

SUNFLOWER HUSK: FROM WASTE MATERIAL TO A USEFUL RESOURCE

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Abstract: Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops, widely used in industry, agriculture, and as a food source, while its by-products, such as husks, can be utilized in various ways. Sunflower husks, constituting up to 40% of the seed's mass, are rich in fiber, polysaccharides, and other valuable components, with applications in livestock production, the energy industry, and agriculture. This paper explores different possibilities for utilizing sunflower husks, with a particular focus on ecological and energy applications, as well as opportunities for further use in industry and agriculture. Due to their composition, sunflower husks are used as fuel (in pellets or as biomass for combustion) and in the production of bio-briquettes. Moreover, ash obtained from the combustion of sunflower husks contains valuable nutrients such as phosphorus, potassium, calcium, magnesium, and trace elements (zinc, copper, manganese, iron), which makes it beneficial for soil fertilization. The efficiency of ash usage has been improved through granulation, enabling better application in agriculture. As sunflower production residues serve as a renewable energy source, sunflower husks represent a significant resource in the context of sustainable development and energy efficiency.

Keywords: sunflower, husks, biomass, eco-friendly fuel, renewable energy sources.

Introduction

Sunflower (*Helianthus annuus* L.) is an industrial plant of great economic importance. It ranks among the most important oilseed crops worldwide and is extensively utilized across various industries, including food, chemical, and pharmaceutical sectors [Premović, 2022]. It is widely cultivated due to its adaptability to diverse ecological and soil conditions. Consequently, sunflower

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cultivation holds a prominent place in agricultural production [Stojadinovic et al., 2008; Kolarić et al., 2019], particularly in terms of cultivated area, yield, and the industrial processing of seeds into oil. Considering that sunflower oil accounts for about 80% of the total oil production in domestic oil mills, the quantities of leftover sunflower seed husks are substantial. The seeds of oilseed sunflower hybrids usually have black husks, while those of confectionery hybrids often feature black husks with white or gray stripes, or are multicolored [Hladni and Miladinović, 2019]. The kernel, being the most valuable part of the sunflower seed, is understandably prioritized during processing, which involves hulling the sunflower and partially removing the husk. The husk serves as a protective layer for the seed, shielding it from external influences. It constitutes up to 40% of the sunflower's mass and includes a black protective layer, phytomelanin, which defends the seed against sunflower moths and weevils. The seed coat is tough and coarse, accounting for between 22% and 56% of the seed's weight [Dimić et al., 2003]. The thickness of the husk and the gap between the seed and husk are crucial during harvesting, transportation, and storage. Sunflower husks are porous and absorb some of the oil extracted from the kernel during processing, leading to higher oil content in the husk portion of the meal and contributing to oil loss. These are the main reasons for removing as much husk as possible during the processing of sunflower and other seeds. Serbia ranks among the leading producers of oilseed crops for industrial processing and human nutrition, with its by-products offering opportunities for reuse, thus completing the cycle of sustainable development. Sunflower husk is a type of biomass containing fiber and residual plant oil from the kernel. It has very low-fat content, which is nutritionally insignificant, making it suitable for livestock feed, direct combustion in solid fuel boilers, or pellet production—a cost-effective and eco-friendly fuel source. One kilogram of sunflower seed husk can replace 0.4 kilograms of fuel oil. Studies show that one ton of oilseed husk can produce 1,353 kWh of electricity and 2,706 kWh of heat [Milojković et al., 2015]. When sunflower husk biomass is burned in boiler furnaces with an efficient combustion process, it does not cause environmental pollution. The combustion products (flue gases) are free of harmful substances, and the residual ash is minimal [Premović, 2022].

The aim of this paper is to describe the potential and possible new applications of sunflower husk in industry, agriculture, and as a renewable energy source, emphasizing its significance as an eco-friendly fuel, as well as exploring further possibilities for its use across various industrial sectors.

Materials and methods

This study analyses the potential applications of sunflower husk relying primarily on desk research. It incorporates and cites findings from numerous scientific papers authored by both domestic and international researchers in relevant thematic fields. The analytical-synthetic method was used during the discussion and the formulation of conclusions.

Results and discussion

The use of sunflower and its husk

By-products of sunflower seed processing include cake and meal, which are rich in proteins, carbohydrates, minerals, and other beneficial components, making them important ingredients in the preparation of concentrated animal feed [Lešić and Hrgović, 2015]. Additionally, sunflower heads can be used as animal feed, while whole plants are suitable for silage preparation. Furthermore, sunflowers are utilized as bird feed, in human nutrition, and as ornamental plants [Ranđelović, 2008; Grompone, 2005]. In high-oil hybrids, the husk content is lower compared to low-oil hybrids, with husk amount influenced by the cultivation location. Sunflower seed husk contains over 50% poly saccharides, primarily cellulose and lignin, and is used in the production of hexose and pentose sugars, with smaller amounts of proteins, oil, and waxes. The wax content in the husk depends on the seed's origin, the cultivation location, and the hybrid type. Newer hybrids have 3.5 to 5 times higher wax content than older hybrids, with approximately 85% of the waxes in crude sunflower oil originating from the husk. Additionally, sunflower husk contains up to 5.4% phenolic compounds, which contribute significantly to its antioxidant potential (De Leonardis et al., 2005). The husk is also used as a raw material for producing livestock yeast. Due to its deep root system and unique ability to absorb water and break down many harmful and toxic substances from the soil, sunflower is often used for drying marshy land and cleaning polluted soils, including those contaminated with lead or radioactive materials. Following the Chernobyl disaster, fields of sunflowers were planted in Ukraine to remediate soil, extracting approximately 90% of radioactive materials (Pinova) [Milojković et al., 2015].

Briquetting sunflower husk (bio-briquette)

In recent decades, global research has focused on biofuels and energy sources from renewable origins that meet ecological standards, with the goal of providing most of the energy from renewable sources by 2100. During the industrial processing of sunflower seeds, significant quantities of sunflower seed husk remain as waste biomass. According to The Law on Waste Management (2018), sunflower husk is classified as non-hazardous waste. Experts estimate that the annual amount of available husk biomass generated from sunflower seed hulling is 1,149.9 tons, which can be fully utilized for energy purposes in the form of biofuel—specifically, bio-briquettes. Bio-briquettes are a product of the technological briquetting process—a compact form of biomass with a much higher bulk density than the biomass material from which the briquette is made. The briquetting process involves compressing lignocellulosic material into the smallest possible volume using a press [Mitić, 1998]. This process transforms biomass into a fuel suitable for a wider range of users, such as households, farms, greenhouses, and others. Briquetting offers several key benefits: it increases the mass per unit volume (enhancing density), reduces handling and transportation costs, decreases required storage space, minimizes biological degradation, and improves combustion efficiency compared to loose biomass combustion. However, the process also has certain limitations, including the need to prepare the material to specific moisture levels and granulation, the potential requirement for additives, investments in specialized technology, and increased energy consumption [Hodolić et al., 2007]. Sunflower seed husk is a high-quality fuel that can be efficiently used for combustion in the furnaces of steam boilers in industrial facilities producing oil. The higher heating value of the fuel (HHV), sunflower seed shells, is determined using a calorimetric bomb, where combustion products are cooled to ambient temperature, and water vapor condenses, transferring latent heat to the surroundings. The lower heating value (LHV) is calculated when the water remains in vapor form. By knowing the higher heating value and the amount of water vapor produced during the combustion of absolutely dry sunflower seed shells, the lower heating value can be calculated using the following formula [Premović et al., 2023]:

$$\text{LHV} = \text{HHV} - 24,4 \cdot W \text{ [KJ kg}^{-1}\text{]},$$

where W [%] is the amount of water vapor generated during combustion, expressed as a percentage relative to the absolutely dry mass of the fuel. The

obtained heating value refers to the absolutely dry mass of sunflower husk as a biofuel.

The higher heating value of fuels with a lignocellulosic composition, according to literature data, ranges between 16 and 20 KJ kg⁻¹ [Blazquez et al., 2014], while the lower heating value of agricultural biomass falls within the range of 13.00 to 18.00 KJ kg⁻¹ [Brkić et al., 2007]. The lower heating value of the dry mass in sunflower husk as a biofuel is approximately 15–17 KJ kg⁻¹, depending on the moisture content of the husk, which typically ranges from 12% to 14% [Brkić et al., 2007].

Use of sunflower husks for energy purposes

The energy crisis, which has been escalating since the 1970s, has heightened interest among researchers and industries in non-fossil fuels [Njit et al., 2010; Bemdes et al., 2003]. Climate change—largely driven by the intensified greenhouse effect—the depletion of crude oil reserves and other fossil fuels, and the environmental burden of their use, coupled with the ever-growing demand for energy, have necessitated the search for renewable and environmentally friendly energy sources. Biomass represents a source of renewable energy (RES) within the European Union. Approximately 63% of "renewable energy" in Serbia is produced from biomass [Martinov et al., 2010]. Biomass is the only renewable source of fixed carbon. Thermochemical conversion leads to more efficient biomass management [Nussbaumer, 2001; Brkić et al., 2007]. The European Union, through Directive 2009/28/EC, has defined detailed goals in this area. The main objective is for the share of RES in primary energy consumption in the EU to reach at least 20% by 2020, with at least 20% of electricity being produced from RES [Nakomčić-Smaragdakis et al., 2015]. Biomass can be categorized into two types: residues (any kind of plant residues, animal waste, and the organic fraction of municipal waste), and biomass derived from dedicated energy crops. Several potential sources of biomass exist for energy production [Lal, 2005]. The production of biodiesel and bioethanol fuels is often accompanied by the parallel production of lignocellulosic "waste" by-products. For example, when sunflower seeds are processed for oil—suitable for biodiesel production—by-products such as sunflower husks and stalks are generated as "waste" [Antal, 2006]. These residues can be used for energy production or to create biochar products. The basic elemental chemical composition of sunflower seed husks is presented in Table 1.

Table 1. The elementary chemical composition of sunflower seed shells is shown in %

Chemical element	C	H	O+N	S	(A)
Content (%)	50.57	5.68	40.91	0.1	2.27

Source: [Brkić et al., 2007]

Energy production from residues would reduce the increased release of CO₂ into the atmosphere associated with the use of fossil fuels [Nussbaumer, 2001]. Thermochemical conversion can also be applied to sunflower residues. However, not all produced residues can be used, nor should they be used, for bioenergy production [Lal, 2005].

Complex fertilizers obtained from sunflower seed shell ash

The ash produced from burning sunflower seed shells is a valuable material for plant fertilization. It contains a significant amount of primary and secondary nutrients for plants: phosphorus, potassium, calcium, magnesium, and some trace elements: zinc, copper, cobalt, manganese, and iron [Suresh et al., 1998]. During the industrial processing of sunflower seeds, the sunflower shells remain unused. Depending on the conditions in which the plant grows, and the fertilizers used, the shells contain various nutrients and trace elements for plants. Therefore, the ash obtained from burning the shells can be used as a fertilizer for plants [Oberberger et al., 2009]. The use of ash becomes more efficient when a homogeneous mass is obtained, and the particle size is uniform. This is achieved through ash granulation [Paleckienė et al., 2010]. Most of the ash consists of particles smaller than 2 mm. The bulk density of sunflower ash is 708 kg/m³ [Paleckiene et al., 2010]. The ash content depends on various impurities, such as unburned sunflower particles. When sunflower shell biomass is burned in boiler furnaces with a proper combustion process, no environmental pollution occurs. The combustion products (flue gases) do not contain harmful components, and the amount of remaining ash is minimal, around 2%, while the volatile content is high, around 80%.

Conclusion

Research on the use of sunflower seed shells suggests that this biomass has significant potential in various industries and as a source of renewable energy.

Often overlooked as a waste product of the sunflower seed processing industry, sunflower seed shells can be efficiently used for biofuel production, such as bio-briquettes- an environmentally friendly fuel with high energy value. Additionally, the combustion process of sunflower shells in boilers does not cause environmental pollution, and emissions are minimal. The use of ash resulting from the combustion of sunflower seed shells in agriculture as a natural fertilizer offers an additional ecological advantage, as the ash contains nutrients necessary for plant growth, such as phosphorus, potassium, and trace elements. Given that sunflower seed shells contain a high proportion of cellulose, lignin, and waxes, their application in the production of hexose and pentose sugars, as well as in animal feed, can contribute to the diverse industrial use of this material. Sunflowers are also used for cleaning contaminated soil, including areas affected by radioactive contamination, making this plant significant in environmental protection. Furthermore, the use of sunflower seed shells in biodiesel production and other renewable energy sources can reduce dependence on fossil fuels and contribute to a reduction in CO₂ emissions, supporting sustainable development. Given all these diverse applications, the use of sunflower seed shells as a resource for biofuels, animal feed, fertilizers, and energy purposes emerges as a key element for the development of sustainable agricultural production and energy efficiency in the future.

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