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Productive Efficiency of Energy-Aware Walnut Production

Ceviz Üretiminde Enerji Bilinçli Üretim Verimliliği

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PRODUCTIVE EFFICIENCY OF ENERGY-AWARE WALNUT PRODUCTION

ABSTRACT

Innovative cultivation and processing facilities are needed in order for the increased production in Türkiye to be efficient, low energy consumption, and high quality. Therefore, an in-depth analysis of the US California-based walnut producer has been made, which can also be an industrial role model to Turkish producers. The orchard of Chandler variety walnut was 70 decares and contains 17-year-old trees. Fuel consumed by agricultural machines during field operation, the rate of meeting the electricity need from solar panels for irrigation and processing, and the data of the hybrid drying (solar wall-natural gas) which is one of the few agricultural applications samples in the world were recorded for sustainable walnut production. In walnut production, spraying (pesticide) had the highest fuel consumption by far compared the all-year applications. The photovoltaic panels in the orchard met 62.8% of the required energy for irrigation engines. To process 42837 kg of walnuts, it was determined that 18.05% of the daily produced energy by roof-top photovoltaic panels was used. It is presenting that walnut production makes a significant direct contribution to the economy as a result of high-quality products with full mechanization and methods of utilizing solar energy technologies in walnut production.

Keywords: Solar Energy, Efficiency, Walnut.

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CEVİZ ÜRETİMİNDE ENERJİ BİLİNÇLİ ÜRETİM VERİMLİLİĞİ

ÖZ

Türkiye'de artan üretimin verimli, düşük enerji tüketimi ve yüksek kalitede olabilmesi için yenilikçi yetiştirme ve işleme tesislerine ihtiyaç duyulmaktadır. Bu nedenle, Türk üreticilere de endüstriyel rol model olabilecek ABD Kaliforniya merkezli ceviz üreticisinde derinlemesine bir analizi yapılmıştır. Chandler çeşidi ceviz bahçesi 70 dekar olup, içerisinde 17 yaşında ağaçlar bulunmaktadır. Tarım makinelerinin bahçe çalışmaları sırasında tükettiği yakıt, sulama ve ürün işleme için gerekli elektrik ihtiyacının güneş panellerinden karşılanma oranı ve dünyadaki sayılı tarımsal uygulama örneklerinden biri olan hibrit kurutma (güneş duvarı-doğal gaz) verileri ile sürdürülebilir ceviz üretimi için kayıt altına alınmıştır. Ceviz üretimindeki tüm yıl uygulamalarına göre açık ara en yüksek yakıt tüketimi ağaçların ilaçlamasında olmuştur. Bahçedeki güneş panelleri, sulama motorları için gerekli enerjinin %62,8'ini karşılamıştır. Toplam 42837 kg cevizin işlenmesi için çatı üstü güneş panellerinden üretilen günlük enerjinin %18,05'inin kullanıldığı belirlenmiştir. Ceviz üretiminde güneş enerjisi teknolojilerinden yararlanma yöntemleri ve tam mekanizasyon ile yüksek kaliteli ürünler sonucunda ekonomiye önemli ölçüde doğrudan katkı sağladığının gösterilmesidir.

Anahtar Kelimeler: Güneş Enerjisi, Verimlilik, Ceviz.

1. INTRODUCTION

Walnut (*Juglans regia* L) is one of the oldest hard-shelled fruit species grown in the World. It is the species of tree in the Juglans plant genus, the type genus of the Juglandaceae family, and in Dicotiledoneae class pomologically (Çolak and Karaca, 2021). Although there are 18 walnut species whose characteristics have been determined in the genus Juglans all over the world, its spreading areas extend to China in the east of Asia, the Himalayan mountains, the Caucasus Mountains in the west, Anatolia, the Balkans and the interior of Austria due to its compatibility with ecological conditions. Among the main producer countries are the United States of America (USA), China, Iran, Türkiye, Ukraine, Romania, India, and France (Büyüksolak, 2019).

The data of the Food and Agriculture Organization of the United Nations (FAO) presented that the total walnut production in 2018 was 3656329 tons in the world. China is the leader with a production of 1586367 tons from 390224 ha orchards, the USA ranks second with 613260 tons from 141640 ha orchards, and Türkiye ranks fourth with 215000 tons of production from 111775 ha orchards. The development of walnut production in Türkiye increased from 116000 tons in the early 2000s to 225000 tons in 2019. Considering the walnut production in Türkiye in the last 5 years, the production has increased by 25% with the planting of new walnut orchards. In addition, a continuous increase was observed in the number of fruit-bearing and non-fruiting trees (TUIK, 2019). Regarding output, it is revealed that the demand for walnut cultivation has increased with the increase in private afforestation initiatives and incentives for walnut orchards. Chandler is the most popular of the foreign varieties in walnut cultivation in Türkiye. In recent years, the Chandler variety constituted 70% of the orchards planted with foreign varieties and replaced the existing domestic varieties (Akça, 2009). Chandler walnut variety is a hybrid of Pedro X 56-244 and was obtained in 1979 in the University of California breeding program. It is the leading commercial walnut variety in the USA and the most important variety grown in California today. California walnut production also constitutes 99% of the total production in the USA with an area of approximately 800 thousand decares (Büyüksolak, 2019).

In the orchard stage of walnut cultivation, fertilization, spraying, weed control, irrigation, and harvesting are carried out based on mechanization. There are also processes such as transportation, processing, and storage after the harvest. Thus, the energy usage in the production and processing steps of agriculture is immense. The provision of the proper amount and efficient use of energy is required for advanced agricultural production. The crop yield and food supply are also known to be directly related to energy. Therefore, the primary purpose is to increase efficiency and reduce costs in agricultural production. Additionally, the energy needed in the production processes should be met with micro-scale solutions at the point where it is consumed. It will be possible for the producers to avoid energy costs and achieve energy independence as a result of meeting their own consumption with sources based on solar energy. Consequently, it is necessary to make an energy analysis in order to compare the link between input and output in the system in terms of energy units numerically. Various studies have been performed on the energy analysis of agricultural products. Nabavi-Pelesaraei et al. (2013) investigated the impacts of energy inputs and energy forms on output levels and the evaluation of CO_2 emissions for hazelnut production in the Guilan province of Iran. The results of energy forms analysis revealed the share of non-renewable and indirect energy was more than renewable and direct energy with a total energy of 2862.62 MJ ha^{-1} for gardening in one year. The ratio of energy output to energy input and CO_2 emissions of hazelnut production found 3.93 and 77.66 $kgCO_{2eq}$. ha^{-1}, respectively. Additionally, diesel fuel determined the highest share of emissions among all inputs with 33.84%. Külekçi and Aksoy (2013) researched the energy consumption of input and output used in pistachio production in Gaziantep province of Turkey. Their data revealed that 23,454.33 MJ ha^{-1} energy consumed by pistachio farms as 0.1–10.0 ha (98 farms) and 20,473.06 MJ ha^{-1} by larger than 10.1 ha (49 farms). The input–output ratio was 0.40 and 0.43 in the first and second groups, respectively. The energy productivity determined 0.02 for both groups of farms. The use of efficiency and economic performance obtained more success in large farms. Beigi et al. (2016) analyzed the input–output energy assessment of almond production in three age groups of orchards (group I 6–10, group II 11–15, and group III 16–20 years old) in Chahrmahal-Va-Bakhtiari province, Iran. Their results presented that 57,027.13, 60,341.14, and 61,640.43 MJ ha^{-1} energy was consumed by group I, group II and group III, respectively. Electricity followed by chemical fertilizer determined as the most energy-consumed input. Furthermore, energy efficiency obtained 0.62, 1.12 and 0.81 in the triple groups of orchards, respectively. Consequently, almond production in the study region did not express an efficient process in terms of energy consumption. Gökdoğan et al. (2019) evaluated the energy use efficiency analysis of chestnut fruit production in the Aydın province of Turkey. The findings exhibited that the total input energy and output energy were 6161.82 MJ ha^{-1} and 70,800 MJ ha^{-1}. The energy output/input ratio, chestnut fruit (yield), specific energy, energy productivity, and net energy found as 11.49, 6000 kg ha^{-1}, 1.02 MJ kg^{-1}, 0.97 kg MJ^{-1}, and 64,638.18 MJ ha^{-1}, respectively. The performed total

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energy input in chestnut production classified as 40.73% direct, 59.27% indirect, 37.08% renewable, and 62.92% non-renewable. Although many types of research were conducted on energy use efficiency analysis in the form of "surveys", It has been seen that processing lines are not taken into account in the literature.

This study examined the production stages of industrially grown walnuts in the California region of the USA. Within the scope of productivity, the effect of full mechanization level on energy consumption and the possibilities of using solar energy technologies (solar electricity and solar wall) were investigated. An in-depth analysis was made of the US California-based walnut producer, which can be an industrial role model for Turkish producers as efficient and innovative for increased production.

2. MATERIAL AND METHODS

2.1. Location

The "orchard" and "processing plant" steps of the research were carried out in a walnut producer company that was established in 1890 in Glenn, California. The orchard is on 17 acres (≌ 70 decares) and contains 17-year-old Chandler walnut trees. The walnut orchard was irrigated with underground water via 2-inch sprinklers for 24 hours every two weeks for all production seasons.

2.2. Fuel Consumption

The measurement of fuel consumption during each agricultural machine was done by the filling fuel tank before operation and refilling the tank after operation with a cylinder gauge. The fuel consumption per plot was defined with the difference between the two readings (the fuel gauge cylinder reading before and after an operation). The unit area consumption (in liters per hectare) was found by dividing the summation fuel consumed per plot by the area operated (Baran ve Gokdogan, 2014).

2.3. Electricity Production and Consumption

In order to determine the real-time electricity production-consumption amounts, measurements were taken. Information was added about the direction, angle, dust, and contamination conditions of solar panel systems. The following equations were used to identify the total electrical energy production and consumption of the facility.

$$Q_u = Q_b + Q_c \tag{1}$$

Where; Q_u, the total electrical energy production of the facility (kWh); Q_b, the electrical energy production of the orchard stage (kWh); Q_c, the electrical energy production of the processing plant roof (kWh).

$$Q_t = Q_s + Q_{ys} + Q_{ta} + Q_{os} + Q_h + Q_k + Q_p + Q_{tm} \quad (2)$$

Here; Q_t, is the total electrical energy consumption of the facility (kWh); Q_s, is the electrical energy consumption for irrigation (kWh); Q_{ys}, is the electrical energy consumption of the washer-cleaner machine (kWh); Q_{ta}, is the electrical energy consumption of pre-cleaner machine (kWh); Q_{os}, is the electrical energy consumption of sort table machine (kWh); Q_h, is the electrical energy consumption of huller machine (kWh); Q_k, is the electrical energy consumption of drying fan (kWh); Q_p, is the electrical energy consumption of packing machine (kWh); Q_{tm}, is the electrical energy consumption of elevator and conveyor (kWh).

$$Q_{net} = Q_t - Q_u \quad (3)$$

The total net electrical energy difference of the facility was determined by the equation below.

2.4. Dryer Performance

Equation 10 was used to determine the performance curve (P_c) of the solar wall (Robinson et al., 2013).

$$P_c = \frac{(T_i\text{-}T_a)}{S} \quad (4)$$

Here, T_i is the temperature of a solar wall (°C), T_a is the temperature of ambient air (°C), and S is solar radiation (m^2C/W). Insufficient application of the “solar wall” to dry walnut forced the system to operate in a hybrid way based on natural gas burning and consumption (m^3) was recorded with the relevant consumption meter range.

2.5. Energy Analysis

In order to the energy analysis, energy use efficiency, energy productivity, specific energy, and net energy gain were computed with modified methods of Banaeian et al. (2010) ve Baran et al. (2017).

$$Energy\ use\ efficiency = Energy\ output\ (MJ/ha)/Energy\ input\ (MJ/ha) \quad (5)$$

$$Energy\ productivity = Walnut\ output\ (kg/ha)\ /Energy\ input\ (MJ/ha) \quad (6)$$

$$Specific\ energy = Energy\ output\ (MJ/ha)/Walnut\ output\ (kg/ha) \quad (7)$$

$$Net\ energy\ gain = Energy\ output\ (MJ/ha) - Energy\ input\ (MJ/ha) \quad (8)$$

3. RESULT AND DISCUSSION

The fuel consumption results are shown in Figure 1. The data on the harvesting equipment present that the consumptions of the shaker, sweeper, collector, and transport were 83.27, 68.13, 54.88, and 17.03 lt, respectively. The consumption of the shaker was found 22.2% more than the sweeper and 51.7% more than the collector. Additionally, the main reason for the low consumption of the transporter can be explained by the closeness of the orchard to the processing facility. On the other hand, the applications of the orchard equipment consumed 7.56 lt for strip spraying, 234 lt for tree spraying, 3.8 lt for spraying suckers, and 34.2 lt for mowing (weed control). Overall, the consumption per decare was 1.19 lt for the shaker 0.97 lt for the sweeper, 0.78 lt for the collector, 0.11 lt for the strip spraying, 6.68 lt for the tree spraying (two applications), 0.05 lt for the spraying suckers and 0.98 lt for the mowing (two applications). Comparing the all-year applications, tree spraying had the highest consumption by far. This might be explained by the reason of usage truck-mounted sprayers. With the target of decreasing fuel consumption, more environmentally friendly walnuts may be producible by reducing the emission gases it emits as well.

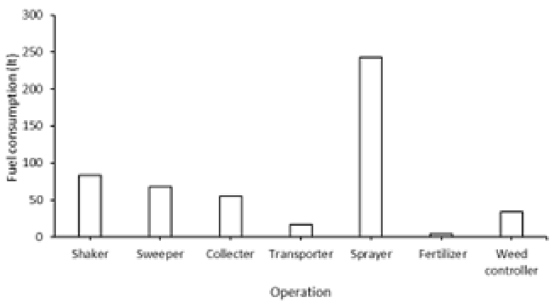

Figure 1. Fuel consumption of operations

For the required energy, photovoltaic panels (poly-silicon) have been used with an installed capacity of 4.8 kW in the southwest direction with a 30-degree angle. The photovoltaic panel system was connected to the grid line. Thus, they interact with each other in the way electricity counter. The energy production of photovoltaic panels used for irrigation purposes is seen in Figure 2. Total energy production for the whole production season was determined at 6185.58 kWh. On the other hand, the irrigation system used 3668 kWh from the grid (Figure 5). In conclusion, the photovoltaic panels met 62.8% of the total energy (9853.58 kWh) to run irrigation engines. However, excessive dust was experienced during the in particular use of harvest equipment which causes efficiency losses in the photovoltaic panels. Therefore, the rate of meeting the needs can be increased by paying attention to the cleanliness of the panels.

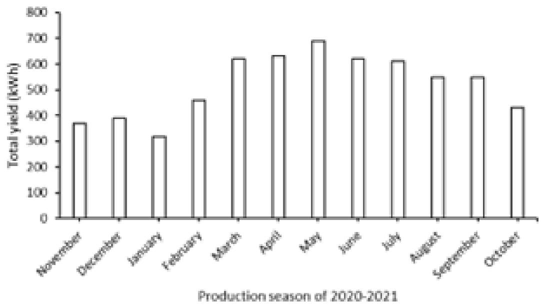

Figure 2. Solar electricity production for irrigation in the season

The harvested walnuts were brought to the facility for processing such as washing, cleaning, hulling, separation, drying, and packing. The facility has solar panels with an installed power of 144.96 kW facing south on the rooftop. Figure 3 shows the daily performance of photovoltaic panels which produced 501.2 kWh of electricity on the day of processing harvested walnuts and the highest power level was reached at 13:00. On the other hand, a total of 90.46 kWh of electricity was consumed for the processing of walnuts. Drying was the highest energy consumption process which is 65% of total consumption (Figure 4). Consequently, regarding the total electricity consumption and the time spent (95 min) in the processing of 42837 kg of walnuts, it was seen that 18.05% of the daily produced electricity was consumed (Figure 5).

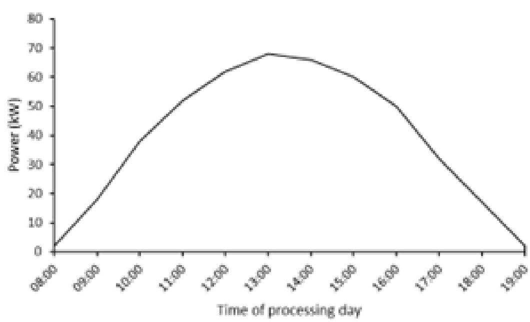

Figure 3. Solar power production during walnut processing day

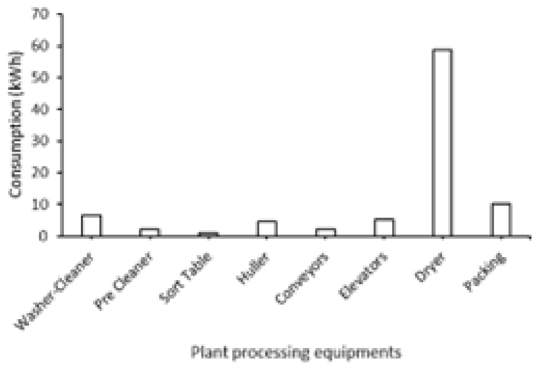

Figure 4. Electricity consumption of processing equipment

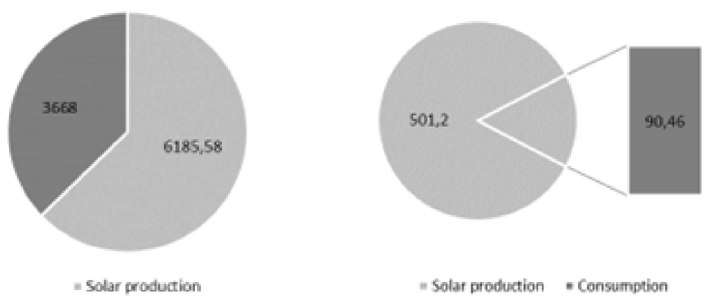

Figure 5. Total net electricity (kWh) difference of irrigation (left) and facility (right)

The drying building, in which the solar wall system is used, is in the form of a gable roof-type roof. It is in the south-north direction and has a roof area of 288 m^2. The roof is an angle of 10 degrees and the solar wall system is mounted directly on it. Thus, the hot air to dry walnuts in the stadium-type dryer is provided. Since the required temperature of 44 °C could not be reached, the dryer worked as a hybrid with natural gas. The data obtained as air temperature measurements made from the entrance to the solar wall and the air suction of the engine are presented in Figure 6. The results displayed that the solar wall system increased the atmospheric temperature by an average of 5.37 °C between 9:00-10:00, by an average of 9.13 °C between 10:00-15:00 and by an average of 3.22 °C with a decreasing effect after 15:00. The highest temperature increase was achieved at 13:52 with 12.3 °C. However, due to the structure and location of the drying building, it was observed that the solar radiation in the evening could not be utilized sufficiently. Therefore, 368.11 m^3 of natural gas was used to dry all walnut samples at desired drying temperature (44 ^{o}C).

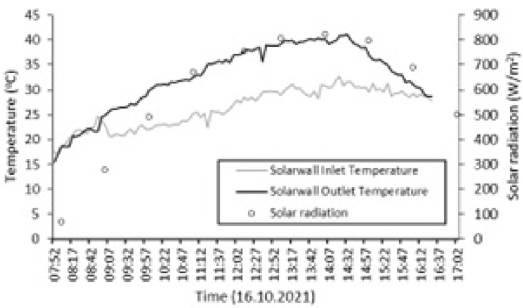

Figure 6. Temperature effect of the solar wall system

Regarding the energy data presented in this study, the energy use efficiency, energy productivity, specific energy, and net energy gain were determined. According to the amount of walnut kernel yield; energy use efficiency, energy productivity, specific energy, and net energy have been calculated as 5.67, 0.20 kg/MJ, 28.00 MJ/kg, and 70554 MJ/ha, respectively. In previous studies, the same parameters were presented for Iranian walnut as 2.90; 0.3 kg/MJ; 3.40 MJ/kg, and 29258.50 MJ/ha, respectively by Banaeian and Zangeneh (2011). Also, Baran (2017) reported the walnut production in Turkey as 0.61; 0.03 kg/MJ; 30.20 MJ/kg, and -9313.02MJ/ha, respectively. The difference between the results can be explained by the amount of walnut yields, solar energy usage, and neglected energy inputs such as human labor, machinery, chemicals, and irrigation water.

4. CONCLUSION

In conclusion, although the shaker had the second-highest fuel consumption, it can be reduced with the proper use of power and application time for shaking trees. Besides, by preventing branch breakage caused by shaking, the idle time of the sweeper and collector can be decreased and fuel consumption can be reduced. On the other hand, the photovoltaic panels met the 62.8% energy needed for running irrigation engines. However, this rate can be increased with frequent panel cleaning. Additionally, it has been observed that the processing facility effectively benefits from roof-top photovoltaic panels. Furthermore, the solarwall system could not produce the required temperature for drying individually and worked as a hybrid with natural gas. Consequently, efficient and green energy use such as solar should be expanded with farm power and machinery management.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study: OT (%60), ZP (%40)

Data Acquisition: OT (%70), ZP (%30)

Data Analysis: OT (%60), ZP (%40)

Writing up: OT (%70), ZP (%30)

Submission and Revision: OT (%60), ZP (%40)

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