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AGRICULTURAL WASTE POTENTIAL OF TÜRKİYE

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Abstract: In Türkiye, agricultural activities are carried out on an area of 38482000 hectares. In Türkiye, where different climates are seen, animal husbandry is done intensively. Some of the animal and herbal products produced are consumed in the country and some are exported and consumed abroad. Many agricultural wastes are generated during animal and plant production activities. These wastes are fresh manures formed during animal production, wastes formed from grain and industrial plants during plant production, wastes formed during and after production in greenhouses, pruning wastes and wastes formed as a result of evisceration of hard-shelled fruits. In this study, agricultural wastes that can be obtained from these products were calculated based on the products with the highest production. According to the results of the study, in the light of 2022 data, the annual amount of manure that can be obtained from our livestock is 20.722 million tons on dry basis, 16.805 million tons of waste from grain and industrial plants, 393,048 thousand tons of waste generated during and after production in greenhouses, 3.045 million tons of pruning waste, wastes generated as a result of evisceration of hard-shelled fruits are 550.186 thousand tons and olive pulp (pomace) resulting from olive oil extraction is 1.630 million tons.

Keywords: Agricultural waste, Biomass, Livestock manure, Pruning waste, Greenhouse waste, Olive pulp

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1. Introduction

In Türkiye, agricultural activities are carried out on an area of 38482000 hectares. The area of 20194000 hectares, which corresponds to 52.48% of this area, is considered as the total cultivated area. 16510000 hectares of this area is planted area, 2960000 hectares is fallow land, 718000 hectares is vegetable garden area and 6000 hectares is ornamental plants area. There are perennial plants and trees on an area of 3671000 hectares, which corresponds to 9.54% of the total area where agricultural activities are carried out. 2385000 hectares of this area consists of other fruit, beverage and spice crops, 385000 hectares of vineyards and 901000 hectares of olive trees. It is considered as meadow pastureland on an area of 14617000 hectares, which corresponds to 37.98% of the total area where agricultural activities are carried out (TUIK, 2022).

If we look at the number of animals in Türkiye, according to the statistics of 2022, there are 17023791 bovine, 56265750 ovine and 361096026 poultry (TUIK, 2022).

While the activities in plant production are carried out at certain time periods during the year, production activities in animal husbandry continue throughout the year. There are many agricultural wastes generated during these activities, which can sometimes be evaluated and sometimes not adequately evaluated because they are formed suddenly and in large quantities. While some of the agricultural wastes can be evaluated directly without any treatment, some of them can be evaluated by going through some special processes. Some of these wastes can be used directly for animal feeding, and some of them can be directly used as fuel due to the thermal value they contain. Some of them are subjected to special processes and the thermal energy contained in them is evaluated by processes such as gasification and pyrolysis, they can be compressed and pressed into pellets or briquettes and used as fuel and can also be used as fertilizer to benefit from the high organic matter they contain. A large part of it is destroyed by burning directly or left to nature in a haphazard way, so no benefit can be obtained.

There is a need for farm scale or factory scale enterprises where these agricultural wastes can be subjected to these special processes. This requires a certain cost and investment. When the agricultural structure in Türkiye is examined, it is seen that the enterprises are small family enterprises. For this reason, the establishment and operation of such evaluation facilities in small family businesses is not considered very possible in practice.

In large enterprises where products are purchased and processed from the producer and their added value is increased, the establishment and operation of such waste recycling facilities is economically more convenient and more economical. It will be more beneficial to use the wastes generated during product processing for another purpose and to bring them into the economy. However, since such investments are not self-financing in a short time, they are not very attractive to establish and operate. In order to increase the number of such

enterprises, it is necessary to support the government and to make the establishment of facilities established for the evaluation of type wastes attractive. This will be an investment in both the country's economy and the environment.

2. Materials and Methods

In many studies, the methods used in the evaluation of agricultural wastes and the waste potentials that can be used in this method and the gains that can be obtained have been calculated. In this study, the amounts of all possible agricultural wastes that can be evaluated have been tried to be calculated.

The agricultural wastes that can be obtained are calculated in five different parts. These are dry matter-based manures that can be obtained from farm animals, post-harvest wastes that can be handled from grain and industrial plants, wastes from glass and plastic greenhouses formed in greenhouse production, pruning wastes, shell wastes formed during fruit extraction of hard crustaceans, and olive pomace (prina) formed during olive oil production.

2.1. Livestock Manure

Two different methods were used to calculate the manure potential. First, the total potential was found according to the calculation method used by Özcan et al (2011). Here, the calculation was made by classifying only the livestock as bovine, ovine and poultry. Based on the annual wet manure production of farm animals, then adding the dry matter content and usability rates, the annual usable manure production was calculated as 18.16 Mton/year. The details of the calculation are shown in Table 1.

In the second method, it was calculated separately for each farm animal by using the standards of the American Agricultural Engineers Association (ASAE, 2003). This standard is based on the manure produced by 1000 kg live weight. Live weights of each animal are given separately. The amount of manure that can be produced and produced according to the standards of the American Agricultural Engineers Association is 23.28 Mton/year on a dry basis. This method is more detailed than the first method. The details of the calculation are shown in Table 2.

Table 1. Annual obtainable manure potential (TUIK, 2022)

2022*	Bovine	Ovine	Poultry
Number of animals	17023791	56265750	361096026
Unit wet manure amount (ton/year)	9.95	0.82	0.03
Total amount of wet manure (ton/year)	169386700	46137920	10832881
Dry matter content (%)	12.7	25	25
Total amount of dry manure (ton/year)	21512110	11534480	2708220
Availability (%)	65	13	99
Usable total amount of dry manure (ton/year)	13982870	1499482	2681138
TOTAL (ton/year)			18163494

Table 2. Manure potential according to american society of agricultural engineers standards (TUIK, 2022)

Type of animal	Number of animals*	Live weight	Manure produced for 1000 kg live weight	Annual fresh manure (ton)	Barn retention rates (%)	Obtainable manure (ton)	Dry matter ratio (%)	Manure as obtainable dry matter (ton)
Cattle	17023791	640	86	342001151.7	50	171000575.8	12	20520069.10
Pig	1648	61	84	3082.19	80	246.75	11	271.23
Sheep	44687888	27	40	17615965.45	13	2290075.51	11	251908.31
Goat	11577862	64	41	11088813.11	13	1441545.70	13	187400.94
Türkiye	3669726	6.8	47	428088.22	68	291099.99	12	34932.00
Horse	74359	450	51	622886.75	29	180637.16	15	27095.57
Broiler	251289799	0.9	85	7016639.41	99	6946473.02	22	1528224.06
Laying hen	109806327	1.8	64	4617136.44	99	4570965.07	16	73135.41
TOTAL (ton)								2328125.63

The annual dry matter-based manure amount that can be obtained in the first method was calculated as 18.163494 million tons, and the annual dry matter-based manure amount that could be obtained in the second method was calculated as 23.28 Mton. The average of these two calculations is 20.72 Mton/year on dry matter basis. This average value will be accepted in this study.

2.2. Grain and Agricultural Products Processing Industry Wastes

In this section, six products that are produced the most in Türkiye are taken as basis. These products are wheat, barley, corn, sunflower, seed cotton and sugar beet. When we look at the literature, although there are different methods for the calculation of agricultural waste, the calculation method based on the harvest index will be used in this research (Mardikis et al., 2004; Polat, 2020). There is a relationship between the amount of agricultural waste and product yield, and therefore between the harvest index and the amount of product. The relationship between the harvest index and the amount of waste can be expressed as in the Equations 1, 2 and 3 given below (Polat, 2020).

$$HI = \frac{M_{ü}}{M_a + M_{ü}} \quad (1)$$

$$Ma = Mü \times (\frac{1}{HI} - 1) \quad (2)$$

$$Mk = Ma \times (1 - r_n) \quad (3)$$

In these equations, HI; Harvest index, Mü; Amount of product (tons), Ma; Amount of waste (tons), Mk; Dry matter amount of the waste (tons), rn; The moisture content is given as (%). It is not possible to obtain and use all of the agricultural wastes. The amount of waste generated should be multiplied by the percentage availability. In the calculations, the harvest indexes were accepted as follows. 0.37 for wheat (Önder et al., 2007; Deniz et al., 2010; Polat, 2020), 0.34 for barley (Deniz et al., 2010; Polat, 2020), 0.42 for corn (Taner et al., 2004; Polat, 2020), 0.35-0.42 for sunflower (Polat, 2020), on average 0.30 for cotton (Baydar and Kanber, 2012; Polat, 2020) and 0.90 for sugar beet (Polat, 2020).

The moisture rates of these products were accepted as follows; 15% for wheat and barley, 47% for corn, 15% for sunflower, 17% for cotton and 30% for sugar beet (Başçetinçelik et al., 2007; Polat, 2020).

The usability percentages for the products in question were accepted as follows; 14% for wheat, 15% for barley, 60% for sunflower and corn, 70% for cotton and 55% for sugar beet (Mardikis et al., 2004; Başçetinçelik et al., 2007; Polat, 2020).

With the help of the formulas given here, the amount of waste that can be obtained for wheat, barley, corn, sunflower, seed cotton and sugar beet is 16,805180 million tons on a dry basis, according to 2022 production data. Details of the calculation are given in Table 3.

Table 3. Waste potential from grain and industrial plants (TUIK, 2022)

Product type	Produce amount* (ton)	Harvest Index	Humidity rates (%)	Availability percentages (%)	Total Waste (ton)	Dry Matter (ton)	Usable Dry Matter (ton)
Wheat	19750000	0.37	0.15	0.14	33628378.38	28584121.62	4001777.03
Barley	8500000	0.34	0.15	0.15	16500000.00	14025000.00	2103750.00
Sweetcorn	8500000	0.42	0.47	0.6	11738095.24	6221190.48	3732714.29
Sunflower	2550000	0.35	0.15	0.6	4735714.29	4025357.14	2415214.29
Cotton (raw)	2750000	0.3	0.17	0.7	6416666.67	5325833.33	3728083.33
Sugar beet	19253962	0.9	0.3	0.55	2139329.11	1497530.38	823641.71
TOTAL							16805180.64

2.3. Greenhouse Wastes

In Türkiye, greenhouse production areas increase and support agricultural production. Greenhouses where greenhouse production is carried out are divided into two as glass and plastic covered greenhouses. Plastic greenhouses are divided into three in themselves as plastic greenhouse, low tunnel plastic greenhouse and high tunnel plastic greenhouse. According to 2022 data (TUIK, 2022), greenhouse production is carried out on a total area of 810881 decares. Glass greenhouse with an area of 59663 decares, which constitutes 7.35% of this area. It is a plastic greenhouse with an area of 471284 decares, constituting 58.12% of it. It is a high tunnel plastic greenhouse with an area of 110426 decares, constituting 13.62% of it, and a low tunnel plastic greenhouse with an area of 169538 decares, which constitutes 20.91%. Vegetables, fruits and ornamental plants are produced in greenhouses. Statistical values show that 8178089 tons of vegetables, 1151293 tons of fruit, 1357624870 branch cut flowers, 197860415 outdoor ornamental plants, 42387977 indoor ornamental plants and 1833300 bulbs were produced in 2022 (TUIK, 2022).

Wastes generated in greenhouse vegetable cultivation are divided into two as waste generated during production and waste generated during dismantling after production. In this section, wastes from tomato, pepper and eggplant plants, which are the most produced in greenhouse vegetable production, will be calculated. There is no scientific data on the amount of waste produced by other vegetables grown. In addition, no major problems have arisen regarding the waste generated by other products. In Türkiye, at the end of the tomato, pepper and eggplant growing season, the waste piles formed as a result of the dismantling wastes are reflected to the public from time to time and it is emphasized that it creates a problem.

In this calculation, the amount of waste in the study conducted by Bilgin et al. (2012) was taken as a basis. Waste amounts have been calculated separately for glass and plastic greenhouses where all three crops are grown. The amount of waste that can be obtained from glass greenhouses is 47836.84 tons annually on a dry basis, and the amount of waste that can be obtained from plastic greenhouses is 345211.21 tons on a dry basis annually. The total amount of waste that can be obtained from greenhouses on an annual dry basis is 393048.05 tons. Calculations related to these wastes are shown in Table 4.

2.4. Pruning Wastes

Pruning is the process of cutting the parts that are aging, drying, sick or preventing development and growth in plants. Pruning can be done for different purposes. For example, in fruit trees with low fruit yield, pruning is done to increase the yield, to make the fruits healthier, to prevent overgrowth, and to give the plants a certain form and preserve this form.

Table 4. Amount of waste that can be obtained in greenhouse production

Glass greenhouse				Plastic greenhouse		
Product	Cultivation area (decare)	Waste amount*	Total waste (ton)	Cultivation area (decare)	Waste amount*	Total waste (ton)
Tomatoes	30980	1.07	33148.60	227317	1.03	234136.51
Pepper	10629	0.93	9884.97	93946	0.93	87369.78
Aubergine	5521	0.87	4803.27	25218	0.94	23704.92
TOTAL		47836.84			345211.21	
GRAND TOTAL				393048.05		

*Dry basis (ton/decare)

In this section, a calculation is made based on perennial fruit trees. Annual pruning waste amounts and usable pruning waste amounts were calculated by utilizing the number of fruit-bearing adult trees from (TUIK, 2022) agricultural statistics, pruning coefficients determined in the study conducted by Bilandzija et al. (2012) and usability rates determined by CEC (California Energy Commission) (Williams et al. , 2015; Sümer et al., 2016). Here, 14 types of trees were considered and total pruning waste was calculated based on the number of trees.

In addition, the pruning wastes of the grape plant, which has an important place in fruit production, were calculated based on the area. In the literature, two different values have been found in this regard as 3 tons (Arık, 2023) and 5 tons (Bekar, 2016) per hectare. This value varies depending on the type and age of the vineyards, and in the calculation in this section, it was taken as 5 tons per hectare.

According to the calculations, the annual amount of pruning waste that can be obtained from 14 types of trees is 3031.60 thousand tons, and the annual amount of pruning waste that can be obtained from vineyards is 13.46 thousand tons. Details about these are given in table 5 and table 6. The annual amount of pruning waste that can be obtained in total is 3045.06 thousand tons. It could not be added to this amount because there is no reliable data on pruning wastes from parks and gardens.

Table 5. Amount of pruning wastes

Fruit tree	Number of trees bearing fruit	Pruning coefficient per tree (kg/year)	Pruning waste (ton/year)	Usable rate (%)	Usable pruning waste (ton/year)
Olive	163035000	9.08	1480357.80	0.70	1036250.46
Hazelnut	395994000	3.05	1207781.70	0.70	845447.19
Pistachio	58144000	8.80	511667.20	0.70	358167.04
Citrus	48428000	5.30	256668.40	0.70	179667.88
Apple	75913000	2.34	177636.42	0.70	124345.49
Cherry	22200000	5.90	130980.00	0.70	91686.00
Peach	20416000	7.23	147607.68	0.70	103325.38
Apricot	19158000	5.79	110924.82	0.70	77647.37
Plum	9184000	7.34	67410.56	0.70	47187.39
Fig	10852000	4.58	49702.16	0.70	34791.51
Almond	13616000	5.81	79108.96	0.70	55376.27
Cherry	5611000	5.37	30131.07	0.70	21091.75
Pear	11554000	2.45	28307.30	0.70	19815.11
Walnut	15327000	3.43	52571.61	0.70	36800.13
TOTAL					3031598.98

Table 6. Pruning wastes from vineyards

Fruit	Area (ha)	Pruning coefficient per hectare (ton /year)	Pruning waste (ton/year)	Usable rate (%)	Usable pruning waste (ton/year)
Grape	3845	5	19225	0.70	13457.5

2.5. Wastes from Some Hard Shell Fruits and Olive Oil Production

In this section, the amount of wastes generated during evisceration of hazelnuts, walnuts, pistachios, almonds and apricot seed and olive oil production has been calculated. Since the evisceration processes of hazelnut, walnut, pistachio and apricot seed are fabricated, the shells obtained come out in large quantities and are pressed, briquetted or pelleted with this shell, which is largely evaluated as solid fuel and brought into the economy. In addition, these wastes can be used in the furniture industry. The rind ratio of the hard-shelled fruits here varies depending on the variety and climate characteristics. For this reason, average values were taken. There is scientific data on pistachio in the literature. The soft shell of the pistachio fruit with a moisture content of 6% constitutes 18.04% of the total weight, the hard shell constitutes 37.93%, and the interior constitutes 44.03% (Gezginç and Duman, 2004). The shell ratio in hazelnut was taken as 50%, in walnut

35-50% (on average 42.5%), in almond 50%, in apricot seed 75%. When we look at the availability rates, only 50% of the shelled walnuts are used in the pastry and dessert sector, so shells can be obtained at this rate. Since the other part is consumed at home, it is disposed of as household garbage and cannot be handled in practice. Since pistachios are mostly consumed as nuts, only 40% of the hard shells can be obtained. According to the data of 2022, the amount of waste that can be obtained in line with this information is 550186.6 tons. This waste is largely considered as solid fuel. The details of the calculation are given in Table 7 and Table 8.

Table 7. Hard shell fruits wastes

Hard Shell Fruits	Annual production (ton)	Usable production (ton)	Shell ratio (%)	Waste amount (ton)	Obtainability (%)	Obtainable waste (ton)
Hazelnut	684000	677844	50	338922	100	338922
Walnut	325000	317200	35-50	134810	50	67405
Pistachios soft shell	119355	116371	18.04	20993.3284	100	20993.33
Pistachio hard shell	119355	116371	37.93	44139.5203	40	17655.81
Almond	178000	174796	50	87398	100	87398

Table 8. Apricot seed wastes

Fruit	Annual production (ton)	Usable production (ton)	Shell ratio (%)	Waste amount (ton)	Obtainability (%)	Obtainable waste (ton)
Apricot seed	95000*	23750	75	17812.5	100	17812.5

*2022 dried apricot production estimation. Approximately 25% of this apricot seed is produced.

Table 9. Olive pulp production

Fruit	Annual production (ton)	Pulp rate (%)	Olive pomace amount (ton)	Obtainability (%)	Obtainable waste (ton)
Olive for oil	2037783	80	1630226.4	100	1630226

Türkiye has an important place in world olive and olive oil production. Olive oil yield varies according to different varieties. One kg of olive oil is obtained by squeezing 3-8 kg of olives. When calculating in this section, it is assumed that 1 kg of olive oil and 4 kg of pulp are obtained from 5 kg of olives. In the light of this information, a total of 1630226 tons of olive pulp was produced in 2022. While some of the olive pomace is used for extraction of olive pomace oil, a large part is used as a fuel by drying. It is practically not possible to use it as animal feed. The details of the calculation are shown in Table 9.

3. Discussion and Conclusion

Türkiye is one of the rare countries in the world with a rich agricultural production pattern. Agricultural wastes generated during this production should be evaluated by bringing them into the country's economy. In the calculations, the data of 2022 were used. According to the results of this study, the amount of manure that can be obtained from livestock in Türkiye is approximately 20.7 million tons on a dry basis. The amount of waste that can be obtained from grain and some industrial plants is about 16.8 million tons on a dry basis, the amount of waste that can be obtained from greenhouses is about 393 thousand tons on a dry basis, the amount of waste that can be obtained from pruning waste is about 3 million tons, the amount of waste that can be obtained from hard shell fruits is about 550.2 thousand tons and the amount of waste generated during olive oil production is approximately 1.6 million tons. Apart from this, there are also wastes from agricultural activities for which there is no sufficient data. Domestic waste and sewage sludge are also organic waste. However, it cannot be said that it is exactly agricultural waste. In this study, agricultural wastes, which generate the most waste and have data about, were calculated. Domestic wastes and sewage sludge amounts are excluded from the calculation here.

In other studies, only a certain group of these wastes was handled. For example, Özcan et al. made calculations based on animal manure, some agricultural wastes, urban wastes and sewage sludge in their study on biogas production (Özcan et al., 2011). In his study, Polat used only wheat, barley, corn, sunflower, sugar beet and seed cotton production data while calculating the changes in the biowaste potential of Türkiye (Polat, 2020). In the biochar study of Sümer et al. (2016), calculations were made based on animal manure, some agricultural wastes and pruning wastes. Başçetinçelik et al. (2007) conducted a study by taking a large part of these wastes. In his study, Karaca (Karaca, 2015) determined Türkiye's annual product residue potential in terms of type, amount and mapping. The products used in the calculation in this study are wheat, barley, oats, sunflower, cotton, maize and groundnuts. In another study, Karaca (2018) determined the amount and energy value of biogas that can be produced from animal manure in Türkiye. In this study, biogas potential was calculated with the number of dairy cattle and laying hens taking into consideration, which have high availability manure. In the studies carried out, the number of animals and product amounts were taken as basis when calculating the amount of manure and crop residue. The values taken

change every year. Sometimes, the crop yield of the fields may change due to reasons such as unfavorable climatic conditions or the farmer changing his planting preference. There are also ups and downs in animal numbers over the years. For this reason, the statistical values taken as a basis in the studies differ from each other because they belong to different years. Although some of these calculations are detailed and some are superficial, they have not been made for all agricultural product wastes.

It is possible to obtain different additives used in the production of energy, fertilizer and composite materials from these wastes by using different methods. The biomass energy that can be obtained from these wastes, especially in Türkiye, which is dependent on foreign energy, is at a level that cannot be ignored. Independence in energy is of strategic importance for countries. Therefore, Türkiye, which is dependent on foreign energy for energy, should evaluate all energy resources in the most efficient way. For this, both the state and the private sector should establish facilities for the evaluation of these wastes. Legal arrangements should be made for the utilization of these wastes, and incentives should be increased by increasing the attractiveness of investments to be made to process these wastes. Evaluating agricultural wastes with more environmentally friendly and more efficient methods will be more beneficial for our environment, Türkiye and our world.

Author Contributions

The percentage of the author contributions is presented below. The author reviewed and approved the final version of the manuscript.

	S.S.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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