



Beyond the fuel tank:

Where else can switchgrass go?

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In the development of sustainable raw materials, *Panicum virgatum*, commonly known as switchgrass, has emerged as a promising candidate. Originally recognized for its use in bioenergy and ethanol production, switchgrass is now being explored for a wider range of industrial applications. Recent research has highlighted innovative uses in composite materials, bioplastics, paper, animal feed, and antimicrobial agents.

Switchgrass offers distinct agronomic advantages. It can thrive on marginal lands with relatively low inputs, tolerates a wide range of environmental conditions, and once established, produces consistent biomass yields. Depending on the variety and management practices, average annual yields are 12.9 metric tons per hectare for lowland ecotypes and 8.7 metric tons per hectare for upland types. These characteristics make switchgrass a resilient and versatile crop for industrial applications.

As industries seek alternatives to petroleum-based products and materials, switchgrass offers a potential path forward. This article reviews key research findings and recent advances in the industrial applications of switchgrass, extending beyond its traditional use in biofuels.

Composite materials

Fiber-reinforced composites are one of the most thoroughly investigated industrial applications for switchgrass. Compared to more established natural

fibers such as hemp and flax, switchgrass provides several agronomic and logistical advantages. It can be cultivated using existing agricultural equipment and grown on land unsuitable for food crops, providing opportunities for diversification without competing with food production.

Research has shown that incorporating cellulose fibers extracted from switchgrass into polymer matrices enhances the mechanical properties of composites. For example, adding 30% switchgrass fiber to polypropylene has been shown to double the flexural modulus of the composite. Additionally, the use of compatibilizers such as maleic anhydride-grafted polypropylene improves bonding between the hydrophilic fibers and the hydrophobic polymer matrix, further enhancing performance.

Lightweight composites containing switchgrass fibers have also been evaluated for automotive applications. Panels produced with 60% switchgrass stem fiber, having lengths of 5 cm and split configurations, demonstrated improved strength, stiffness, impact resistance, and tensile properties compared to conventional jute-based composites. These materials have potential use in vehicle interior components such as door panels and headliners, where weight reduction is a key factor in improving fuel efficiency. While these applications are still under development, the use of switchgrass in composites continues to show promise.

Bio-based antimicrobials

Another area of emerging interest is the use of switchgrass-derived compounds in antimicrobial applications. In addition to its structural components, switchgrass contains non-structural extractives, including polyphenolic compounds such as vanillic acid, rutin, caffeic acid, and quercetin derivatives. While these compounds are known to inhibit fermentation during biofuel production, recent studies have shown that they possess significant antimicrobial properties.

Ethanol-extracted polyphenols from switchgrass, when combined with sodium hypochlorite, have been shown to reduce the populations of foodborne pathogens, such as *Escherichia coli* O157:H7 and *Salmonella Typhimurium*, on food-contact surfaces. Treatments achieved a reduction of *E. coli* populations by up to 4.43 log within one minute, and *Salmonella* populations were reduced to undetectable levels under the same conditions.

Such findings suggest that plant-based antimicrobials derived from switchgrass may provide an alternative or complementary approach to conventional chlorine-based disinfectants. These compounds can be recovered during the pretreatment stages of biorefinery processing, providing a potential value-added co-product. While further validation is needed, particularly under commercial processing and regulatory standards, this application offers a promising use for switchgrass-derived extractives.

Feedstock for bioplastics and specialty chemicals

Switchgrass is also under study as a feedstock for bioplastics production. Research has shown that genetically engineered switchgrass can produce polyhydroxybutyrate (PHB), a biodegradable polyester used in packaging and single-use products. Additionally, enzymatic hydrolysis and fermentation of switchgrass hydrolysates can yield sugars suitable for PHB production. Pretreatment methods such as radio-frequency-assisted heating have been found to improve sugar yields compared to conventional hot water treatments. These advances contribute to improved process efficiency and product viability in bioplastics manufacturing.

Beyond PHB, switchgrass hydrolysates have been successfully used to produce specialty chemicals. Xylitol,

a low-calorie sweetener used in functional foods and dental products, has been produced from steam-exploded switchgrass hydrolysates at concentrations exceeding 13 g L⁻¹. The same fermentation processes can also yield carotenoids, which are valued in nutraceutical and cosmetic applications. Carotenoid concentrations reached 7.81 mg L⁻¹ under optimized fermentation conditions using *Rhodospiridium toruloides*.

The ability to derive multiple chemical products from switchgrass contributes to the overall economic

potential of integrated biorefineries. Although commercial-scale processes remain in development, current research supports the feasibility of producing bioplastics and specialty chemicals from switchgrass.

Pulp and paper applications

Switchgrass has also been explored as an alternative fiber source for the pulp and paper industry. Its relatively low lignin content and favorable cellulose structure make it a viable candidate for pulping. Pulp yields of up to 80% have been achieved, with mechanical strength optimized at yields between 55%

and 60%. Papers produced from switchgrass pulp exhibit good brightness and printability, making them suitable for packaging, printing, and specialty paper applications.

Cellulose fibers extracted from switchgrass have demonstrated tensile properties similar to those of cotton and linen. This opens additional possibilities for their use in nonwoven textiles and thermoplastic composite reinforcements. However, challenges related to fiber uniformity and processing need to be addressed before large-scale commercial adoption can occur.

As industries increasingly seek sustainable fiber sources, particularly in regions facing constraints on wood-based pulp production, switchgrass presents an option worthy of continued investigation. Its compatibility with circular bioeconomy principles makes it an attractive candidate for future pulp and paper applications.

Opportunities in animal feed markets

Traditionally, lignocellulosic biomass has been considered too recalcitrant for use in animal feed. However, advances in pretreatment technologies are changing this perception. Ammonia fiber expansion (AFEX) pretreatment has been shown to improve the digestibility of

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switchgrass and enable the extraction of high-protein fractions suitable for ruminant feed. Proteins can be recovered from AFEX-treated switchgrass using aqueous ammonia and surfactants. In addition to protein recovery, significant quantities of fermentable sugars are also generated, contributing to the overall efficiency of the process.

Proteins can be optimally extracted from AFEX-treated switchgrass using a solution of 3% aqueous ammonia at pH 10.5, with the addition of Tween-80 non-ionic surfactant improving the recovery. Subsequent hydrolysis of the remaining material can yield approximately 325 grams of sugars per kilogram of switchgrass.

Incorporating switchgrass-derived proteins into animal feed may provide a means to reduce reliance on imported soy-based protein sources and support more regionally sourced feed systems. This is particularly relevant in areas where soybean cultivation is limited or where local sustainable feed options are being pursued. While further evaluation of nutritional quality and regulatory requirements is necessary, the potential for switchgrass in animal feed markets remains to be explored.

Overcoming challenges to industrial adoption

Despite its potential, several challenges must be addressed to advance industrial adoption of switchgrass. One major issue is variability in biomass composition. The content of cellulose, hemicellulose, and lignin can vary significantly depending on the cultivar, climate, soil conditions, and harvest timing. For example, the cellulose content in Kanlow switchgrass ranges from 31.66% to 38.5%, depending on the plant part and processing method. Hemicellulose content ranges from 25.04% to

32.8%, while lignin content can range from 17.29% to over 21% across various cultivars. This variability can impact processing efficiency and product consistency, presenting challenges for industries that require uniform feedstock quality.

Handling and processing logistics also present obstacles. The fibrous, low-bulk-density nature of switchgrass makes it difficult to store, transport, and flow through process-

ing equipment. Solutions such as pelletization, pre-compaction, and adapted handling systems are necessary to address these challenges.

Pathogen risks are another concern in large-scale switchgrass cultivation. The emergence of pathogens such as Panicum mosaic virus in some breeding plots has raised concerns about potential yield losses and crop quality. Addressing these risks will require the implementation of integrated pest management strategies, increased genetic diversity in breeding programs, and ongoing monitoring of plant health.

Economic factors also influence adoption. The establishment period for switchgrass can extend up to three years, with yields reaching full potential only after the third year. Early yields are approximately 30% in the first year and 70% in the second. Combined with market uncertainties, these factors can make growers hesitant to commit land to switchgrass. Policies that offer economic incentives, risk-mitigation tools, and stable offtake agreements will be important in supporting broader cultivation and industrial utilization of switchgrass.

A promising future beyond biofuels

Current research suggests that switchgrass has the potential to contribute to a diverse range of industrial applications, extending beyond biofuels. Composite materials, antimicrobial agents, bioplastics, pulp and paper products, and animal feed are all areas where switchgrass is showing promise. Its agronomic characteristics, including adaptability to marginal lands and relatively high biomass yields, make it an attractive crop for sustainable production systems. However, significant work remains to be done in refining processing technologies, establishing supply chains, and addressing technical and economic challenges.

Many of the applications discussed here are still in the research or early development stages. While laboratory and pilot-scale studies have demonstrated feasibility, large-scale commercial adoption will depend on continued innovation and collaboration across disciplines. Switchgrass remains a valuable focus of study within the emerging bio-based economy. As industries continue to seek renewable and sustainable alternatives to petroleum-derived products, switchgrass offers potential pathways to diversify raw material sources and contribute to a more circular, low-carbon future.

ASABE member and YPC E-2050 Global Engagement

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Further reading

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