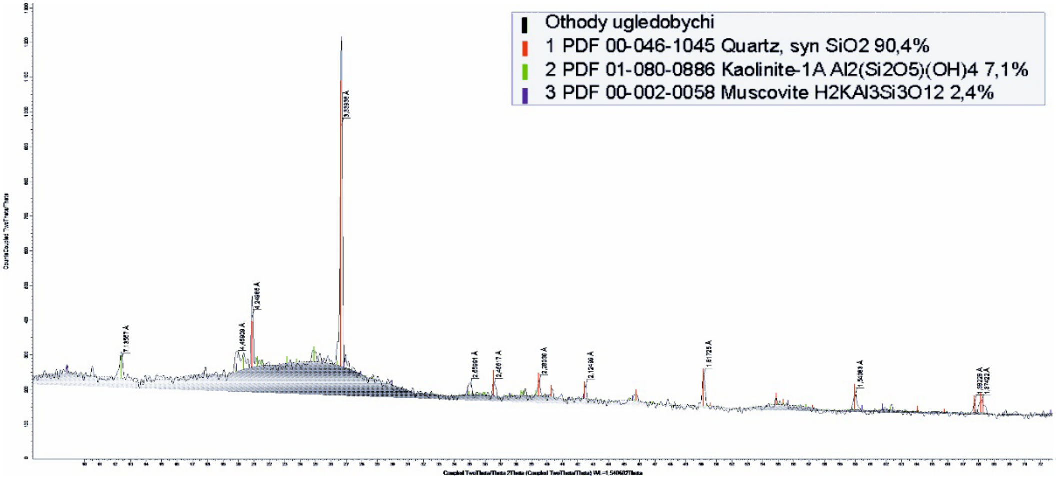


Figure 4. X-ray diffraction peaks of coal production residue

According to the data presented in the image, the structure of coal production residue is characterized by minerals such as quartz, kaolinite, and muscovite. It has been identified that a significant portion of the structure, specifically 90.4 %, is comprised of quartz minerals. Additionally, compounds in the form of kaolinite and muscovite make up 7.1 % and 2.4 % of the structure, respectively.

The X-ray Diffraction (XRD) analysis of the coal production residue clearly identifies the presence of quartz, kaolinite, and muscovite as the principal mineral constituents. The dominance of quartz at 90.4 % of the structure suggests a highly siliceous nature, which is consistent with the SEM analysis that showed a dense, crystalline microstructure typical of quartz. The kaolinite and muscovite, accounting for 7.1 % and 2.4 % respectively, add to the layered silicate structure observed, which could contribute to the overall mechanical properties of the residue such as plasticity and cation exchange capacity. These findings correlate with the IR-spectra, which indicated peaks corresponding to Si-O stretching modes characteristic of silicate minerals (Chang-Hua, 2003). The presence of minor peaks related to organic functionalities, likely from residual coal materials and minor sulfur or phosphate groups, supports a complex composition that includes both inorganic and trace organic elements. The elemental composition analysis further corroborates this, with significant amounts of silicon and aluminum from the quartz and kaolinites, and iron from the muscovite, all contributing to the chemical diversity observed in the SEM and confirmed by the XRD peaks. Overall, the combination of XRD, IR-spectra, SEM, and elemental composition analyses provides a comprehensive understanding of the mineralogical and chemical makeup of the coal production residue, highlighting its potential uses and environmental interactions.

Humates are studied worldwide as valuable organic raw materials for the production of feed additives for livestock. Due to their unique composition and properties, humates can be utilized in animal and poultry feed. They serve as a source of minerals, including chelated microelements, for animals. Numerous studies by both domestic and international researchers have shown that humates can be effectively used in pure form to feed animals and birds. Adding humates to the diet (up to 2 kg per day) has been shown to increase the live weight of pigs by 10–15 %, while also reducing feed costs by the same percentage. Furthermore, humates are excellent enterosorbents, protecting animals and birds from diseases by adsorbing harmful substances in the intestines and reducing mortality rates in pigs and chickens (Disetlhe, 2017). The use of humates improves the morphological and biochemical composition of the blood, enhances the absorption of nutrients in the food, and promotes the growth and development of animals.

Currently, normal diets for animals often fall short in providing adequate amounts of energy, protein, sugars, and other nutrients. This deficiency is particularly notable in minerals and biologically active substances (Dobrzanski, 2009). Using local and non-traditional sources of minerals and biologically active substances can significantly mitigate these deficiencies. One such source could be humates, which do not disrupt the digestive processes in animals' stomachs. Including humates in the diet of calves has been shown to enhance the absorption of organic substances and increase the uptake of nitrogen, calcium, and phosphorus. Studies conducted in Udmurtia have demonstrated that humate components positively affect fetal development in the womb, activate metabolic processes, stimulate the function of hematopoietic organs, protect animals from anemia, and reduce mortality in young animals. In trials, calves receiving humates in their diet showed a 34.2 % higher average daily growth rate compared to those in the control group placed on a usual mineral substrate. A similar effect was observed when feeding young chickens with humates (Edmonds, 2014).

Several authors have determined the optimal feeding schedules and norms for using humates in pig nutrition (Ergin, 2009). In large poultry and pig farms, humates are commonly incorporated into compound feeds in dry form. The primary condition for animals to effectively utilize dietary nutrients is ensuring that the feed is balanced in terms of all standardized organic and mineral substances. The inclusion of humates in feed compositions has been found to stimulate digestive processes in young animals, with nutrient absorption rates improving by an average of 2.5 to 6.51 %. Additionally, incorporating humates into compound feeds and feed additives can enhance metabolic processes in the bodies of animals and birds. Analyzing the literature on the chemical composition of humates, it is noted that the most efficient method of use involves isolating humic acids and their bases, including humates, from lignite coal. Humates derived from lignite allow for their use in small quantities, universally, and regardless of the season, due to the high concentration of nutrients and biologically active substances they contain. Most humic substances chemically bond with inorganic components (such as clay and oxides). A significant feature of humic substances is their ability to interact with metal ions, oxides, and clay minerals, and to react with organic compounds like alkenes, fatty acids, surfactants, and pesticides.

Due to their colloidal properties and ability to form chelates, humic acids and their salts can significantly alter the toxic effects of various xenobiotics and unwanted substances ingested with food and water. Since no toxic, allergic, mutagenic, or teratogenic effects of humic acids have been found, in 1999, the European Medicines Agency approved humic acids and their salts (humates) as veterinary drugs for treating diarrhea, dyspepsia, and toxicity in farm animals. The content of humic substances in lignite can reach up to 85 %. The terms “humic substances” and “humates” are associated with soil and originate from the term “humus,” which refers to a complex of organic dark-colored compounds that determine soil fertility. For instance, the most fertile soils (humus-rich soils) can contain up to 12 % humic substances. Most natural humic substances are in a water-soluble form which has limited economic value. For practical application, it is necessary to convert humic substances into a water-soluble form, such as humates. Soluble humic acid is available as potassium humate or sodium humate. Potassium humates are preferred as soil additives in agronomy because additional sodium is rarely needed. Sodium humates are better suited for animals as sodium is an essential inorganic electrolyte for animal health and its levels must be consistently maintained (Gomez-Rosales, 2015).

There is limited information on the mechanisms by which humates enhance the efficiency of animal product production when used in animal feeding. However, existing studies suggest that the inclusion of humates is beneficial for livestock. The positive effect of humic acids could be linked to their ability to influence the metabolism of proteins and carbohydrates in microbes, possibly leading to the direct elimination of bacterial cells or viral particles. The detoxifying benefits of humate components encompass a wide range of toxins accumulated through farming activities. When humic acids are added to the diet, they adsorb heavy metals, nitrates, fluoride, organophosphates, carbaryl, and chloride organic insecticides. Humic acids can form a protective layer in the gastrointestinal mucosa against infections and toxins, ensuring effective nutrient utilization in the feed.

Conclusions

The exploration of coal mining waste as a source for humates has revealed its significant potential in enhancing livestock nutrition and promoting sustainable agricultural practices. This study has systematically investigated the chemical and physical properties of humates derived from coal mining byproducts, providing a solid foundation for their application as innovative feed additives. Advanced analytical methods such as SEM, XRD, and IR spectroscopy were utilized to characterize the structural and compositional attributes of humates. SEM analysis confirmed the presence of a dense, crystalline matrix primarily composed of quartz, kaolinite, and muscovite. These minerals, prevalent in coal mining waste, contribute essential nutrients when processed into feed additives. XRD analysis further delineated the mineral phases, offering a precise quantification that supports the nutrient supply potential of humates. IR spectroscopy provided insights into the functional groups, revealing a complex interplay of organic and inorganic compounds within the humates, which are critical for their biological activity and efficacy as feed supplements. The integration of humates into animal diets has demonstrated multiple benefits, such as enhanced nutrient absorption, improved digestive processes, and effective detoxification of harmful substances. These effects are attributed to the unique properties of humates, which include their ability to form protective barriers in the gastrointestinal tract, adsorb toxins, and interact beneficially with the body's metabolism. Moreover, the use of coal mining waste for producing humates aligns with global efforts towards sustainability by providing a method to repurpose industrial byproducts into valuable agricultural inputs. This not only aids in waste reduction but also enhances the economic viability of industries involved, offering a compelling case for the broader adoption of humates in livestock nutrition.

In conclusion, this research underscores the transformative potential of humates derived from coal mining waste, advocating for their increased use in feed formulations to realize benefits across environmental, agricultural, and economic domains. The continued development and application of such innovative practices are crucial for advancing sustainable livestock management and ecological conservation.

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