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UTILIZATION OF AGRICULTURAL WASTES FOR SUSTINABLE DEVELOPMENT

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Abstract: Embracing the idea of recycling wastes or changing waste to energy and other materials is an indispensable choice for sustainable development, and it is also a principal waste management mechanism. In whole world huge amount of wastes produced after harvesting. Those wastes can be a good source for alternative energy, new material like bio-composite and also for manure purposes. This study principally focuses on the utilization of agricultural wastes for sustainable development in areas related to organic manure usage, bioenergy production from the agricultural residues, and manufacturing of bio-composites. This article also addresses the potential of agricultural wastes in particular regions and the extent of their utilization to come up with a broader understanding of their effectiveness and practicality.

Keywords: Biomass, Agricultural wastes, Sustainability, Bioenergy

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1. Introduction

In the contemporary and dynamic world, population growth, technological advancement, food production abundance, and ultimately waste accumulation are expected outcomes. Bearing in mind the global population is increasing and it tends to rise, the core point is that how well the waste can be managed. This applies to agricultural wastes as well. Embracing the idea of recycling wastes or changing waste to energy is an indispensable choice for sustainable development, and it is also a principal waste management mechanism. Accordingly, this means guarantees the shift from a subsistence economy to a progressive economy.

The residues from the cultivation and processing of raw agricultural products such as field crops, fruits, vegetables, meat, poultry, dairy products, and crops are defined as agricultural wastes. They are the by-products of the production and processing of farm products that possibly comprise substances that profit users. Reasonably agro-wastes are having values inferior to the cost of gathering, transportation, and processing for useful purposes. Agricultural wastes exist in the form of liquids, slurries, or solids. The compositions of agricultural wastes greatly depend on the nature and kind of farm activities. They include animal manure, carcasses, food processing wastes and drops, and discarded fruits and vegetables. Although potential evaluations of agricultural waste are scarce, it is normally supposed that agricultural wastes contribute a substantial portion of the total waste materials in the developed world.

One-third of all edible components of food produced for human consumption is anticipated to be lost or wasted (FAO, 2015), with losses estimated to be worth $1 trillion USD (FAO, 2013). According to (Agamuthu, 2009) it is estimated that about 998 million tons of agricultural waste are produced annually. Out of which organic wastes covers up to 80 percent of the total solid wastes produced in any farm while manure amounts up to 5.27 kg/day/1000 kg live weight, on a wet weight basis (Obi et al., 2016). Indeed, an upsurge in agricultural production has resulted in an increased volume of livestock waste, crop residues, and industrial by-products. Similarly, there is a likelihood of a significant rise in agricultural wastes accumulation worldwide as developing countries keep on strengthening agricultural activities.

Innovation, science, and engineering have been the precursors for the rise in agricultural production that is considered a milestone as it meets the food demand due to the surge of population. Nonetheless, an increase in agricultural wastes accumulation continues to be a significant management challenge. This study principally focuses on the utilization of agricultural wastes for sustainable development in areas related to organic manure usage, bioenergy production from the agricultural residues, and manufacturing of biocomposites. This article addresses the potential of agricultural wastes in particular regions and the extent of their utilization to come up with a broader understanding of their effectiveness and practicality.

2. Agricultural Production in Turkey

In Turkey agricultural activities are at the forefront of the economy, agriculture has a great significance in meeting food demand, industrial raw materials and plays a huge role in exporting commodities and creating employment opportunities. Thus a huge amount of agricultural waste is generated annually. Agricultural wastes are residues from growing and processing agricultural products, which have no direct and considerable use. Crops and animals account for over 90% of Turkey's agricultural industry. Ecological and health issues associated with wastes produced by the agricultural industry are significantly high (Dumanli et al., 2007). Approximately three-fourths of total Turkey's cropland and annual production is covered by cereal products such as wheat and barley. Cottonseed and sugar beet are among the other important products of Turkey having an estimated annual production of approximately 2 million tons, and 10 million tons, respectively (Dumanli et al., 2007).

According to the sources from the Turkish Statistical Institute (TUIK) the total production from crops such as wheat, corn, nut, legumes, citrus, sunflower, tobacco, mulberry, cotton, rose, rice, sugar beet, olive, peanuts, tea, sesame, and fruits is presented in Table 1. Having the above agricultural production, the potential of agricultural residues from main crops is computed using the ratio of product to residues, and the averaged amount is represented in Table 2. Moreover, the potential of residues from main fruits has been computed as it appears in Table 3.

Similarly according to the data from TUIK, the potential of animal production in Turkey has been depicted in Table 4. By using the values provided in Table 5 the amount of waste from animals can be determined. For cattle, the body weight is taken as 400 kg, 50 kg for small ruminants, and 2 kg for poultry. Along with this, the daily amount of wet waste, as a percentage of body weight is chosen as 5% for cattle, 4% for small ruminants, and 5% for poultry (Onurbas and Türker, 2012). According to these values, daily amounts of wet waste are considered as 20 kg for cattle/day, 2 kg/day for small ruminant, and 0.1 kg for poultry/day.

Table 1. Crop production in Turkey

Types of produce	Year	Tons
Cereals	2019-2020	33401704
Rice	"	600000
Dried pulses	"	1230281
Potato	"	4979824
oil seed	"	2100000
Sugar beet	"	18054320
Nuts	"	1308701
Citrus Fruits	"	4301415
Other fruits	"	530723
Tea		1407448
Root and Tuber	"	3328051
Vegetables cultivated for their fruit	"	24336795
Leguminous vegetables	"	734342
Other vegetables	"	1788209
Total vegetables	"	26859346

Table 2. Agricultural residue potential in Turkey from main field crops (Ergudenler and Isıgıgur, 1995; Ozturk and Bascetincelik, 2006; Onurbas et al., 2011; Okello et al., 2013; Riva et al., 2014)

Agricultural crops	Residue types	Ratio of product Residue (RPR)	Production (Ton)	Residue (Ton)	Reference
Wheat	Straws	1.125	19000000	21375000	1,4
Barley	Straws	1.22	7600000	9272000	1
Maize	stalks	1.6	6000000	9600000	4
Rapeseed	Stalks	1.7	180000	306000	3
Sugar beet	Leaves	0.13	18054320	2347062	4
Rice	Straw	1.1	600000	660000	1
Soybean	Straws	2.13	150000	319500	1
Chickpea	Straws	1.3	630000	819000	2
Beans	Stems	1.45	225000	326250	5
Cotton	Stalks	2.3	1320000	3036000	1
Potato	Vines	0.4	4979824	1991929.6	5
Tubers	Leaves	0.5	3328051	1664026	1
Walnut	Shells	0.66	225000	148500	1
Hazelnut	Shells	0.87	776046	675160.02	1

Table 3. Agricultural residue potential in Turkey from main fruits (Ozturk and Bascetincelik, 2006; Okello et al., 2013; Riva et al., 2014)

Fruit Type	Residue types	Ratio of product Residue (RPR)	Production (Ton)	Residue (Ton)	Reference
Grape	Pruning	0.42	4100000	1722000	1
Lemon	Pruning	0.3	950000	285000	1
Mandarin	Pruning	0.29	1400000	406000	1
Orange	Pruning	0.35	1700000	595000	1
Banana	Stalk-Peels	2	548323	1096646	3
Fig	Pruning	0.21	310000	65100	2
Pear	Pruning	0.22	530723	116759.06	2
Cherry	Pruning	0.19	664224	126202.56	1
Peach	Pruning	0.4	830577	332230.8	2
Apricot	Pruning	0.19	863856	164132.64	1
Apple	Pruning	0.19	3618752	687562.88	1
Grape fruit	Pruning	0.11	249185	27410.35	1

Table 4. Number of farm animals in Turkey from TUIK for 2020

Animal Type	Number of Animals
Cattle	18157971
Sheep	42126781
Goat	11985845
Other	225713
Poultry	386 080 582

3. Potential of Agricultural Crop Residues in the European Union

Varying climatic features and agronomical practices across the member states are the leading reasons for great variations of yields, crop types, and arable areas, in the European Union. In terms of area cultivated and amount of production, cereals and oilseeds are of great significance. Likewise, depending on variability in rain-fed conditions, crop residues produced from annual crops are quite variable in yield from one year to another (Scarlat et al., 2010).

As a common agricultural practice, some portion of the substantial amount of agricultural residues is left in the field after harvest. The amount of residue production depends on several factors such as the types of crops, crop rotation, crop mix, and agricultural practices (Summers et al., 2003). The amount of residues is directly related to crop yield, total arable area. Along with these all reasons the availability of residues is also affected by the amount that can be used for agricultural or industrial purposes.

According to the data from the Food and Agricultural Organization FAO database, the agricultural production of the European Union for the year 2019 is shown in Table 6. The estimate of agricultural residues is directly related to crop production thus, depending on the crop yield and type the potential of residues of specific crop that can be employed for different purposes by using data and the ratio of product to residue is as follows.

Similarly the potential of residues from fruit crops has been summarized in Table 7 by applying the same approach used in assessing the amount of residues in Turkey. The European Union is characterized by the production of large of amount of livestock. According to the FAOSTAT the animal population is represented as it follows in Table 8. By employing the data given in Table 8 the total wet waste in daily basis is estimated with the approach of body mass ratio and has been summarized in Table 9.

Table 5. Wet waste estimation from the population of animals in Turkey

Animal Type	Body weight (kg)	% of weight	Number of Animals	Wet waste 10^3kg/day
Cattle	400	5	18157971	363159.42
Sheep	50	4	42126781	84253.56
Goat	50	4	11985845	23971.69
Poultry	5	5	386 080 582	96520.14

Table 6. Agricultural residue potential in the European Union from selected crops

Crops	Yield (Ton)	RPR	Residue (Ton)
Barley	63618190	1.22	77614191
Beans, green	995526	1.45	1443512
Hazelnuts	132410	0.87	115196
Maize	70092950	1.6	112148720
Potatoes	56403790	0.4	22561516
Rapeseed	17040880	1.7	28969496
Rice, paddy	2849130	1.1	3134043
Sorghum	1022120	1.25	1277650
Soybeans	2813260	2.13	5992243
Sugar beet	120577650	0.13	15675094
Walnuts	169730	0.66	112021
Wheat	155641710	1.125	175096923
Pulses	4916439	1.3	6391370
Tubers	56403790	0.5	28201895
Tree-nuts	1105770	0.66	729808
Vegetables	55295312	0.4	22118124

Table 7. Agricultural residue potential in the European Union from fruit crops

Crops	Yield (Ton)	RPR	Residues (Ton)
Apples	12044780	0.19	2288508
Apricots	771200	0.19	146528
Bananas	643610	2	1287220
Cherries	578055	0.19	109830
Cherries, sour	295790	0.19	56200
Figs	92420	0.21	19408
Grapefruit	103190	0.11	11351
Grapes	24216454	0.42	10170911
Oranges	6096740	0.35	2133859
Pears	2080036	0.22	457608

Table 8. Number of farm animals in the EU for 2019 according to FAOSTAT

Animal Type	Number of Animals
Buffaloes	459100
Cattle	86877723
Poultry	1280598
Goats	12219237
Horses	2879538
Pigs	148236856
Sheep	97272502

Table 9. Wet waste estimation from the population of animals in the EU

Animal	BW (kg)	NA	WW
Buffaloes	400	459100	9182
Cattle	400	86877723	1737554.5
Poultry	50	1280598	2561.2
Goats	50	12219237	24438.5
Sheep	5	97272502	243181.2

BW= body weight, NA= number of animals, WW= wet waste, 10^3 kg/day

4. Organic Manure

Organic fertilizers are mineral sources that are found in nature having an adequate amount of plant nutrients. They are capable of resolving issues caused by artificial fertilizers. They minimize the need to apply chemical fertilizers on a regular basis to preserve agricultural productivity. Organic fertilizers gently discharge nutrients into the soil, maintaining nutrient balance for plant growth and development. Organic fertilizers obtained from animal waste and plant residue serve as an effective energy source of soil microbes which play a great role in improving soil structure and crop growth.

Although better than chemical fertilizers when used improperly organic fertilizers can cause over-fertilization or nutrient deficiency in the soil (Lewu et al., 2021). Thus, the application of organic manure and residues is advantageous and has a positive impact to attain a sustainable agricultural industry. Using livestock manure as a fertilizer has a substantial effect on agricultural input energy demands (Obi et al., 2016). Manure can contribute a considerable amount of nitrogen, phosphorus, and potassium. Poultry manure is rich in phosphorus and has a favorable impact on crop growth and productivity. It is also important for agricultural use when mixed with mineral phosphorus fertilizer. Moreover, manure enhances soil fertility by increasing action exchange capacity, as well as improving water-holding capacity, and soil structural stability (Andong et al., 2019; Mokwunye, 2000).

According to (Jacinthe et al., 2011) manure applied to cultivated increases soil nutrients, and helps to absorb carbon in the soil. Comparing to traditional farming practices, Organic farming practices expand the size of the soil microbial population, additionally, the organic farming process enhances carbon substrate more effectively than conventional farming. Organic manure has a major role in facilitating composting. In the process of rapid composting of dairy manure with rice chaff changes in biochemical and microbiological parameters were found to be feasible for treating agricultural wastes, where dairy manure to rice chaff 3:1 volumetric ratio exhibited the most rapid temperature increase, the highest microbial population, and enzymatic activities, and hence the highest compositing rate (Liu et al., 2011).

5. Agricultural Wastes as Biofuels

The total energy consumption of the world was estimated at about 524 exajoules per year and has been anticipated to increase by about 65% by 2040 (Kambo and Dutta, 2015). In energy summits depletion of resources, the surge in price, and adverse ecological concerns related to the use of fossil fuels are the main discussion subjects. Decreasing consumption by replacing it with a sustainable and renewable energy resource would be among the most efficient lines of tackling these concerns. Biomass is a material of plant and animal origin including the materials acquired as a result of natural and artificial conversion. Materials including animal and municipal solid wastes are also labeled as biomass (Demirbaş, 2001). Biomass is the only renewable energy source that can be transformed into solid, liquid, and gaseous fuel (Özbay, 2001).

In their study (Hamawand et al., 2016) discovered that cotton waste represents a large percentage of the agricultural waste created as a by-product in Australia. Due to its woody structure, cotton stalk is found to be more appropriate for the production of energy pellets. Likewise, the difficulty, capital, and operating costs of such appellation are lower than the other alternatives. What is more important is that these palettes have the potential to be used in power plants to generate electricity. Agricultural wastes comprise lingo-cellulosic, which may be converted into biofuel using biochemical or thermochemical techniques, as shown in Table 10 below. For biochemical conversion for biofuel generation, feed-stocks with moisture content more than 30%, their C/N ratio of less than 30%, and high cellulose and hemicellulose content are required. While, Materials with less than 30% moisture, a C/N ratio of more than 30%, and a high lignin content are preferable for thermochemical conversion and subsequent treatment for biofuel generation.

In the biochemical method, various microorganisms are involved and the application of enzymes is essential to break down the feedstock into intermediate components such as sugars and amino acids before its conversion into liquid or gaseous fuel, such as biogas, bioethanol, and biodiesel. On the contrary, the thermochemical process is characterized by the application of heat and chemicals to produce synthesis gas or syngas, bio-oil, biochar, and biocoal. Even though thermochemical path uses a broad spectrum of wastes, from the standpoint of fossil fuel consumption and greenhouse gas emissions, the biochemical route is more preferable to the thermochemical route (Mu et al., 2010).

Table 10. Methods for Biofuel production

	Conversion Pathways	Methods	Biofuels		
Agricultural Waste	Biochemical Conversion	Fermentation	Bioethanol		
		ABE Fermentation	Bio-butanol		
		Anaerobic Digestion	Biogas		
		Dark Fermentation	Biogas		
	Thermochemical Conversion	Pyrolsysis	Syngas	Bio-oil	Char
		Gasification	Syngas		
		Torrefaction	Bio-oil		

6. Biogas

In Turkey imports of energy are expected to rise from nearly 70% to 90% of the total energy demands as the total energy demand is expected to double in the next decade. Meanwhile, it is predicted that the total biomass energy production will reach 52.5 Mtoe by 2030 (Balat, 2011). The biogas potential in a volume equal to animal-based waste potential in Turkey is said to be about 1.7 billion m3 per year. While biomass-based energy potential contributes to sustainable development, further investigation is necessary to figure out and formulate solutions at all levels to accelerate biomass usage (Ozturk et al., 2017). The poultry industry is one of the promptly growing industries in turkey. Most of the provinces engaged in large-scale poultry farming have over 1PJ biogas potential. The industry has a faster pace than the typical pace in the globe which proves the efficiency of the sector. Nevertheless, one of the major challenges of this industry is eliminating wastes (Avcioglu and Turker, 2012).

Generating biogas from farm residues makes an effective decrease of non-renewable energy consumption and particularly greenhouse gas release because of the reduction of methane emission that would have occurred due to manure storage. Thus designing biogas systems as per the climatic features and production facilities for low investment costs, high efficiency, and easy installation, operation and maintenance would certainly strengthen the growth of the biogas industry.

7. Biocomposites

Bio-composites are materials manufactured using renewable resources which are abundantly available. Bio-composites are ecologically friendly and decomposable, having characteristics that can be easily manipulated as per their particular application (Vinod et al., 2020). They are well-matched in the biomedical, automotive, and food industry. From the manufacturing industries' perspectives as bio-composites are multipurpose materials, farming for the production of raw materials is much encouraged, which consequently decreases the greenhouse effect (Ferreira et al., 2019).

Using residues or organic wastes in the formulations of composite is also a different method. For instance, improving the properties of the composites using biochar in polymer composites is a relatively new approach (Das et al., 2015). Through the process of pyrolysis, organic wastes can be changed into biochar, liquids and non-condensable gases as the feedstock are subjected to high temperatures. Biochar, charcoal-like material which is produced by burning organic matter, can play a great role in reducing toxic emissions because of its bulk surface area, pore size distribution, particle size distribution, packing, and density. Additionally, it is also helpful in reducing pollution by binding the heavy metals in soils and liquids (Väisänen et al., 2016). Nowadays finding novel and innovative ways of utilizing wastes and residues evolving from industrial and agricultural practices is one of the alarming ecological challenges. According to Sun et al., 2013 biomass residues are the potential raw material for biochar production. In addition to pyrolysis through pyrolytic processes, such as torrefaction biomass can be transformed into biochar. Nearly all forms of biomass can be changed into biochar. Biochar tends towards being cheap adsorbent, because of its capability to store some of the most familiar ecological contaminants.

Waste biomass streams have the highest potential to be economically feasible sources of biochar, On the other hand, being cost-effective farm residues have high potential in the area of energy generation and pollutant reduction (Roberts et al., 2009). Research on the development of composites made of different waste materials is being dynamically undertaken as the result of the worldwide demand for fibrous resources, wide range scarcity of trees, and growing ecological alertness. Developing composites using agricultural residuals such as stalks of most cereal crops, husks, cobs, shells, and other wastes has been among the promising options (Wang et al., 2009). Because they are abundant, prevalent, and easily accessible farm residues are one of the best alternative materials to replace wood. Apart from their availability and renewability, from an economic, environmental, and technological point of view utilization of agricultural residues is beneficial (Çöpür et al., 2007). Pyrolysis is a potential process for producing biochar and biofuels from digestates. Through intermediate pyrolysis, (Neumann et al., 2015) obtained bio-oil, pyrolysis char, and non-condensable gases from digestates obtained from an anaerobic digestion unit. They were able to transform approximately 91 percent of the biomass's initial energy content into products that could be used. Apart from plant fibers, biochars can be created from cow or chicken (Schouten et al., 2012; Hass et al., 2012) manure. Schouten et al. (2012) applied cattle manure to make biochar in an attempt to see whether anaerobically generated digestate and biochar had more carbon sequestration capacity than the manure. The study anticipated that the nitrogen mineralization of digestate and biochar would be lower than that of manure. According to the findings, the release of nitrogen in soil produced from the by-product decreased with anaerobic digestion and much more following pyrolysis.

According to a study, applying chicken dung biochar to a typical acid and severely weathered soil raised pH, enhanced nutrient availability, and lowered harmful and non-essential element levels (Hass et al., 2012). To conclude, the energy conversion industry is heavily focused on the use of organic matter and residues by traditional or even novel methods, yet there is an excess of underutilized or even completely unutilized residual material. Thus, instead of employing these materials as a local source of energy, their potential use could be considerably expanded by integrating them further into alternative technologies (Väisänen et al., 2016).

The potential of using organic materials and residues as ingredients or reinforcements in natural fiber-polymer composites NFPCs has been a center of interest, particularly in the last decade. The use of organic wastes in NFPCs has many advantages. Organic wastes and residues may be integrated into NFPCs in a variety of ways. For instance, relative levels of materials generated from non-renewable sources, such as matrix polymers and certain additives, can be reduced. As a result, the proportion of raw materials derived from renewable sources will rise, potentially lowering composites' overall raw material prices. The use of straw and other agricultural waste for composite material production has become a global interest. A study aimed at utilizing rice straw and corn-based adhesives for the development of eco-friendly materials composites made from hot-water treated straw and cornstarch showed a better interface and greater flexural characteristics (Liu et al., 2012).

8. Conclusion

Out of the ever-growing agricultural industry, a huge amount of agricultural waste is generated annually. Practically agro-wastes are having values inferior to the cost of gathering, transportation, and processing for useful purposes. Though part of residues is employed for immediate purposes, managing or eliminating agricultural wastes is one of the principal challenges of the modern agricultural industry and environmental safety. In handling the issue making estimates and knowing the potential application of every agricultural waste source is vital. Thus, it has been clear that the role of utilizing agricultural wastes in sustainable development is significant from organic manure to bioenergy and biodegradable materials.

Author Contributions

All authors had equal contribution and all authors reviewed and approved the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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