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CELLULOSE DERIVED FROM SPENT COFFEE GROUNDS FOR NANOCELLULOSE PRODUCTION AND ITS POTENTIAL AS FUNCTIONAL CARRIER SYSTEMS AND BIOCOMPOSITE FILMS

Kumar P.¹ (PhD student), **Salman M.¹** (Master Student)
Scientific Supervisor – PhD, Associate Professor, Boulkrane M.S.¹

¹ITMO University
Pankajkumar@itmo.ru

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Abstract

The coffee industry in the world generates about 6-10 million tons of spent coffee grounds (SCG) every year, most of which are disposed using landfills or by burning, which exerts a lot of strain on the environment. High in polysaccharides (45-50%), SCG is one of the promising lignocellulosic feedstocks to cellulose extraction. The standard alkaline extraction guidelines rely on the application of high concentrations of NaOH and high temperatures, which limit their sustainability. The cavitation with ultrasound assists in increasing the mass transfer and structural disruption, and urea plays the role of swelling cellulose destabilizing the hydrogen bonds. This research focuses on synergistic ultrasound-alkali-urea that can be used to recover cellulose in a more lenient condition, and to use this cellulose to obtain nanocellulose to apply in the functional carrier system and bio-composite film in food applications.

Keywords

Spent Coffee Grounds (SCG), Nanocellulose, Biocomposite films.

ЦЕЛЛЮЛОЗА, ПОЛУЧЕННАЯ ИЗ ОТРАБОТАННОЙ КОФЕЙНОЙ ГУЩИ, ДЛЯ ПРОИЗВОДСТВА НАНОЦЕЛЛЮЛОЗЫ И ЕЕ ПОТЕНЦИАЛ В КАЧЕСТВЕ ФУНКЦИОНАЛЬНЫХ НОСИТЕЛЕЙ И БИОКОМПОЗИТНЫХ ПЛЕНОК

Кумар П.¹ (Аспирант), **Сальман М.¹** (магистрант)
Научный руководитель – доктор технических наук, профессор Булькран М. С.¹

¹Университет ИТМО
Pankajkumar@itmo.ru

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Аннотация

В мире кофейная индустрия ежегодно производит около 6-10 миллионов тонн отработанной кофейной гущи (ОКГ), большая часть которой утилизируется на свалках или сжигается, что оказывает значительное воздействие на окружающую среду. ОКГ, богатая полисахаридами (45-50%), является одним из перспективных лигноцеллюлозных сырьевых материалов для экстракции целлюлозы. Стандартные методы щелочной экстракции основаны на применении высоких концентраций NaOH и высоких температур, что ограничивает их экологичность. Кавитация с помощью ультразвука способствует увеличению массопереноса и разрушению структуры, а мочевины играет роль набухания целлюлозы, дестабилизируя водородные связи. Данное исследование посвящено синергетическому ультразвуково-щелочно-мочевинному методу, который может быть использован для извлечения целлюлозы в более щадящем режиме, а также

для получения наноцеллюлозы из этой целлюлозы для применения в функциональных носителях и биокompозитных пленках в пищевой промышленности.

Ключевые слова:

Отработанная кофейная гуша (ОКГ), наноцеллюлоза, биокompозитные пленки.

The high rate of food demand in the world has enhanced food production and agro-industrial waste production. The process of coffee processing generates a lot of by-products like coffee pulp and spent coffee grounds (SCG). The process of coffee cherry produces about 40-50% coffee pulp biomass and the world coffee production is estimated to be 9.4 million tons per year. The main components of coffee pulp are neutral detergent fiber, lignin, and ash. These residues are harmful to the environment of producing countries when not disposed of properly. The traditional disposal techniques used e.g. landfilling and composting do not exhaust the chemical potential of lignocellulosic biomass. Conversion to fuels or chemicals has been studied but these methods tend to consume a lot of energy and will add low value. Thus, there is a need to have sustainable valorization strategies [1] The most natural biopolymer is cellulose. It is very crystalline, biodegradable, mechanically strong and attractive in terms of barrier properties. Nonetheless, it is hygroscopic and not thermoplastic and this restricts its widespread use in industries. The nanocellulose has provided an opportunity to address these limitations. It is composed of high specific surface area nanoscale cellulose structures that possess high mechanical properties. Addition of nanocellulose to polymer crowds augments the strength and the barrier properties [2].

Polyvinyl alcohol (PVA) is a nontoxic, biodegradable, semicrystalline polymer suitable for ecofriendly packaging but has reduced mechanical strength and oxygen barrier performance in humid conditions due to its hydrophilic nature; therefore, this study aims to valorize coffee residues as a sustainable source of cellulose and nanocellulose to reinforce PVA and enhance the performance of biodegradable packaging materials.

Particularly, this study is expected to produce cellulose by applying various pretreatment methods to SCG. It is also expected to compare the effects of concentration of alkali, addition of urea, and ultrasound irradiation on the yield of cellulose and its structure. Another objective is to create nanocellulose using purified cellulose and use it in PVA films. The research questions further attempt to examine the impacts of reinforcement on the thermal, mechanical, chemical and optical characteristics of the composite films. Four systems, including NaOH, NaOH-ultrasound, NaOH-urea, and NaOH-urea-ultrasound, were used to treat SCG. The impact of 5-10% NaOH, 3% urea, and 30 minutes of ultrasound (40 kHz) was tested.

Alkaline treatment facilitated delignification and hemicellulose hydrolysis, urea facilitated fiber swelling and reagent penetration and ultrasound cavitation facilitated structural disruption and cellulose exposure. FTIR indicated a reduction of lignin and hemicellulose by the reduction of bands at 1730 cm^{-1} and 1510 cm^{-1} whereas XRD indicated no changes in cellulose I with crystallinity indices of 56-65% meaning selective attack of amorphous regions. TGA exhibited thermal stability at the highest temperature of degradation of 316-322°C and SEM disclosed fibrillation and surface erosion at the end of ultrasound treatment. Bleached cellulose will be transformed into nanocellulose and embedded into PVA films with glycerol to create biodegradable composites to entrap coffee-derived polyphenols, which will help in the creation of active packaging materials.

Literature

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