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Determination of Energy Production Potential from Walnut (*Juglans regia* L.) Residues in Kırşehir Province

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A R T I C L E I N F O

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A B S T R A C T

The present study aims to evaluate the energy production potential from walnut (*Juglans regia* L.) residues, specifically pruning waste and shell biomass, in Kırşehir province, Türkiye. Data collected between 2019 and 2023 were analyzed to quantify the biomass availability and its corresponding energy potential across various districts in the region. The findings reveal that total biomass production from pruning residues increased from 1220.36 t in 2019 to 1322.69 t in 2023, resulting in an energy potential growth from 19,904.02 GJ to 21,573.11 GJ. A similar trend was observed in shell biomass, which rose from 483.11 t to 523.62 t, resulting in an energy potential increase from 9164.60 GJ to 9933.12 GJ. The Kaman district consistently dominated, accounting for over 55% of the total energy potential, while Boztepe and Çiçekdağı exhibited the lowest contributions. The total energy production potential from walnut residues in 2023 was estimated at 31,506.22 GJ (31.51 TJ), corresponding to an annual electricity generation capacity of approximately 8751.74 MWh. The study emphasizes the higher energy potential of pruning residues compared to shell biomass and highlights regional disparities in biomass availability, underscoring the need for targeted strategies to optimize resource utilization. The findings indicate that the utilization of walnut residues for bioenergy purposes has the potential to substantially mitigate fossil fuel dependency and to promote sustainable energy development in the region.

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Introduction

The walnut (*Juglans regia* L.) is a hard-shelled fruit with high nutritional value, playing a significant role in both human nutrition and agricultural economics. The walnut fruit, which is abundant in both its shell and kernel, is widely utilized in the food, pharmaceutical and cosmetics industries (Yılmaz and Akça, 2017). However, the shells and other plant residues generated during walnut production are often regarded as waste and are not utilized efficiently.

In recent years, the utilization of agricultural waste as an energy source has gained increasing importance. The mounting global energy demand and the associated environmental concerns related to fossil fuel consumption have prompted a shift towards renewable energy sources (Degirmencioglu et al. 2019). Biomass waste derived from agricultural production presents a significant potential for sustainable energy production (Ertuğrul et al. 2024). In this context, walnut shells, due to their high energy content, constitute a valuable resource for biofuel production (Gupta et al., 2019).

Research studies have demonstrated that thermochemical conversion processes are effective methods of utilizing walnut shells and other agricultural residues. For instance, Shah et al. (2018) analyzed the thermal properties of walnut shells and found that their calorific values are comparable to those of wood waste and lignite coal. In a similar vein, Naderi and Vesali-Naseh (2019) demonstrated that hydrothermal carbonization of walnut shells results in the production of fuel products characterized by high carbon content, low ash content, and thermal stability. Moreover, Li et al. (2023) emphasized that the catalytic co-pyrolysis of walnut shells with oily sludge plays a substantial role in waste management and recycling. Jekayinfa and Omisakin (2005) investigated the potential use of agricultural waste as a local fuel source and concluded that biomass sources could contribute to energy savings and waste disposal.

Kırşehir province is a prominent agricultural production region, with a notable role in walnut cultivation. However, no comprehensive study has yet been conducted to determine the energy potential of the shells and pruning residues generated from walnut production in this region. However, previous research has indicated that Boyacı et al. (2021) assessed the energy potential of plant waste from greenhouse tomato production in Kırşehir and demonstrated that utilizing the thermal energy potential of tomato waste is crucial for reducing reliance on imported energy. The findings also highlighted the environmental benefits of using these residues as bioenergy sources, such as reducing fossil fuel dependency and lowering CO_2 emissions. A similar approach to walnut waste would enable the transformation of these agricultural byproducts into energy, thereby contributing to sustainable energy production.

The study aims to quantity of biomass waste derived from walnut production in Kırşehir province, assessed its energy potential, and explored its utilization possibilities.

Material and Method

Material

Location

Kırşehir is located in the central region of Türkiye, with coordinates spanning from 39°41' to 39°48' North latitude and 33°25' to 34°43' East longitude. The province falls within the geographical confines of the Central Anatolia Region, with Kırıkkale to the north, Aksaray to the south, Nevşehir to the east, and Ankara to the west delineating its borders. The province's total area is approximately 6,570 km², and its continental climate is characterized by hot, dry summers and cold, snowy winters (Kırşehir Governorship [Kırşehir Valiliği], 2025).

The topography of the region is predominantly characterized by plateaus, low hills, and agricultural plains, with an average elevation of approximately 985 meters above sea level. The region is traversed by the Kızılırmak River, which is regarded as Türkiye's longest river, thereby contributing to the area's agricultural potential. The region's climate, classified as semi-arid, and the topography, predominantly comprising plateaus, low hills, and agricultural plains, at an average elevation of 985 meters above sea level, are conducive to walnut cultivation, in addition to other agricultural activities such as wheat and barley production.

The province's geographic and climatic conditions exert a substantial influence on walnut production, affecting parameters such as growth rate, yield, and nut quality. The province has seen a rise in interest in sustainable agricultural practices and the utilization of agricultural residues for energy purposes, making it a valuable case study for bioenergy potential assessments.

Data

The dataset encompasses the period from 2019 to 2023, incorporating annual walnut production volumes, as well as the number of fruit-bearing and non-bearing walnut trees in various towns within Kırşehir. A summary of these data can be found in Table 1, obtained from the Turkish Statistical Institute (TurkStat) (Turkish Statistical Institute, 2025).

Method

To assess the biomass potential of walnut residues in Kırşehir province, walnut production areas and their respective output levels were systematically organized using Excel. The yield values were computed alongside the potential biomass production and the corresponding energy output derived from this production. Furthermore, an extensive literature review was conducted to evaluate the biomass and energy potential, and relevant formulas were analyzed based on previous studies. According to Bilandzija et al. (2018), the number of fruit-bearing walnut trees was considered, with an assumption that 0.485 t ha^{-1} of biomass available for energy production after pruning with a potential of 16.31 MJ kg^{-1} lower heating value (LHV). Bilandzija et al. (2018) investigated the biomass amount of continuous plantations. After pruning, weight data of the pruned biomass of each tree were determined and mean values of the plantation are calculated accordingly.

Considering total number of trees and mean value of pruned biomass of each tree, total annual pruned biomass quantity were determined by multiplying the values. Bilandzija et al. (2018) calculated the ratio of walnut shell by considering mean fruit yield of each tree, mean kernel percentage and number of tree data.

Table 1. Annual walnut production and tree statistics for Kırşehir (2019-2023).

Fact	Year	Towns						
		Akpınar	Akçakent	Boztepe	Kaman	Merkez	Mucur	Çiçekdağı
Number of fruit-bearing trees	2019	4115	780	120	199207	27632	22320	7600
	2020	4180	780	130	199000	30270	22350	7600
	2021	28308	810	159	199000	30390	22350	7600
	2022	28415	810	167	206000	31030	21365	7600
	2023	28180	850	169	221000	32030	21365	7600
Number of non-bearing trees	2019	1910	2380	501	45460	31310	29012	14350
	2020	1940	2380	493	44000	33640	32015	14350
	2021	1965	2460	460	44000	33570	37015	14350
	2022	1973	2660	457	41000	33090	38018	14350
	2023	2020	2770	437	42000	32220	38018	12550
Production (t)	2019	221	10	1	1296	562	363	74
	2020	251	10	2	1791	605	447	76
	2021	1730	12	3	1781	608	447	91
	2022	1518	10	3	2130	642	368	98
	2023	1042	1	5	2452	593	395	35

The researchers determined the kernel percentage and yield data according to Cerović et al. (2010). The ratio of walnut shell residues was stated as 0.202 $t\,ha^{-1}$ and available shell residues for energy production were 0.192 $t\,ha^{-1}$ with a LHV of 18.97 MJ kg^{-1}. Considering production area (PA) of walnut cultivated in Kırşehir and the data gathered from Bilandzija et al. (2018) the equations 1 and 2 are derived for energy potential of walnut pruning residues (EP_P) and energy potential of walnut shell residues (EP_S). The total energy potential (EP) is calculated thorough Equation 3 (Ertuğrul et al. 2024).

$$EP_P\,(\mathrm{MJ}) = 0.485 \cdot PA \cdot LHV \quad (1)$$

$$EP_S\,(\mathrm{MJ}) = 0.192 \cdot PA \cdot LHV \quad (2)$$

$$EP\,(\mathrm{MJ}) = EP_P + EP_S \quad (3)$$

In the hypothetical scenario where all available waste is utilized for electricity generation, the electricity equivalent of potential energy output can be calculated using Equation 4.

$$EP_E\,(\mathrm{kWh}) = EP \cdot 0277778 \quad (4)$$

Results and Discussion

From 2019 to 2023, assumption of total biomass production that can be obtained by pruning increased from 1220.36 t to 1322.69 t, reflecting an 8.4% growth. Kaman district consistently contributed the highest available pruning waste potential, accounting for approximately 55% of the total in 2023 with 727.50 t. In contrast, Boztepe and Çiçekdağı showed the lowest production levels, with Boztepe remaining stable around 3-3.5 t and Çiçekdağı decreasing from 40.74 t (2019-2022) to 31.96 t in 2023 (Figure 1).

Depending on the potential available pruning waste amounts, energy production potential from pruning increased from 19,904.02 GJ in 2019 to 21,573.11 GJ in 2023, marking an 8.4% rise. Kaman demonstrated the highest contribution with 11,865.53 GJ in 2023, surpassing half of the total potential (Figure 2).

Shell biomass production grew from 483.11 t in 2019 to 523.62 t in 2023, an 8.4% increase. Kaman led in shell biomass production with 288.00 t in 2023 (Figure 3).

Accordingly, energy potential from walnut shells increased from 9164.60 GJ in 2019 to 9933.12 GJ in 2023. Kaman remained the leading contributor, accounting for 5463.36 GJ in 2023 (Figure 4).

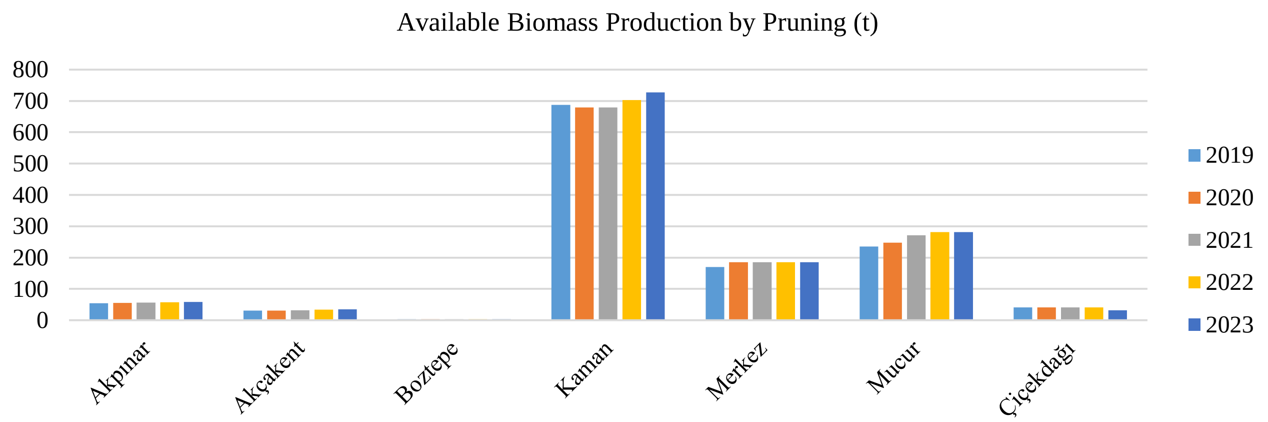

Figure 1. Assumption of available biomass production by pruning between 2019-2023

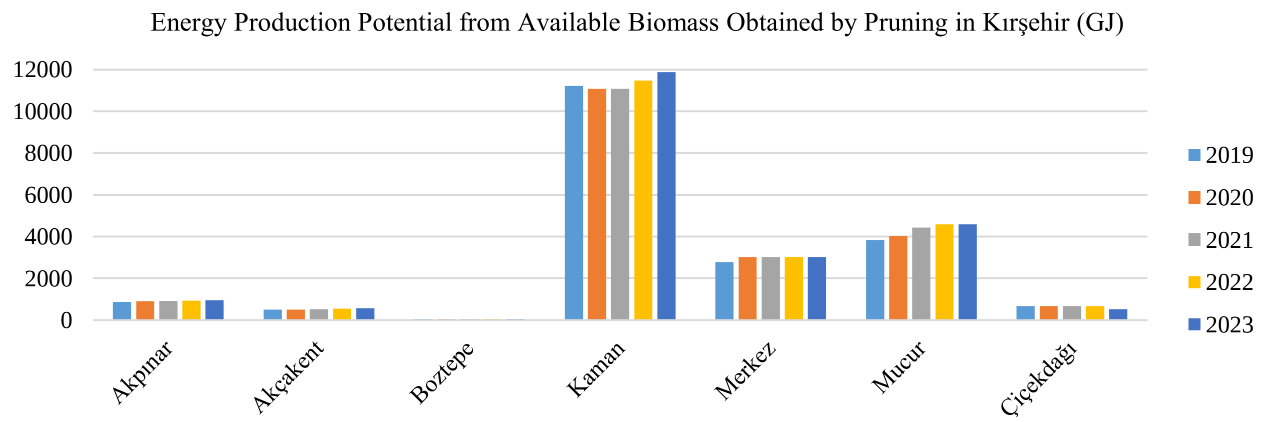

Figure 2. Energy production potential from available biomass obtained by pruning in Kırşehir between 2019-2023

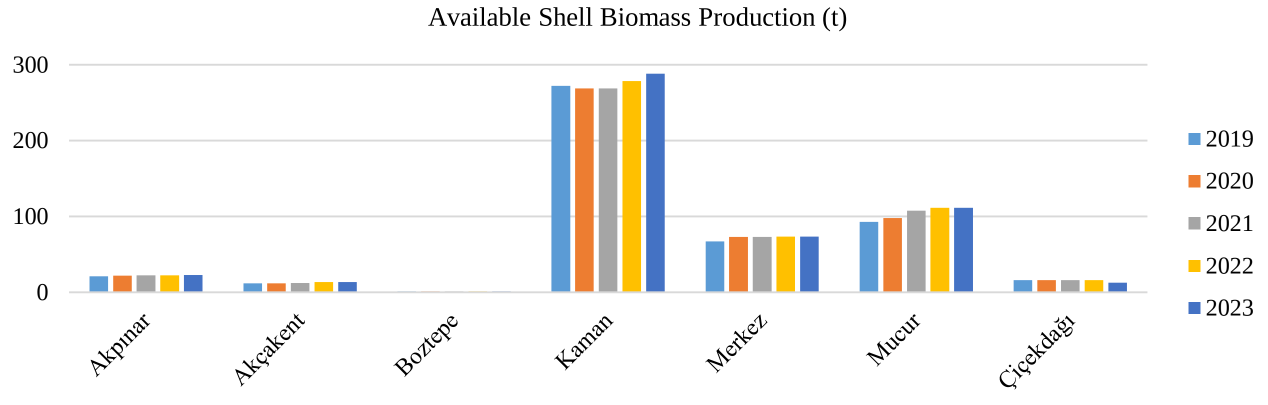

Figure 3. Assumption of available shell biomass production between 2019-2023

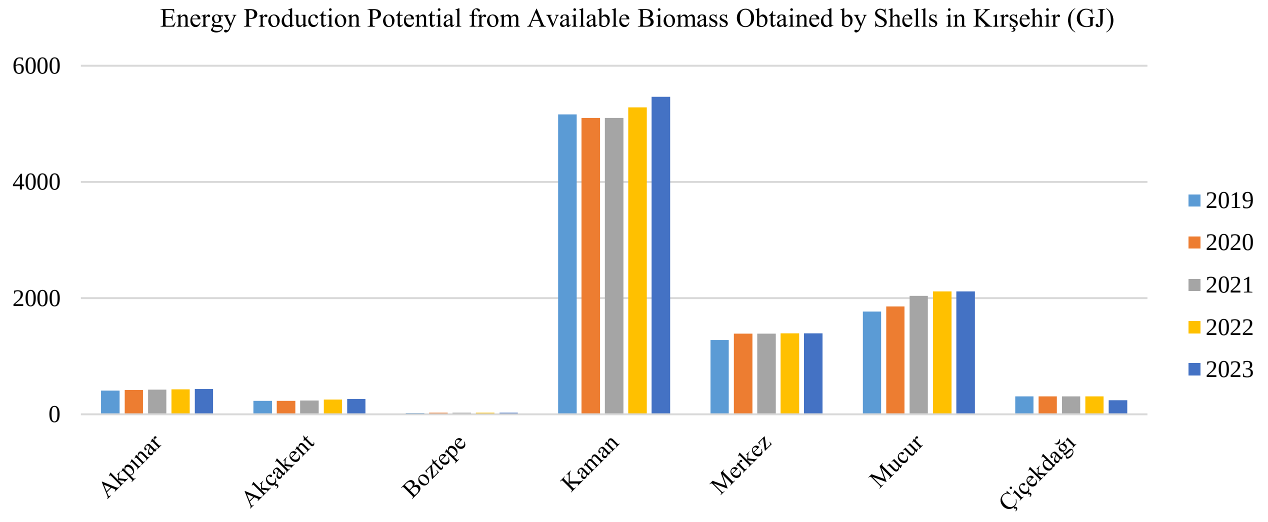

Figure 4. Energy production potential from available biomass obtained by shells in Kırşehir between 2019-2023

Table 2. Total energy production potential from walnut residues in Kırşehir (TJ)

Year	Akpınar	Akçakent	Boztepe	Kaman	Merkez	Mucur	Çiçekdağı	Total
2019	1.28	0.73	0.08	16.37	4.04	5.60	0.970	29.07
2020	1.33	0.73	0.08	16.17	4.41	5.89	0.970	29.58
2021	1.35	0.75	0.08	16.17	4.41	6.47	0.970	30.20
2022	1.36	0.81	0.08	16.75	4.41	6.70	0.970	31.08
2023	1.39	0.83	0.08	17.33	4.42	6.70	0.761	31.51

Results show that considering direct combustion method to produce energy, pruning residues contain higher potential than shell residues. Nevertheless, the pyrolysis method for walnut shell can be regarded as a promising biomass source for the production of bio-oil, biochar, and syngas (Goklani et al., 2022).

The total energy production potential from walnut residues rose from 29,068.63 GJ (29.07 TJ) in 2019 to 31,506.22 GJ (31.51 TJ) in 2023, an 8.4% increase. Kaman consistently contributed the largest share, providing over 17,328.89 GJ (17.33 TJ) in 2023 (Table 2). The total contribution of walnut residues is 31,506.22 GJ (31.51 TJ) which is higher than the potential contribution of greenhouse tomato wastes in Kırşehir, 4,046 GJ (Boyacı et al. 2021). Boyacı et al. (2022) determined the potential for bioenergy production from animal manure as 2791.41 GJ in the Kirşehir province which is considerably lower than the possible contribution of walnut residues to energy production. Ünal (2005) found that the total energy potential of walnut residues in Türkiye is 1,790 TJ, which is considerably higher than the 31.51 TJ potential of Kırşehir. It can be concluded that, in the event of losses being disregarded, there exists a possibility of annual electricity production of 8751.74 MWh from walnut residues.

A spatial representation of the total energy production potential from walnut agricultural wastes in 2023 has represented in Figure 5. The map highlights the dominant role of Kaman, which significantly surpasses other districts with 17,328.89 GJ of energy potential. Considerably lower energy potentials as 346.37 GJ for greenhouse tomato wastes (Boyacı et al. 2021) and 258.39 GJ for animal manure (Boyacı et al. 2022) in Kaman have been determined in previous research. Akpınar, Mucur, and Merkez (Central Town) also contribute notably, while Boztepe and Çiçekdağı show lower energy potentials.

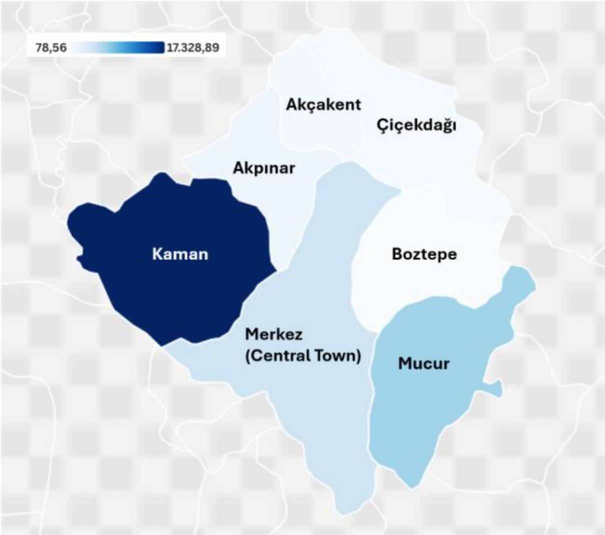

Figure 5. Energy production potential from walnut residues in 2023

The reduction in energy potential observed in Çiçekdağı may reflect regional agricultural shifts or decreased walnut production activities. This geographical distribution emphasizes the regional disparities in walnut biomass availability, guiding future biomass energy development strategies.

Conclusion

This study highlights the significant energy potential of walnut residues in Kırşehir, particularly the contribution of pruning and shell biomass. The results show a consistent increase in both biomass production and energy potential from 2019 to 2023, with Kaman district emerging as the main contributor. The data indicate that walnut pruning residues have a higher energy potential compared to shell residues, making them a valuable resource for bioenergy production.

The total energy production potential for 2023 was determined to be 31.51 TJ, which corresponds to an estimated electricity generation capacity of 8751.74 MWh. The spatial distribution of energy potential highlights regional disparities, suggesting that targeted strategies could optimize biomass utilization across the province. The decline in energy potential in districts such as Çiçekdağı indicates the need for further research into local agricultural practices and resource management.

Overall, the use of walnut agricultural residues for energy production represents a sustainable approach to reducing dependence on fossil fuels and promoting renewable energy solutions. The findings suggest that targeted incentives for agricultural waste collection and biomass utilization could enhance the feasibility of walnut residue-based bioenergy production. Implementing local subsidies and infrastructure for biomass processing may significantly contribute to sustainable energy strategies.

Declarations

Authors Contributions

ÖE gathered and analyzed the data, prepared the draft manuscript, reviewed and revised the draft.

Data Availability Statement

The data source of the research is publicly accessible at https://www.tuik.gov.tr/

Declaration of Competing Interest

The researcher stated that no conflicts of interest or interpersonal connections could have impacted the published results.

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