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Utilization of Rice Straw as a Low-Cost Natural By-Product in Agriculture

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Abstract: In Egypt, rice (*Oryza sativa*) is a major crop in terms of total production and it is considered the third most important grain crop in all over the world behind wheat and corn. Rice production is associated with large quantities of straw, which traditionally have been removed by the practice of open field burning. However, burning of the agricultural residues especially in Egypt, particularly rice straw (about 3 million tons per year) lead to what is known locally as "Black Cloud" in the media. This work aims to document the problems take place from Rice straw burning like potentially harmful effects on people's health, especially for those with sensitive eyes and respiratory problems, environmental impacts represented by increasing of global methane emission rates from rice fields and solutions represented by best management practices should be applied for rice straw annually produced under national and international scales.

Keywords: Agricultural waste, black cloud, environmental ecosystem and rice straw.

INTRODUCTION

Pollution is the contamination of the environment by the introduction of contaminants that can cause damage to environment and harm or discomfort to humans or other living species. It is the addition of another form of any substance or form of energy to the environment at a rate faster than the environment can accommodate it by dispersion, breakdown, recycling, or storage in some harmless form. Environmental pollution consists of five basic types of pollution, namely, air, water, soil, noise, and light.

Rice is one of the export food crops, which contribute to national income. The extension of rice-cultivated areas increased the straw yield from about 2.44 million tons in the period 1984-1987 (basic period) to 6.618 million tons in 2003/4 with increasing percent equal 258%. Rice grains contains 12.5% water, 3% protein, 78% starch, 3% vegetable fat over mineral salts, potassium, sodium, calcium, manganese, iron, phosphorus, sulfur, iodine, vitamins A, B, E. Farmers usually get rid of rice straw by burning it in the field to cultivate the successive crop. There is a general awareness in Egypt about field burning of agricultural residues, this procedure leads to unacceptable air quality. This is partly brought about by recent reports on what is locally known as "the Black Cloud" in the environmental ecosystem. Probably the most prominent example of this is rice straw, of which in recent years nearly 3.7 million tons per year is burned in the field, creating both an economic waste and environmental problems. An integrated approach is needed in order to make optimally efficient use of agricultural product and byproducts. In view of the actual raising of food prices, high population growth rate, and higher energy prices in Egypt. Efficiency and increasing of the whole production chain process become more important. In this context, the beneficial reuse of agricultural waste will be economically profitable for both the farmer and the industry. Reducing the large-scale rice straw burning will minimize air pollution particularly in Cairo city and other areas in the Nile Delta consequently will reflect on human health.

The goal of this article is to through light on ways and means of the beneficial utilization of rice straw. New technologies and finding solutions for such problem in Egypt will contribute to the environmental protection, minimizing health hazards as well as the economic return on agriculture and industry.

PRODUCTIVITY AND` GLOBAL QUANTITIES OF RICE STRAW

Rice is a major crop in terms of total production. It is considered as the third most important grain crop in the World behind wheat and corn. Associated with rice production is a corresponding annual production of rice straw. According to annual reports published by the International Rice Research Institute [1], rice is one of the most widely grown cereal crops in the world with at least 114 countries

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growing it in the year 2007, at least 50 of them produced over 1 million tons, while its major counterpart is Asia (90% of world production and consumption with the top 9 producers in Asia).

Parr *et al.* [2] stated that, globally, rice cultivation produces large quantities of straw, as an agriculture waste, ranging from two to about 9 tons/ha. Components of rice straw are mainly cellulose, and hemicelluloses encrusted by lignin, in addition to a small amount of protein, which makes it high in C:N ratio. Therefore, it is resistant to microbial decomposition compared to straw from other protein-rich grains such as wheat and barley. Rice straw is also one of the most abundant and renewable energy sources in the world. Its annual production is about 731 million tons, which is distributed in Asia (667.6 million tons), America (37.2 million tons), Africa (20.9 million tons) Europe (3.9 million tons) and Oceania (1.7 million tons) [3, 4]. The straw has been traditionally removing from the field by the practice of open-field burning. This practice clears the field for new plantings and cleans the soil of disease-causing agents. Nowadays, field burning is the major practice for removing rice straw, but it increases air pollution and consequently affects public health.

MOAC [5] reported that rice is number one staple food crop in Nepal. As per the preliminary estimate, rice was grown in 15, 49,262 hectares with a total production of 42, 99,246 metric tons and a productivity of 2,775 kilograms per hectare. Thailand Research Fund [6] reported similar results in terms of annual production; the estimated maximum production of rice husk, rice straw, and corn cob were; 6.2, 32.2 and 1.8 million tons per year, respectively. However, the potential of un-utilized rice husk and corn cob at the national level was reported to be rather low due to extensive utilization for both energy and non-energy purposes. On the other hand, as much as 12.9 million tons per year of rice straw remain unutilized.

LOCAL QUANTIIES OF RICE STRAW

Under Egyptian conditions, Sabaa and Sharaf [7] estimated the total area of rice cultivation as about one million feddan (one feddan = 4200 m^2) per year until 1987, which produces about 2.4 million tons of paddy rice at an average of 2.4 tons per feddan. They added that the rice area in Egypt is the largest rice producer in the Near East region. Currently, the major practice to eliminate such massive amounts of post-harvest rice residues is fielded open burning. Although field burning provides effective destruction of weed seeds and pathogenic microbial spores, the produced black smoke represents a threat to public health. The geographical distribution of rice cultivation is indicated in Table 1.

Stahl and Ramadan [8] mentioned that rice is a major summer crop in Egypt covering 1.5 million feddan in (2003) out of a total cultivated area of about 7.8 million feddan. In that year, the total production of paddy rice in Egypt was 5.8 million tons of which 0.7 million tons are exported to the Arab countries. However, the international prices for rice have been under strong downwards pressure since 1998. They added that rice cultivation is mainly in the Nile Delta areas due to its high water requirements (about 5600 m^3), which restricted in Upper Egypt and desert regions.

Table 1. Rice cultivation area and rice straw production.

Governorates	Area (10^3 feddan)	Amount of rice straw (10^3 tons)
Dakahlyia	437.6	875.2
Kafr El- Sheikh	255.0	510.0
Sharkyia	271.0	542.0
Beheira	195.8	391.6
Gharbiya	161.7	323.4
Damiat	65.8	131.6
Fayoum	20.0	40.0
Qaliubia	17.6	35.2
Total	1.424.5*	2849

Source: Abou Hussein and Sawan [9]; * about 1.4 * 10^6 feddan

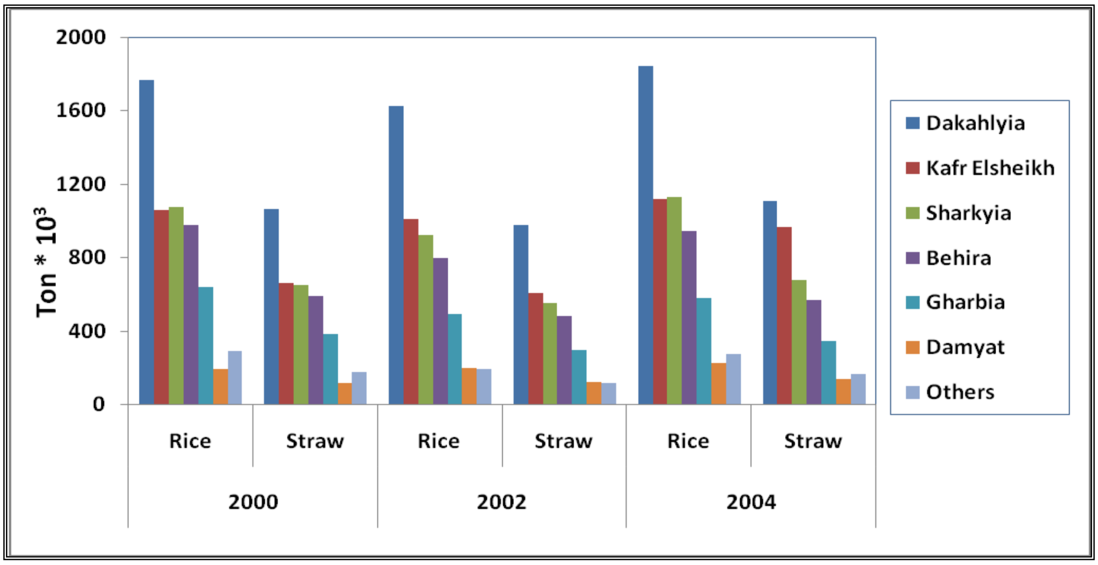

Figure 1. Rice yield and straw production in the various Egyptian governorates.
(*C.f.* Guidance Brochures, 2000-2003, Ministry of Agriculture, Egypt).

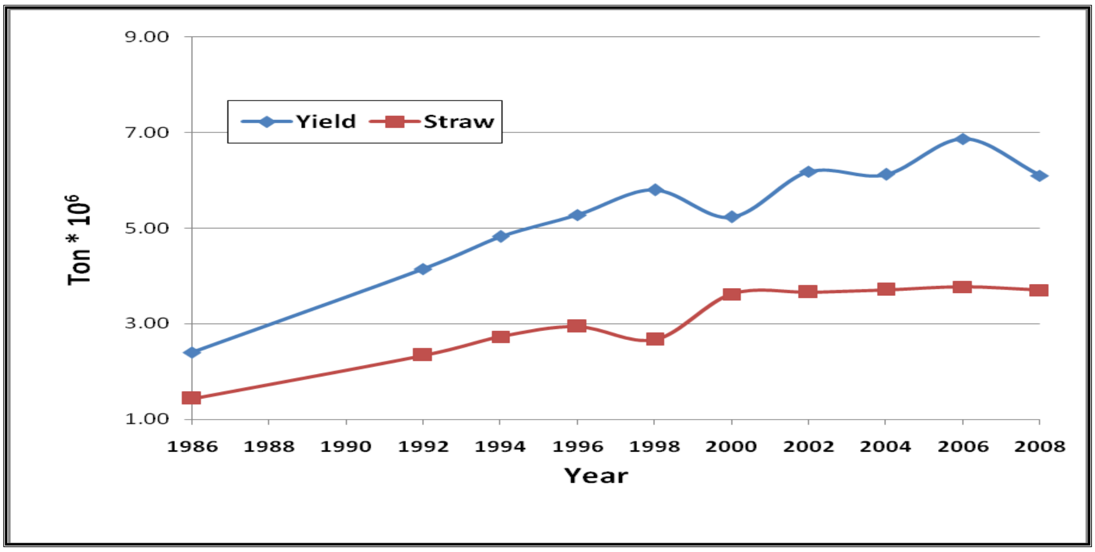

Figure 2. Rice yield and straw production increases during the period 1986 2008.
(*C.f.* Guidance Brochures, 1986-2008, from Ministry of Agriculture, Egypt).

PROBLEMS OF BURNING RICE STRAW

Rice straw is being open-field burnt due to agricultural considerations such as control of disease infestation for future crops [10] and nitrogen immobilization in case of soil incorporation [11]. In many rural communities, rice straw is used as a fuel in domestic cook stoves. Rice straw is also used in boilers for power generation. In Squint agricultural region in Jiangsu province in China, about 37% of rice straw were burned in the field during 2001 to 2005 [12], and China is the biggest rice producing country in the world contributing to 28.19% of its production in the year 2008 [13]. Gadde *et al.* [14] has attempted to estimate open-field burning of rice straw in India, Thailand, and the Philippines, and has reported such estimates to be 14, 48, and 95% of rice straw, respectively. However, the level of difficulty in such estimates became apparent from looking at the methods used in doing so. The authors could have estimated those using personal communication in case of India, institutional analysis in case of Thailand, and questionnaire survey in case of the Philippines. On the other hand, different uses of rice straw vary from year to year depending on a number of factors, thereby imparting great uncertainty.

According to Abou Hussein and Sawan [9], the estimated amount of agricultural waste in Egypt ranges from 30 to 35 million tons. Some of the agricultural waste is used as animal fodder, and other waste is used as fuel in indoor primitive ovens that causes health problems and pollution to the environment. The rest is burned in the field such as rice straw, causing local and regional air pollution problems.

Off-field utilization of rice straw and other crop residues continues to attract increasing attention due to concerns associated with environmental impacts from open burning for disposal. California, which produces approximately 17% of US rice, introduced legislation in 1991 initiating a phased reduction in rice area available for burning in recognition of the air quality impacts and the potential for increased adverse health effects, such as possible lung disease from exposure to biogenic silica and elevated incidence of asthma attacks [15]. This legislative act, the Connelly-Areias-Chandler Rice Straw Burning Reduction Act, AB 1378, mandated a reduction in the fraction of rice area in the Sacramento Valley that could be burned from 90% in 1992 to 25% in 1998, with conditional burning allowed up to a maximum of 25% or 125,000 acres (50,600 ha) after the year 2000.

In the absence of any large-scale existing market for rice straw, incorporating straw into the soil has been the primary response by growers to reduced burning allowances. Soil incorporation has a number of benefits as well as disadvantages, the latter including possible reductions in grain yields through higher incidence of disease as mentioned by Webster [16] and higher greenhouse gas (methane) emissions from straw decomposing in the soil under anaerobic conditions, as reported by [17]

Environmental Impact

The dominance of rice in the cropping pattern causes several problems: a) In rice fields, the presence of a subsurface drainage system that was installed for other crops causes substantial water losses through the system and leads to large application of irrigating water [18]. b) Neue [19] identified rice field methane emissions as a major source of atmospheric methane. He explains that in wetland rice soils, flooding a field cuts off the oxygen supply from the atmosphere, resulting in anaerobic fermentation of soil organic matter. Methane, a major end product of anaerobic fermentation, is released from submerged soils to the atmosphere through the roots and stems of rice plants. Estimates of global methane emission rates from rice fields range from 20 to 100 Tg per year (1 Tg = 1 million tons), which corresponds to 6 to 29 percent of total annual anthropogenic methane emission. c) A new phenomenon dubbed the "Black Cloud" which in October or November chokes the population on thick black smoke appeared for the first time in 1999. Farmers are blamed on burning harvest waste products such as rice stalks.

Haywood [20] showed that black carbon is emitted as chain-like structure close to the combustion source which collapses as time progresses to a more compact structure. Possible silica emissions are not specifically monitored up till now. Numerous studies have linked the particulate matter to aggravated cardiac and respiratory diseases.

Health hazards

Seasonal air pollution episode that has been observed in the fall every year since 1999 is locally known as the “Black Cloud” (Figure 3.). The black cloud is a dark haze that envelops Greater Cairo and surrounding areas during the fall months for varying number of days [21, 22].

In the same respect, Fleishman [23] reported that the impact of this haze is significant; it has potentially harmful effects on peoples’ health, especially for those with sensitive eyes and respiratory problems. Children’s lungs become very susceptible to illness when inhaling such high aerosol loadings hence, long-term exposure to these hazes can lead to asthma**.**

Figure 3. Rice straw burning and "Black Clouds".

Furthermore, the opaque particle cloud over Cairo and its neighboring regions may affect regional climate through the scattering or absorption of radiation [24]. It may even influence the growth of plants in the Nile Delta by altering the amount of radiation that is available for photosynthesis [22]. Also, Rosenfeld [25] referred that high aerosol loads are likely to influence the water cycle by suppressing precipitations**.**

Open burning of crop residues, like the burning of rice straw, is not thought to be a net source of carbon dioxide (CO_2) because the carbon released to the atmosphere during burning is reabsorbed during the next growing season. However, crop residue burning is a significant net source of CH_4, CO, NOx and N_2O, which contribute to global warming where CO and O_3 are indirect greenhouse gases (GHGs) as reported by Intergovernmental Panel on Climate Change. [26].

Burning of agricultural crop residues as an energy source implies that burning would occur under controlled conditions and thus reducing emissions of GHGs as compared to open burning. They added that, its calculated Global Warming Potential (GWP) indicates the greenhouse gases contribution to global warming, where a unit is equivalent to the global warming impact of 1 ton of CO_2 emissions as the reference. CH_4 and NOx have a GWP of 23 and 296 respectively over a period of 100 years**.** Wuebbles and Hayhoe [27] stated that the emission of chemically active gases, including carbon monoxide, non-methane hydrocarbons, and nitric oxide, along with methane, also lead to the chemical production of tropospheric ozone, another greenhouse gas, as well as control the concentration of the hydroxyl radical, which regulates the lifetime of almost every atmospheric gas**.** This is the reason they are classified as indirect GHGs.

Local Impact

The environmental impact of agricultural waste burning that is most felt by the public in Egypt, specifically in Greater Cairo, is the fine particulate matter carried by the winds from the rice fields in the Delta area to the urban areas of Greater Cairo city.

In a field study by the Ministry of Housing and Ain Shams University in Egypt, the relationship between particulate matter (PM) pollution and mortality rates was explored, and the same for sulfur dioxide. The study investigated the impact on cardiac and respiratory diseases in Egypt between 1995 and 2001. The results concluded a positive relationship between increased pollution with suspended particles and sulfur dioxide on one hand, and the high rate of mortality from cardiac and respiratory diseases on the other. A relationship was also found between smoke pollution rates and mortality from lung cancer.

Numerous scientific studies have also linked particle pollution exposure to a variety of problems, and predominantly respiratory and cardiovascular problems [28].

The health impacts include

• Increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty in breathing,

• Decreased lung function,

- Aggravated asthma,
- Development of chronic bronchitis,
- Irregular heartbeat
- Nonfatal heart attacks,
- Premature death in people with heart or lung disease.

Several studies have been conducted to understand the main reasons for the increased pollution levels in Cairo using ground-based and satellite air quality data [21]. However, the genesis of the fall episodes (the black cloud season) is still under discussion and needs more investigations. In order to acquire further synoptic information and visualization of the aerosol characteristics, it is useful to analyze satellite data as well, since these data provide horizontal and vertical covering with fairly high (e.g. daily and monthly) temporal resolution. Marey, *et al.* [29] utilized data from several satellite instruments to examine the most likely reasons for the black cloud formation over Cairo.

WISE AND ECONOMIC USES OF RICE STRAW

Enormous quantities of agricultural wastes such as rice straw are produced annually worldwide. Figure (4) show some useful applications of rice straw as; organic fertilizer, animal fodder, soil mulching, wood and paper industry and source of energy.

The high content of silica in rice straw limits its direct application as animal fodder, in papermaking and as a solid fuel. Thus, farmers proceed towards its immediate disposal, even through open burning, despite the stringent regulations banning this practice, for its serious health hazards, to prepare the land for the next crop. On the other hand, the depletion of petroleum, natural gas and other conventional fuel sources is motivating researchers to develop new renewable sources of energy. The use of biomass as a source of energy is being widely addressed as reported by [30,31]. The production of bio-oil by fast pyrolysis from the rice straw was addressed by [32, 33]. Several fast pyrolysis reactor configurations exist today including ablative reactors, entrained flow reactors, rotating core reactors, vacuum pyrolysis reactors, circulating fluidized bed reactors, and deep bubbling fluidized bed reactors.

Mendoza and Samson [34] demonstrated that recycling rice straw could substitute 2 – 4 bags of fertilizers per hectare per cropping or about 2.5 kg N per ton straw**.** However, new approaches of using rice straw for controlling weeds in different crops have been suggested by WHO indicated that rice straw can be used for mulching, which benefits in preventing weed growth as well as supplies organic matter for N fixation by heterotrophic N-fixing microorganisms, which could be absorbed by succeeding crop.

Figure 4. Some economic utilization of rice straw.

Evaluation of Rice Straw as Organic Fertilizers in Soils

Crop residues are organic and biodegradable materials. Either utilization technology must use the residues rapidly, or the residues must be stored under conditions that do not cause spoilage or render the residues unsuitable for processing to the desired product. There are many methods for utilizing agricultural waste in Egypt, which can be summarized as follows:

Composting of rice straw and soil amendments of such agricultural residues along with farm wastes could be of great benefit for soil fertility and management of the occurred soil-borne diseases [35]. Composting is the aerobic decomposition of organic materials by microorganisms under controlled conditions. In addition, Geisel, 2001 and El-Haggar *et al.* [36,37] reported that composting is one of the best-known recycling processes for organic waste to close the natural loop. The major factors affecting the decomposition of organic matter by microorganisms are oxygen and moisture. Temperature, which is a result of microbial activity, is also an important factor.

The other variables affecting the process of composting are nutrients (carbon and nitrogen), pH, time and the physical characteristics of the raw material (porosity, structure, texture and particle size). Aeration is required to recharge the oxygen supply for the microorganisms. In addition, A Grower's Guide [38] mentioned that aerobic composting systems can be classified as turned windrows, aerated static piles, passive static piles or windrows and aerobic in vessel systems. In any aerobic system, composting is most rapid when microbial activity is maximized. This accomplished by using starting material that have proper balnce of carbon and nitrogen and keeping compost pile moist and well aerated (Table 2). Concerning size of materials Geisel [36] concluded that material decomposes best if it is 0.5 to 1.5 inches in size.

Rice straw has a high C:N ratio and is slow to decompose on its own. If it is incorporated into, soil combined with a low C:N material such as cattle manure or municipal sludge and inoculated with active ligno-cellulose decomposing microorganisms, such as actinomycetes, a more favorable ratio is achieved for rapid decomposition and the produced material would have a higher nutrient content, [39].

Table 2. Main criteria for aerobic composting

Factor Starting Materials	Acceptable Range	Optimum Range
C:N ratio	20:1 - 40:1	25:1 - 30:1
Particle size mm	1/8-2	Varies with material
Water content %	40 - 70	50-60
Oxygen concentration %	>5	>10
pH	5.5 – 9.0	6.5 – 8.0
Temperature °F	110 - 150	125 - 140

Hence, the present review revealed that composting of the agricultural wastes could turn the problem into a solution. Farmers are strongly encouraged to adapt such environmentally and economically sound measures for management of crop diseases.

Although the use of compost may not control diseases to a level that may replace the use of fungicides; their integration into current disease management practices will reduce the fungicide use and the associated problems.

El-Saied *et al.* [40] found that treating the sandy soils with rice straw (RS) based hydrogels led to reduce the leached N to be 45-54%; in reverse trend it led to increase the release of both P and K to reach 346 and 174% that of the non- conditioned soil, respectively. Conditioning sandy soil increased the retained nutrients in the soil after leaching. These increments ranged between 70 and 164% for N, 93 and 394% for P and 19 and 92% for K.

Application of Rice Straw in Cultivation of some Vegetable Crops

Application of rice straw for plantation of mushrooms is well known in Egypt. There are some large farms and many small farms producing mushroom mostly in the Delta. In this respect, the consumption of mushroom in Egypt is quite low; therefore, the amount of straw used by this way remains very limited but still sensible and promising. Oyster mushrooms (*Pleurotus spp.*) have become increasingly popular in recent years and are now cultivated in many subtropical and temperate countries.

Commercial cultivation is usually carried out on straw, but the non-composted cotton waste supplemented with rice bran and calcium carbonate used in Singapore also proved an effective substrate. Rice straw is an essential substrate for the growing of Agarics Bosporus in Asia. In Japan, Taiwan and Korea, rice-straw composts have been used for many years with consistent results. Rice straw has enough nutrients and regarded as the best material; for mushroom growing in all countries that produce rice, e.g. China, the Philippines and Indonesia [41].

Daba *et al.* [42] had carried out relatively recent investigation on the production of mushroom using primary substrate of chopped rice straw. The technique applied is summarized in filling the substrate into galvanized metal boxes with perforated floors. The substrate is subjected to pre-fermentation or pasteurization for one hour in order to destroy the vegetative form of competing microorganisms. Spawn was transferred to polyethylene bags containing the sterilized rice straw substrate and left 21 days at 27ºC and humidity of 80%. It is worthy to refer to the nutritional value of the resulted mushroom fruit bodies, which contain about 50.0% carbohydrates, 24.5% proteins, 5.0% lipids, 3.0% fiber, 6.0% ash and energy value 320 Kal./ 100 g dry weight.

Abdel-Satar [43] concluded that cultivated vegetable crops on compacted rice straw bales such as straw berry, pepper, tomato, cucumber and okra in open field or under greenhouse were promised method to utilize rice straw residues. In addition, the cultivation on compacted rice straw bales was used in the soil, which suffered from soil borne diseases and high salinity. In addition, after harvesting the vegetable crops, the agricultural wastes; will be thoroughly mixed with rice straw and used as compost for a soil to increase soil fertility. The compacted rice straw bales were used for two years.

Utilization of Rice Straw for Animal Feeding

Rice straw, one of the major agricultural by-products of Egypt, contains 65.5% holo-cellulose (34.2 cellulose and 27.9% hemi-celluloses), and 10.2 lignin. This made it a good fodder for ruminants. Previous studies by Tengerdy and Szakacs [44] suggested that, since ligno-cellulosic crop residues contain appreciable quantities of cellulose, hemi-celluloses and lignin, they are potentially good substrates for production of single cell protein as animal feeds. However, the low protein content about 2.0% of dry rice straw is the main problem. The chemical composition (%) of rice straw compared to other crop residues in Egypt is recorded in Table (3).

El-Haggar *et al.* [37] stated that, the chemical treatment method with urea or ammonia is more feasible than the mechanical treatment method. The best results were obtained by adding 3% of ammonia (or urea) to the total mass of the waste. Rice straw is the most abundant feed resource for ruminant animals in vietnam especially during the dry season [45]. For increasing its nutritive value by ammonization using urea or anhydrous ammonia are well established and are being applied in many countries in Asia. When urea is used in the wet ensiling system, the usually recommended level is 4 kg urea per 100 kg air-dry straw, little over half of which remains in the straw when this is finally fed to the animal.

Table 3. The chemical composition (%) of some crop residues in Egypt.

Crop Residues	Cellulose	Hemi-cellulose	Lignin	Crude Protein	Ash	Digester factor
Rice straw	34.2	27.9	10.2	2.0	16.2	23.6
Wheat straw	39.0	36.0	9.6	2.6	7.8	38.2
Barley straw	40.4	28.1	9.1	2.7	8.1	37.8
Bean hay	42.1	21.3	13.2	4.8	4.4	42.9
Barseen hay	39.2	17.9	14.8	4.3	8.2	48.6
Maize stalks	38.1	32.8	7.9	3.7	6.4	40.9
Corn cobs	37.4	37.9	5.8	2.1	7.4	61.6

Source: Abou Hussein and Sawan [9].

Industry of Wood, Paper and Building Materials

Rice straw is the most important ligno-cellulosic material. Rice straw is used to produce fiberboards. In comparison to wood fibers, rice straw has low quality due to its high percentages of no fibrous materials included in it. However, with care to rice straw fiberization, the properties of board can be increased considerably**.**

In Egypt, the general company for paper industry RAKTA [46] produces and trades in printing paper and carton products. Until recently, the Company used 150,000 t clean rice straw bales annually for the manufacture of writing paper. Straw quality, RAKTA set specifications for the supply of straw for paper-making. They also placed restrictions on rice varieties that were acceptable and stipulated demand at 114,000 t yr^{-1}.

El-Samni [47] added that when burning the rice straw, ash is highly pozzolanic and suitable for use in lime-pozzolana mixes and Portland cement replacement**.**

Using of Rice Straw as a Fuel in Egyptian Villages

Kargbo *et al.* [48] stated that rice straw, as agricultural waste biomass could be a source of alternative energy to substitute fossil energy for reducing greenhouse gas emission as well as avoiding the local pollution problems from open burning. Rice straw is attractive as a fuel because it is renewable and considered to be carbon dioxide neutral but has not yet been commercially used as a feedstock for heat and energy because of insufficient incentives or benefit for farmers to collect rice straw instead of field burning. Direct comparison of straw with coal, still the dominant solid fuel in electricity and heat generation, often reveal inferior properties of straw. In particular, it has a low energy density and heating value, is a bulkier fuel (with poorer handling and transportation characteristics). Straw contain silicon oxide (SiO_2) which could result in high quartz ashes that can cause corrosion problems in the convective pass of the boiler and handling systems.

Baxter *et al.* [49] mentioned that, a major hurdle with respect to the utilization of rice straw for chemical and energy production is the associated costs and logistic of collecting, transport, handling and storage. Straw fuels have proved to be extremely difficult to burn in most combustion furnaces, especially those designed for power generation due to the rapid formation of deposits.

Washing rice straw with water is effective in removing substantial amount of alkali metals. The removal of such elements is beneficial in increasing the fusion temperature of straw in furnaces; prolong life of boilers because corrosion problems are avoided, volatile matter release rates were substantially fast with washed samples than with untreated samples. However, straw washing has only been tested at small plants.

Kargbo *et al.* [48] concluded that the aforementioned pretreatment technologies of rice straw could increase both its physical and chemical properties for energy use. This reduces the associated costs and logistics of handling, transportation and storage.

Production of Clean Electrical Energy

El-Haggar *et al.*[37] stated that, biogas is a mixture of gases mainly methane and carbon dioxide that results from anaerobic fermentation of organic matter by bacteria. Biogas is ranked low in priority in Egyptian energy policy and there is no estimate of the share of biogas of the total biomass potential of energy in rural Egypt. Alaa El-Din *et al.* [50] mentioned that 76.4% of the gross energy consumed originated from burning crop residues and dung cakes, while 23.6% of the needs were met by conventional sources, e.g. kerosene, bio-gas and electricity. The efficiency of releasing energy from biomass by direct burning in primitive stoves is very low (5-10%). The contribution of crop residues and animal dung to net energy used in rural areas represented only by one-third of total energy consumption, while conventional sources met about two-thirds. The available crop residues after harvest are estimated at about 22.6 million tons, out of which about 13.7 million tons or 61% are used for direct burning. Animal droppings, principally of cows and buffaloes, are used as organic manure ("Balladi manure") or as fuel for rural cooking.

Xiong *et. al.* [51] showed great promise to be used as a biochemical pretreatment agent in 2G biofuel platform. Therefore, more research focus should be oriented towards the exploration of the lignocellulolytic bacterial strains and assessment of their ligninolytic potential in order to facilitate their utilization as effective bio-pretreatment agents in 2G biofuel production.

Removal of these nutrient-rich resources from the fields deprives the farmer of much needed fertilizer; their replacement often means the use of chemical fertilizers at a severe financial, and energy cost.

RECOMMENDATIONS AND BEST MANAGEMENT PRACTICES OF RISE STRAW PRODUCED IN EGYPT

The perspective views of the subject of rice straw particularly in Egypt has to be concentrated to the beneficial utilization of this low-cost byproduct. This goal can be achieved through the extension in:

- If possible, establishing organic fertilizers plants in every village. The logistic means for packing and transporting the rice straw will be very helpful to the farmers to avoid open field burning.
- The strict laws and regulations have to be respected and fulfilled for protecting the environmental conditions and consequently human health.
- Attention has to be directed also to the proper technique for the use of rice straw as animal fodder through the enrichment of N to enhance the protein content and satisfy the requirement of animal feeding. This will be reflecting on the cost of meat production.
- Training programs for the farmers to get use of rice straw as soil mulching or substrate for growing some vegetables particularly mushroom, as a source of protein, will contribute in solving burning problems.
- Economical uses of rice straw as industrial material or energy source have to be taken into consideration for the optimal benefit of it.
- State authorities and social organizations have to put the strategy and means of acts to handle the problem of rice straw, since the scientific and technical bases as well as experience are well known.

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