A Review of Rice Straw Utilization Opportunities as Low Cost Agriculture in Egypt

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Abstract Rice production is associated with vast quantities of straw, which have historically been eliminated through the practice of burning fields in the open. However, the burning of agricultural leftovers, particularly rice straw in Egypt (about 4.4 million tons per year), results in what is called locally as Black Cloud, reverse process and utilization for rice straw a major challenge due to technical, social, institutional, and socioeconomic constraints, what was once a valuable resource is now being burned as a waste. Rice Straw could be used properly to create bioethanol, mushrooms, pulp, biofuels, paper, fertilizers, and animal feed, as well as conservation for agriculture. This article examines the composition of rice straw and husks, the procedures involved in the manufacturing of valued products, and the different applications for these materials. These include agricultural additives, energy generation, environmental adsorbents, building materials, and a variety of products.

Keywords: agricultural waste, rice straw, rice husk, sustainable environment, silica and cellulose

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1 Introduction

Rice is a main grain for the majority of the world's population, particularly in Africa but its annual production generates enormous volumes of straw (estimated as ~8 $\times 10^{11}$ kg) and husks (~1.5 $\times 10^{11}$ kg) [1]. Rice straw is presently used for practical reasons, such as the manufacturing of biofuels, paper, fertilizers, and animal feed. Rice is the primary cereal crop for more than fifty percent of the world's population. Rice production is recognized as a significant source of greenhouse gas emissions, particularly methane, due to rice management practices and the burning of rice straw after harvest. After harvest, the majority of rice straw is either burned in situ, integrated into the soil, or used as mulch for the next crop. Straw incorporated into the soil degrades slowly and may harbor rice illnesses, but burning is becoming socially unacceptable due to considerable atmospheric pollution[2], which includes greenhouse gas emissions and smoke. As noted, all of the components from the rice production cycle can be utilized despite efforts to discover economically and socially acceptable uses for agricultural waste[3]. Broken rice and rice bran are fully utilized by the food industry and are therefore not considered in this review[4]. However, it is worth noting that rice bran has potential applications as a functional food due to its ability to inhibit Salmonella colonization of the gastrointestinal tract[5], in addition to being a source of oil with a variety of reported beneficial health properties and a high smoke point. Many studies showed the possibility of using rice straw for the production of fuel and other products. Due to the fact that rice husks are created off-site during grain processing, a greater proportion of them are utilized, despite the fact that they were historically regarded as waste and frequently thrown or burned[6]. However, rice husk is readily available and inexpensive; therefore, it has long been used as a source of energy for minor applications. In recent years, a variety of rice husk derived goods, such as polymeric composite resins and polymeric lumber as a substitute for natural wood, have been created by blending ground rice husks with polymer resins, energy-generating pellets can be created too. This study presents the status of the rice straw burning practice in Egypt and examines current

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procedures for utilizing rice production's waste straw and husks to expand its full usage[7].

The rice straw recycling system was able to change the negative perception towards agricultural waste, after the crucial challenge of burning rice straw and its emissions from fires beside the black smoke caused an environmental imbalance that threatened the lives of all living creatures for many years. burning it, as well as its contribution to creating job opportunities for many laborers that can generate income for them that improves their standard of living through the process of collecting, pressing and selling straw, as the optimal use of agricultural residues helped fill the shortage of organic fertilizers, achieve clean agriculture and protect the environment from Pollution and providing job opportunities in rural areas[8], thus improving the economic and environmental situation in the Egyptian countryside.

In order to make full use of rice straw, it is now recycled in designated sites using shredding and baling machines, to make pellets used to obtain industrial organic fertilizer, and to produce biogas to obtain organic fertilizer and energy, and to use it as an unconventional feed for livestock by adding urea and ammonia injections, and germinating barley seeds on Rice straw and its use as green and dry fodder for livestock, production of mushrooms as human food, and in poultry farms as a bedding for the farm floor with a mixture of sawdust, pressed and sold to paper mills and brick factories, and used in the manufacture of concentrated feed for animals, the manufacture of building bricks, furniture and housing construction[9].

2 Scalable Solutions for Sustainable Rice Straw Management

Rice straw and rice husk fiber are underutilized agricultural leftovers that have the potential to be used in polymer composites that would conserve wood and petroleum. R12 Traditionally, much of the produced rice straw has been burned in the field, as a quick and easy method of disposal. However, this results in the generation of atmospheric pollution from smoke and greenhouse gases; the latter are affected by moisture which enhances emission of CO2, CH4 and other organic carbons, whilst inhibiting N2O emission[10]. In addition to rice straw as shown in

[7] Abdelaal, H. S. A., & Thilmany, D. (2019).
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[9] Singh, G., Gupta, M. K., Chaurasiya, S., Sharma, V. S., & Pimenov, D. Y. (2021).
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Figure 1, various other substrates can be digested to produce biogas, including food waste, animals waste, poultry manure, and cow manure, among others. The expense of installing biogas systems is a barrier to the widespread adoption of biogas technology.

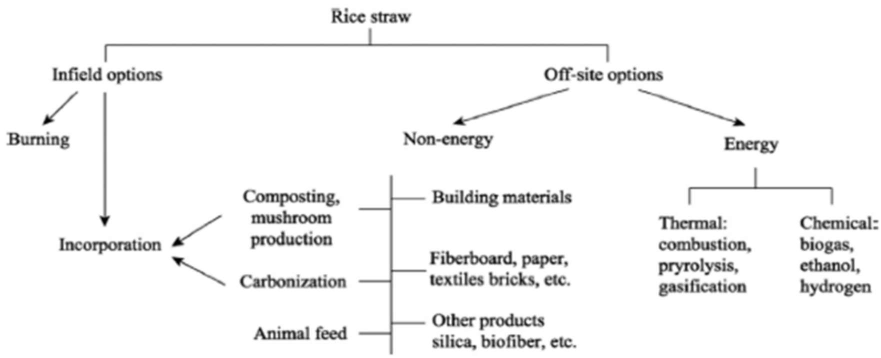

Figure 1: Summary of main options for use of rice straw.
Source: (Goodman, 2020) [11]

2.1 Incorporation

Incorporating rice straw into the soil is a typical method of management, but sufficient time must be allowed for its breakdown to maintain effectiveness and production efficiency[12]. In addition, after soil inclusion, straw management considerations must be considered for greenhouse gas emission (GHGE)[13]. Rice straw has a slower decomposition rate; hence, some farmers avoid incorporating it into the soil, particularly in intensive cropping systems. Rice straw composting is done by adding animal manure and enzymes to rice straw and mixing by a turner and ensilage, in order to homogenize the mixture. The biophysical processes of decaying matter can drastically improve thru mechanized composting. In turn, the compost can serve as fertilizer for growing vegetables and other crops, or can be used directly as soil conditioner. As soil conditioner, it improves the nutrient and organic matter content of the soil. R13 Straw integration is a typical approach for

[11] Goodman, B. A. (2020).
[12] Gummert, M., Nguyen, ·, Hung, V., Chivenge, P., & Douthwaite, B. (2020).
[13] Sander, B. O., Samson, M., & Buresh, R. J. (2014).

boosting soil fertility[14], however its influence on increasing methane emission is a cause for worry[15].

Rice straw could be pyrolysis under control to make biochar. Combining biochar soil aids in carbon sequestration, reduces GHG emissions, and promotes sustainable soil management. Biochars generated from rice straw as well as husks can be used to enhance soil characteristics. Significant increases in rice seedlings substance were noted after biochar amendment, In soils with low silica content, use of xerogel silica produced from micronized rice husk ash has been reported to boost rice crop yields[16]. However, soil type has a substantial impact on the value of biochar as a soil amendment for enhancing soil properties.

2.2 Energy Production

Rice is a main food for the majority of the world, its production is extensive. Nonetheless, it also produces vast quantities of non-food biomass, primarily in the form of straw and husks. Although they have been underutilized and most rice straw is being burned, these cellulosic materials have the potential for significant use. These include agricultural additives, energy generation, environmental adsorbents, building materials, and a variety of specialized products. This article investigates employing rice straw and husks to produce clean energy, the procedures involved in the manufacturing of valued products

Although pyrolysis and gasification can be used to make bio-diesel, rice husk pellets are also a viable alternative to diesel oil and coal for small-scale electricity generating[17]. The large generation of ash including silica and alkali might damage combustion equipment and cause agglomeration. However, there are potentially beneficial applications for the ash[18]. have presented a reactor that uses rice husk mixed with sawdust or charcoal to produce high-quality fuel. Rice husk briquettes made using starch or gum arabic as binders offer superior combustion qualities to firewood[19]. Carbonization of rice husk yields char with a somewhat high heating

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[19] Yahaya, D.B. , Ibrahim, T.G. , 2012.

value, with the addition of starch as a binder and ferrous sulphate or sodium hypophosphite to improve ignitability.

As with other organic wastes, rice straw can be utilized for energy production, including the production of ethanol, biogas, and bio-oil, as well as direct burning. Although ethanol is the most often utilized biofuel for transportation, manufacturing of ethanol from lignocellulose sources is still in its infancy[20]. Rice husk briquettes or pellets can be used as a substitute for fossil fuel in the gasification process to convert rice husk synthesis gas in a reactor with controlled air; this gas can be used as fuel or in a power generating system to generate electricity. In the past decade, rice straw has attracted the utmost interest of scientists as a potential source of energy in the form of bio oil. Several organizations have successfully recovered oil from straw using thermo-chemical techniques, and pyrolysis is one of these promising methods. Rice straw was pyrolyzed on a fluidized bed equipped with a mechanism for char separation. The optimal temperature for bio-oil extraction The oil was rich in oxygenated hydrocarbons[21]. Rice Utilization Biomass is a unique resource for the sustainable manufacture of bio-derived chemicals and fuels to replace products obtained from fossil fuels. Although lignin is a significant component of lignocellulose materials, its complex cross-linking polymeric network renders it intractable to present chemical methods, and alternative catalysts are being developed for its deploy medication[22].

2.3 Rice straw silage for livestock feed

Utilization of Rice Straw as a low cost natural food of rice straw for animal feed, There growing demand for animal source foods which consider a major concern for Egyptian population therefore rice straw affordable source of food for livestock feed. Rice straw includes 65.5% holo-cellulose (34.2% cellulose and 27.9% hemi-celluloses) and 10.2% lignin. Thus it was suitable for feeding ruminants. Previous research by Tengerdy and Szakacs[23] revealed that, because ligno-cellulosic crop residues include substantial amounts of cellulose, hemi-celluloses, and lignin, they may be suitable substrates for the manufacture of single cell protein for use in animal feeds. However, the biggest issue with dry rice straw is its low protein level of

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[22] Pineda, A. , Lee, A. , (2016).
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approximately 2%. According to El-Haggar et al.,[24] the chemical treatment approach using urea or ammonia is more practical than the mechanical treatment method. Adding 3 percent ammonia (or urea) to the entire mass of garbage produced the best results. Rice straw is the most plentiful form of feed for ruminants in Vietnam, particularly during the dry season[25]. Ammonization techniques employing urea or anhydrous ammonia to increase a crop's nutritional content are well-established and utilized in a number of Asian nations. When urea is used in the wet ensiling technique, the suggested amount is 4 kg of urea per 100 kg of air-dried straw little more than half of this amount remains in the straw when it is fed to the animal.

2.4 Exploitation of paddy straw for the fabrication of pulp and paper

The Food and Agriculture Organization of the United Nations (FAO) reported in 2018 that the worldwide forest area decreased by 3.2 million hectares (0.1% per year) between 2010 and 2015. Global urbanization and rising demand for wood and wood products are the primary causes. As a result of the high cost and limited supply of wood, many developing nations have begun to rely on non-wood based pulps (bamboo, corn straw, bagasse, flax, jute, sisal, etc.) for paper manufacture. Particularly in India and China, 70% of the pulp industry's raw materials come from non-wood plants, including wheat straw, cereal straw, and bagasse[26]. There are numerous advantages to utilizing non-wood resources in the pulp and paper business. The use of non-wood pulps will reduce deforestation. Use of agricultural leftovers in the paper sector will reduce wood and cellulose fiber imports in wood-shortage nations. Customer satisfaction will grow as a result of their desire for paper made from recycled or non-wood fibers. Agricultural leftovers are simpler to pulp than wood pulps[27]. In 2013, the global demand for paper was 402 million tons per year[28]; by 2021, the demand reaches 521 million tons per year. Increasing demand for paper does not indicate an increase in the literacy rate, but paper is in great demand for wrapping and packaging of goods and commercial products. Despite the various advantages of exploiting rice straw in the paper industry, it is not regarded a profitable biomass due to its high silica concentration (10 to 17 percent).

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[25] El-Dewany,G,Awad,F,. (2018).
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[27] Rodriguez et al. (2008).
[28] Kulkarni, A. (2013).

2.5 Mushroom Production

The rice straw mushroom species is often utilized because it grows quickly and has a 14-day growth period. The species develops in tropical climates at temperatures between 30 and 35 degrees Celsius during the mycelia development stage and between 28 and 30 degrees Celsius during the fruiting body production stage which fit in Egyptian climate especially in summer. Rice straw spawn, labor, and water are the key inputs for mushroom cultivation. Typically the mushroom harvest begins in the third week following inoculation and concludes one week afterwards[29]. In Vietnam's Mekong River Delta, outdoor mushroom farming is widespread crop. The minimal cost of investment is a benefit of this firm that generates income. It yields 0.8 kg of mushrooms every 10 kg of dried straw, resulting in a net profit of USD 50–100 per tons of straw. Due to increased investment requirements and the need for stringent control over growing conditions, indoor cultivation is a less prevalent technique. On the other hand, the yield per 10 kg of dry straw is around 2 kg higher for mushroom cultivation indoor.

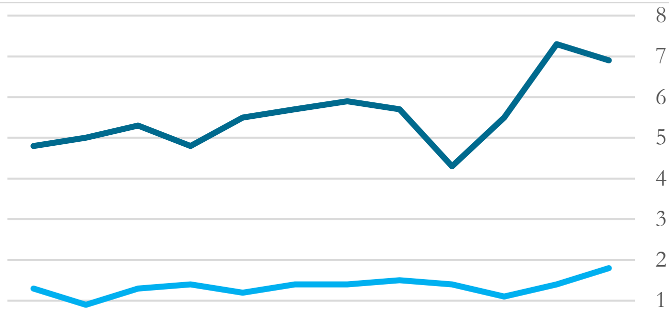
3 Africa Context

In notwithstanding the of Asia's dominance in rice production and consumption, the importance of rice in other regions of the world is not diminished. It is the primary food crop in the majority of African nations. Population growth over the past two decades has increased the demand for the crop that is currently the second most important source of energy in Africa. In fact, the current rate of rice consumption in Africa exceeds its rate of production, which is balanced with the help of effortless and sustainable imports from Asia. Egypt, Madagascar, and Nigeria are the leading rice producers in Africa, followed by Mali, Tanzania, Sierra Leone, and Senegal. It is primarily grown in countries along the western and eastern coasts of Africa and has become a crop of paramount political significance. The 2007–2008 rice crisis in Africa is a classic example of the extent of public unrest caused by its shortage or price fluctuations, illustrating its significance[30].

[29] Singh, G., Gupta, M. K., Chaurasiya, S., Sharma, V. S., & Pimenov, D. Y. (2021)
[30] Abdelaal, H. S. A., & Thilmany, D. (2019).

3.1 Local Context

The total cultivated area reached 1.3 million acres of rice. Figure 1 show the rice production and total rice cropping area in Egypt from 2006 to 2019.Study show that Dakahlia Governorate is the largest governorate of rice cultivation, where the rice area reached 369 thousand acres, 29.3%, and rice production reached 1.1 million tons, or 30.3%, followed by the Eastern Province, with an area of 278 thousand acres, at a rate of 22, 1%, and the amount of production amounted to 868 thousand tons, at a rate of 23.0%.Kafr El-Sheikh Governorate, with an area of 266 thousand acres, representing 21.2%, and the amount of production amounting to 742 thousand tons, or 19.7%. Then, Al-Bahira governorate has an area of 192 thousand acres, at a rate of 15.3%, with a production amount of 511 thousand tons, at a rate of 13.5%. Al-Gharbia comes with an area of 100 thousand acres, 7.9%, a production amount of 342 thousand tons, at 9.1%, and finally Damietta, 53 thousand acres, 4.2%, with a production amount of 167,000 tons, at a rate of 4.4%.



	2019/2018	2017/2016	2015/2016	2014/2015	2013/2014	2012/2013	2011/2012	2010/2011	2009/2010	2008/2009	2007/2008	2006/2007
Production in Million Tons	4,8	5	5,3	4,8	5,5	5,7	5,9	5,7	4,3	5,5	7,3	6,9
Cropping Area	1,3	0,9	1,3	1,4	1,2	1,4	1,4	1,5	1,4	1,1	1,4	1,8

Figure 1: Rice annual Production Amount and Cropping Area

Source: Egyptian Statistical Authority[31]

[31] https://www.capmas.gov.eg/

Table 1: Average productivity of rice in major Egyptian Cities 2019

Item	Average quantity (Ton / Acre)		Rice straw (Tons)	Barley rice (Tons)	Cultivated area with rice
Governorates	Rice straw	Barley Rice			Acre
Damietta	1.65	3.18	86590	167064	52613
Dakahlia	1.89	3.1	697970	1143287	368756
Sharkia	1.59	3.13	441430	867976	277658
Kafr Al sheikh	1.56	2.79	413492	741713	265903
Gharbia	1.64	3.43	163107	341931	99588
Behera	1.39	2.66	267127	510665	192147
Total	**1.65**	**3.0**	**2069716**	**3772636**	**1256665**

Source: Egyptian Statistical Authority[32]

2.1 million tons of rice straw produced in 2019, with a productivity of 1.65 tons of straw/Acre, was planted with rice. 43.9 thousand tons of straw were burned out of the total amount of straw produced, cultivated area with rice and Average quantity rice straw per ton as shown in Table 2 .

3.2 Egyptian Disposition Practices

Disposition style rice straw is crucial topic attract attention from Egyptian Government Table 2 shows the main practices by Egyptian Farmers The percentage of farmers who used straw as animal feed reached 65.9% of the total number of farmers and given what the state has done in the form of the Ministry of Environment to spread awareness among farmers the importance of making use of rice straw by using it in many fields to obtain a reasonable return.

Table2: Distribution disposal methods of rice straw in major Egyptian Cities 2019

Item	Disposition style rice straw				
Governorates	Burning oven	Burning	Converted to animal feed	Selling	Buried in the land
Damietta	0	0	3075	3123	0
Dakahlia	969	9509	104422	12809	0
Sharkia	3853	483	33451	29703	370
Kafr Al sheikh	1486	122	28709	39883	1410
Gharbia	812	2772	8094	37844	0
Behera	208	0	7583	24145	0
Total	**7327**	**12886**	**185333**	**147507**	**1780**

Source: Egyptian Statistical Authority[33]

[32] https://www.capmas.gov.eg/
[33] https://www.capmas.gov.eg/

The percentage of farmers who sold straw reached 23.4%. As for burning straw, it was followed by two types of farmers, one of whom burns it in the home oven and reached 5.1%. as for the other one, he started and started burning straw on the ground, and their rate was (0.5%), which is negligible, because the farmers were aware of the possibility of selling and benefiting from it. The percentage of Gharbia Governorate farmers who burned was 54.9%, while the farmers of Kafr El- Sheikh Governorate accounted for 30.5% of the total farmers who did by burning. It became clear that 12.5% of the farmers had disposed of straw by placing it under a mattress under livestock. As for the method of disposing of straw by (burying the land), it reached 0.2% of the total, because the farmers who bury straw on the ground are the area. Rice planted with a small rice planting area.

3.3 Government Initiatives

Government of Egypt is pursuing a strategy plan aiming to achieve a contribution of renewable energies by 20% of the total electricity generation by the year 2030, and to diversify its energy source through the development of new and renewable energy resources. Egypt has a good potential for biomass resources but very limited work has been done to quantify this potential for power generation. The main sources of biomass waste in Egypt are agricultural waste (crop residues), followed by municipal solid waste, animal waste, and sewage waste.

4 Conclusion and future research

Improving the value chain of rice straw byproducts and implementing sustainable straw business practices are the key to persuading farmers not to engage in open-field burning and avoiding the resulting negative environmental and health impacts. Rice straw incorporation into the soil is an option; however, it must be carefully required to ensure timely degradation and minimize GHGE emissions. The stash of rice straw with balers plays a crucial role in its sustainable utilization. In the remaining chapters of the book, alternative straw management options such as straw-based mushroom and feed production, mechanized composting to produce organic fertilizer, etc. are debated. This study focuses on the scalable options that will increase the economic value of Egyptian rice production. Information that has been reviewed and updated, as well as scientific evidence regarding the sustainable operations of rice straw, will be useful for future improvements and relevant regulations. How rice straw can be used to produce biofuel and high-end materials such as bioplastics, bio fibers, and silica could be the subject of another publication.

It is crucial to consider whether burning straw should keep going or whether it should be converted into a variety of valuable products. In addition to providing sustainable solutions for managing large quantities of straw, the technologies discussed above have the potential to improve the socio – economic status of farmers. The most important requirement is the full participation of the federal and state governments in the development of schematics detailing how cleaner technologies can be implemented at the root level for the proper management of biomass. Despite the progress of using rice straw Study show there still gap of local practices and lack of awareness of agriculture's uses potentials to fully exploitation of rice straw and husks.

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