energies

MDPI

Article

Contribution to the Energy Situation in Tajikistan by Using Residual Apricot Branches after Pruning as an Alternative Fuel

Sayfullo Akhmedov, Tatiana Ivanova *, Surayyo Abdulloeva, Alexandru Muntean and Vladimír Krepl

Department of Sustainable Technologies, Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Kamýcká 129, 165 21 Prague, Czech Republic

* Correspondence: ivanova@ftz.czu.cz; Tel.: +420-224-382-603

Received: 25 July 2019; Accepted: 15 August 2019; Published: 18 August 2019

Abstract: A lack of access to energy in the rural areas of Tajikistan is one of the current problems of the country. Tajikistan's goal is to reach energy independency, and the main prospects for the country's energy sector, which relies on energy imports during the long heating periods, are: higher exploitations of hydropower and development of other renewables, mainly biofuels. Tajikistan is a highly agrarian country, where agriculture is the dominant source of income for the majority of the population. Apricot belongs to the primary agricultural commodities; however, the cultivation and management of apricot orchards is associated with the annual accumulation of significant amounts of wood waste (residual branches after pruning), which represent a source of easily available biomass. Thus, the main focus of the present research was to investigate the properties (physical, chemical and mechanical) of densified briquettes and pellets from the residual apricot tree branches through the laboratory measurements by the standard methodologies and to calculate the energy yield and potential of this material for Tajikistan as a similar study has not been conducted yet. The results showed a good quality of apricot-based biofuels characterised by the high calorific value (*NCV* dry basis of 19.3 MJ kg^{-1}), relatively low ash content (1.7%) and suitable values of the main chemical elements that fulfil the standard requirement on graded wooden biofuels. The total yearly energy yield of residual apricot branches was calculated to be 3245 TJ.

Keywords: briquettes; energy yield; pellets; properties; waste biomass

1. Introduction

According to the World Bank [1], more than 20% of Tajikistan's GDP comes from agriculture; moreover, it plays an essential role (provides food, income, employment) for the people in rural areas, which present two-thirds of the population. The main agricultural products of the country are wheat, cotton, apricot and grapes [2] (Figure 1). Tajikistan is highly mountainous and only 7% of the area is suitable for an arable agriculture. Orchard farming has had a big influence on the county's post-war (Tajik Civil War 1992–1997) economic improvements. Generally, all orchards and horticultural sites are situated in foothills, mount hills and valleys [3].

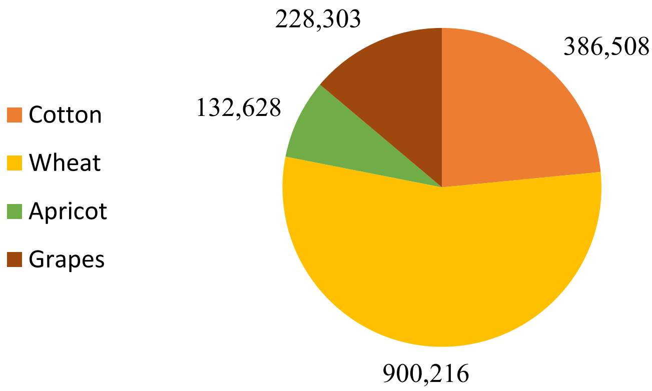

Figure 1. The average quantity of the main agricultural products obtained yearly in Tajikistan, tons. Data from [2].

The apricot tree's (*Prunus armeniaca* L.) fruits belong to the most essential organic products, and they are highly valued commodity to buyers [4]. Apricot production is globally rising every year, and in 2017, a total of 4,257,241 t was produced worldwide. The development of apricot orchards has turned out to be a necessity in present-day Tajikistan, which is also listed among the large producers and belongs to top 25 apricot-producing countries with 11,221 ha being harvested in 2017 [5]. However, according to the Statistical Agency TAJSTAT [2], the overall area of apricot orchards in the country is 61,617 ha, including small-scale plantations. Tajikistan's main apricot orchards are located in the Sughd region (northern part of the country, dominant agricultural region) and mountainous areas [3]. Turning cotton fields into apricot gardens and expanding apricot cultivation for dried fruit production in Sughd is now nearly a national idea [6]. The apricot tree has a peripheral crown and refers to deciduous bushes that develop in heavy clay soils or even on gravel and rocky lands [7]. Pruning and forming fruit plants, including apricot, is the main agro-technical treatment, which should be done continuously to adjust growth and development in order to improve productiveness and the fruits' quality [8]. Most of the fruiting bodies are placed on 2–5-year-old branches; 7–8-year-old branches usually dry up and fall off. Proper trimming improves booming and development of the tree [9]. Pursuant to the data from the Institute of Horticulture and Vegetable Growing [7], about 156 trees are grown in one ha in Tajikistan, and after pruning, approximately 15–20 kg of branches for each tree are yearly available for utilization as residual biomass, which is, however, usually improperly wasted.

Tajikistan faces significant problems in energy supply. The main source of energy in the country is water (hydropower), and there is an immense potential of water resources that can be used to produce electricity. Despite the fact that, Tajikistan is currently using only small share of this potential, over 90% of the total electricity is generated by large hydropower plants [10]. The sources of the primary energy supply of the country are illustrated in the Figure 2.

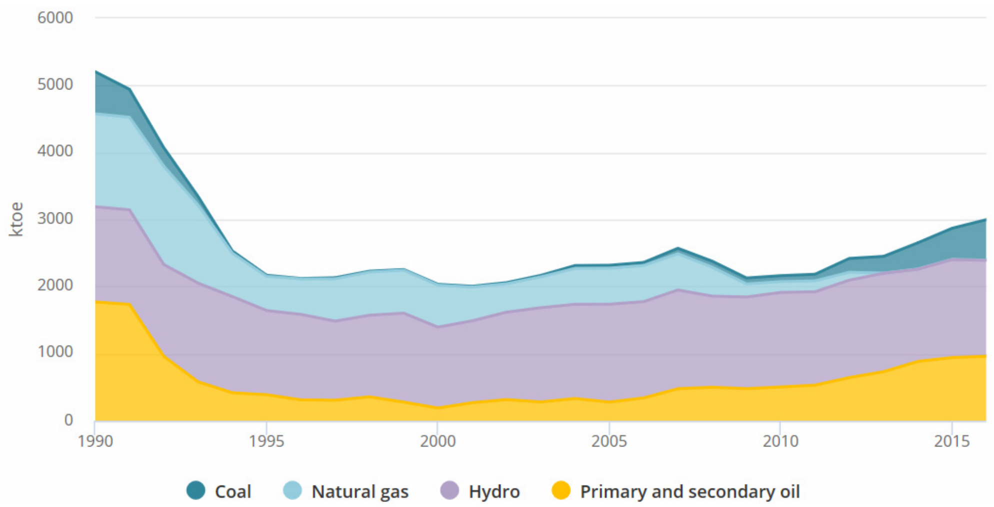

Figure 2. Total primary energy supply of Tajikistan by source. Reproduced with permission from [11], IEA, 2018.

The major part of power plants and well-developed electric grid are located in the southern part of the country; thus, southern Tajikistan is better supplied with electricity. The northern part of the country has a connection to the national electric grid system, too, but it is considered to be sensitive to the frequent electricity shortages as compared to other regions, especially in the winter period of the year [12]. As an improvement of energy supply and consumption in the industrial sector, housing as well as the public sector, together with the development of alternative resources and networks are important for countries like Tajikistan, to deal with these above-mentioned issues, it is crucial to introduce new energy technologies and to expand the use of renewable energies. In 2007, the Government of Tajikistan has announced the decree No 41, which focused on the development of a renewable energy programme [13]. Renewable resources, such as solar, wind and biomass, can effectively cover an energy shortage in Tajikistan. The energy shortages during winter caused by the decreases in river flow and lower hydropower production, along with an increased demand for heating as well as a lack of cheap alternative energy, create a deficit between supply and demand, which results in load shedding [10]. Tajikistan is struggling badly with the crisis related to the general deficiency of conventional energy sources, which adversely impacts on the industrial ability and the whole economic system. The wind power potential is hardly ever used on a commercial scale [14]; nevertheless, utilization of biofuels in agricultural areas for heat and electricity production is recognized not only as effective but also as important for 75% of households [15].

Agricultural waste materials are a viable source of renewable and clean energy [16]. Theoretically, yearly-accumulated waste obtained from the cultivation of the main agricultural products in Tajikistan represents an attractive source of biomass that can be used for biofuel production. However, in the case of wheat, which is the most abundant crop, energy utilization of residual straw is limited as it is the predominant cattle forage in the country [17]. Positive and negative characteristics of densified fuels based on cotton residues as well as their potential for Tajikistan were already studied by Akhmedov et al. [18] and Stavjarská [19]. A number of studies (e.g., [20–27]), mainly from Italy, Spain, Chile or Moldova, have previously discussed the fuel properties, combustion behaviour and possible energy application of vineyard pruning residues. The advantage of apricot pruning residue is that it is a source of wooden biomass, and it can be collected easily in contrast with a biomass of other agricultural crops as branches are harvested by farmers and stocked in a vicinity of orchards. Thus, there is good access for the biomass transportation cargo units. The only available study [28] has evaluated the main physical and chemical characteristics of apricot chips together with the biomass of similar trees, like peach, cherry, pear, apple, hazel, walnut, plum and sour cherry. Utilization of residual wood biomass from apricot tree pruning in the form of solid biofuels seems to be a suitable solution for waste treatment and the production of local energy. The main objective of this research was to investigate the energy potential and fuel properties of briquettes and pellets made of residual apricot branches.

2. Materials and Methods

The apricot branches after pruning as waste biomass used in the given research were brought from Tajikistan. Prior to densification, the material was crushed by the hammer mill 9FQ–40C (Green Energy Machine Product, Vlčnov, Czech Republic; power input of 5.5 kW) using the screen with a hole diameter of 6 mm. The production of pellets was done by the pelleting line MGL 200 (Kovo Novak, Citonice, Czech Republic; power input of 8.85–10.85 kW) with a size of matrix holes of 6 mm. The briquettes were produced by the hydraulic piston briquetting press Brikstar 50 (Briklis, Malšice, Czech Republic; power input of 5.6 kW) with a diameter of the pressing cylinder of 65 mm, working pressure of 18 MPa and maximum working temperature of 60 °C.

The determination of pellet and briquette properties was carried out in accordance with the methodology of the international and European standards for solid biofuels. For further testing, a representative sample of apricot wood-based biomass was prepared according to BS EN 14780:2011 [29], using laboratory hammer mill IKA MF 10.1 for primary grinding and afterwards laboratory knife mill Grindomix GM 100 for the final homogenization.

The moisture content (w) was determined by the standard BS EN ISO 18134–3:2015 [30] at 105 °C. A laboratory dryer Memmert 100–800 (Memmert GmbH, Schwabach, Germany) was used, and the resulting moisture was calculated as the mean of duplicate measurement by the following Equation (1):

$$w = \frac{m_2 - m_3}{m_2 - m_1} \times 100, \% \tag{1}$$

where m_1—mass of empty crucible, g; m_2—mass of crucible with sample before drying, g; m_3—mass of crucible with sample after drying, g.

The ash content (AC) measurement was carried out based on BS EN ISO 18122:2015 [31] in the muffle furnace LAC LH 06/13 (LAC, Rajhrad, Czech Republic) with respect to the time and temperature requirements. The ash content on a dry basis was calculated from several repetitions as given in Equation (2):

$$AC = \frac{(m_3 - m_1)}{(m_2 - m_1)} \times 100 \times \frac{100}{100 - w}, \% \tag{2}$$

where m_1—mass of empty crucible, g; m_2—mass of crucible with sample, g; m_3—mass of crucible with ash, g; w—moisture content of the test sample, %.

The gross calorific value (GCV) was measured by the bomb calorimeter MS–10A (LAGET Ltd., Prague, Czech Republic) following the standard BS EN 14918:2009 [32] and calculated by the simplified Equation (3) with respect to repeatability precision:

$$GCV = \frac{dTk \times Tk - (c_1 + c_2)}{m}, \text{ J g}^{-1} \tag{3}$$

where dTk—temperature jump, °C; Tk—heat capacity of calorimeter, (9051) J °C^{-1}; c_1—repair on the heat released by burning spark wire, J; c_2—repair on the heat of burning paper, J; m—sample weight, g.

The net calorific value (NCV) was calculated from GCV applying Equation (4):

$$NCV = GCV - 24.42 \times (w + 8.94 \times H), \text{ J g}^{-1} \tag{4}$$

where GCV—gross calorific value, J g^{-1}; 24.42—coefficient corresponding to 1% of the water evaporated from the sample at 25 °C, w—moisture content in the sample, %; 8.94—coefficient for the conversion of hydrogen to water, H—hydrogen content in the sample, %.

Carbon (*C*), nitrogen (*N*) and hydrogen (*H*) content determination was performed in accordance with the standard BS EN ISO 16948:2015 [33] using the laboratory automatic device LECO CHNS628 (LECO Corporation, Saint Joseph, MI, USA).

The mechanical durability (*DU*) of pellets was measured by a pellet tester (RIAE, Prague, Czech Republic) under 50 rpm for 10 min per repetition as stated by [34] and mechanical durability of briquettes was measured in the rotating durability drum (CULS, Prague, Czech Republic) with 21 rpm for 5 min in accordance with BS EN ISO 17831–2:2015 [35]. *DU* was then calculated as given in Equation (5):

$$DU = \frac{m_A}{m_E} \times 100,\ \% \tag{5}$$

where m_A—sample weight after durability test, g; m_E—sample weight before durability test, g.

The determination of the yearly amount of waste obtained after the pruning of apricot orchards from one hectare (W_{ha}) was found by the following Equation (6):

$$W_{ha} = Q_{Tha} \times Q_{TW},\ \ \mathrm{t\ ha^{-1}} \tag{6}$$

where Q_{Tha}—number of trees per one hectare of apricot orchard; Q_{TW}—amount of waste obtained from pruning of one tree, kg.

Determination of the total yearly amount of apricot waste biomass (W_T) obtained after the pruning in Tajikistan was calculated as (7):

$$W_T = W_{ha} \times Q_{TT},\ \mathrm{t} \tag{7}$$

where W_{ha}—yearly amount of apricot waste from one hectare, t; Q_{TT}—total area of apricot orchards in Tajikistan, ha.

The total energy yield (E_{YA}) of apricot wooden waste generated in Tajikistan was determined by the following Equation (8):

$$E_{YA} = W_T \times NCV, \mathrm{TJ} \tag{8}$$

where W_T—total yearly quantity of apricot waste, t; *NCV*—dry basis net calorific value of apricot waste biomass, J g^{-1}.

3. Results and Discussion

Solid biofuels produced by mechanical densification of residual biomass from apricot pruning are illustrated in Figure 3. By visual assessment, both pellets and briquettes seem to be of good mechanical properties (strong, smooth surface without cracks).

Figure 3. Initial material of apricot waste biomass and produced solid biofuels (pellets and briquettes).

Tested parameters of residual apricot biomass as well as produced biofuels are evaluated below and, moreover, compared with the properties of other materials, like cotton stalks, wheat straw and residual biomass from vineyard pruning, which are also the most available sources of biomass in Tajikistan, due to the country's agricultural practices.

According to Ivanova et al. [36], the moisture content of biomass for the production of densified biofuels should not exceed 20%, and the required moisture content as received from graded wood pellets should be at most 10% [37], and a maximum of 12% or up to 15% moisture content is recommended for different quality classes of graded wood briquettes [38]. The moisture content of biomass is largely affected by the relative air humidity and other drying conditions [39]. A high moisture content of the raw material can have a negative impact on the final properties of solid biofuels, such as the calorific value as well as strength and durability [40,41]. The measured moisture content of used apricot wood was 6.19 wt% as received, which is thus suitable for densification.

Another important parameter of biomass-based biofuels is the ash content. The amount of ash can affect the operation of a combustion devise as well as the time spent for the ash removal as it has an influence on deposit formation in the boilers [42]. That is why the content of ash should be known, and it is regulated by the modern standards of biofuel quality [43]. Table 1 shows that the ash content of apricot waste is significantly lower in contrast to other materials. However, in comparison with the standard requirement for graded wood briquettes and pellets, the measured ash content in apricot biomass exceeds the limits for class A biofuels, but fully fulfils the requirement for class B (*AC* dry basis ≤ 2% for pellets and *AC* dry basis ≤ 3% for wood briquettes).

Table 1. Content of tested residual apricot biomass in comparison with other selected materials.

Parameter	Apricot Tree Wood	Cotton Stalks	Wheat Straw	Vine Wood Wastes
Ash content, (wt% d)	1.71	3.22 [1]	5.20 [2]	3.46 [3]

wt%—percentage by weight, d–dry basis, [1] Data according to Akhmedov et al. [18], [2] Data based on Lunguleasa and Spirches [43], [3] Data found by Muzikant et al. [26].

In accordance with Tang et al. [44], calorific value is the decisive factor that determines the usefulness of biomass for energy applications. The results of *GCV* and *NCV* (dry basis) of apricot branches after pruning as well as calorific values of other materials studied by different authors are presented in Table 2.

Table 2. Results of calorific value for tested apricot material in comparison with other materials.

Parameter	Apricot Tree Wood	Cotton Stalks	Wheat Straw	Vine Wood Wastes
Gross calorific value, (MJ kg^{-1} d)	20.47	18.93 [1]	16.86 [2]	19.47 [3]
Net calorific value, (MJ kg^{-1} d)	19.29	17.69 [1]	15.55 [2]	18.87 [4]

[1] Data according to Akhmedov et al. [18], [2] Data based on Bradna et al. [45], [3] Data measured by Cosereanu et al. [46], [4] Data from Spinelli et al. [47].

In agreement with many studies performed by different researches, e.g., Cosereanu et al. [46] and Kamperidou et al. [42], it was found that herbaceous biomass typically has a lower calorific value than wood biomass. From Table 2, it can be observed that the gross and net calorific values of apricot wood waste are the highest in comparison with other sources of biomass that could also be generated in Tajikistan in large quantities. According to the standard requirement [37,38], *NCV* as received of the best quality class A1 graded wood pellets should be ≥ 16.5 MJ kg^{-1} and ≥ 15.5 MJ kg^{-1} for briquettes, which would be fulfilled in the case of the tested apricot material.

The research also indicated the basic element content in apricot pruning waste (see Table 3). According to Ivanova et al. [39], the hydrogen content in wood biomass is usually around 6%. The nitrogen content in the biofuels is listed among the necessary stated parameters, as nitrogen has a direct impact on the formation of harmful nitrogen oxides (NO_x) during fuel combustion [39,48]. Table 3 shows that, from the viewpoint of *N* content, the apricot waste biomass is the cleanest in comparison with the other selected materials. In accordance with strict limits for graded wood briquettes as well as pellets, the *N* content on a dry basis is ≤ 0.3% for class A1 solid biofuels, ≤ 0.5% for class A2 and ≤ 1% for class B. Thus, apricot wood waste exceeds the class A1 requirements, but fulfils the A2 limits.

Table 3. Content of carbon, nitrogen and hydrogen in tested apricot biomass in comparison with other biomass materials.

Parameter	Apricot Tree Wood	Cotton Stalks	Wheat Straw	Vine Wood Wastes
Carbon, (wt% d)	47.28	48.56 [1]	42.67 [2]	43.88 [3]
Nitrogen, (wt% d)	0.36	0.90 [1]	0.50 [2]	0.61 [4]
Hydrogen, (wt% d)	6.27	5.69 [1]	5.34 [2]	6.22 [4]

[1] Data according to Akhmedov et al. [18], [2] Data based on Bradna et al. [45], [3] Data published by Zabava et al. [49], [4] Data found by Muzikant et al. [26].

Moreover, Cichy et al. [28] have published low sulphur (< 0.01% d) and chlorine (0.011 ± 0.003% d) contents in apricot branches, which would contribute to low corrosion in boilers and an insignificant atmospheric pollution factor for generated sulfur oxides and hydrogen chloride.

The main indicator of the mechanical quality of manufactured briquettes and pellets is their mechanical durability. Mechanical durability simply expresses how densified fuels are, and how well they are formed. It is the measure of the resistance towards shocks and/or abrasion during transport and manipulation [36,50]. The results of the durability tests are presented in the Table 4.

Table 4. The results of the mechanical durability for the tested briquettes and pellets made from apricot wastes in comparison with the durability of solid biofuel from other materials.

Parameter	Apricot Tree Wood	Cotton Stalks	Wheat Straw	Vine Wood Wastes
Mechanical durability of pellets, (%)	94.37	97.82 [1]	94.40 [2]	-
Mechanical durability of briquettes, (%)	96.15	97.63 [1]	95.65 [3]	91.6 [4]

[1] Data according to Akhmedov et al. [18], [2] Data published by Zabava et al. [49], [3] Data published by Guo et al. [51], [4] Data measured by Vacek [27].

In general, from Table 4, it is visible that the mechanical durability of cotton-based biofuels is the highest, followed by the apricot-based biofuels, then biofuels from wheat straw, and the lowest durability was reported for the briquettes from vineyard pruning biomass. The determined mechanical durability of produced apricot briquettes is similar or even higher than the average values for wood briquettes measured by Brožek et al. [52], i.e., the *DU* of poplar chip briquettes is about 94.3%. Mechanical durability is not listed among required parameters for graded wood briquettes, but it is stated for wood pellets as ≥ 97.5% for class A and ≥ 96.5% for class B [37], which was not fulfilled. However, the mechanical durability can be improved during the processing/pressing, e.g., a higher working pressure used for densification increases the density of the produced biofuels [53]. Several authors have tested a dependence of mechanical durability on storage conditions. For example, Brunerová et al. [54] have measured no difference in *DU* of degistate briquettes stored for nine months outdoors in contrast to indoor constant conditions; Brožek [55] has found that the *DU* of briquettes made of spruce shavings stored for a long time in closed heated rooms was on average 5% higher than the *DU* of briquettes stored in closed unheated rooms; Brožek [56] published that if briquettes are stored in well-closed leak-proof plastic bags, neither the location nor the storage time influence their life time and mechanical quality; however, in the case of using net plastic bags, the damages of briquettes stored in various conditions for different storage times were monitored. The study of Kaliyan and Morey [57] concluded that the proper relative air humidity for storage of densified products is 60–70%, air temperature around 25 °C and an increase in the moisture content of densified products to more than 13% can influence the *DU* negatively.

Table 5 shows the energy potential expressed as total energy yield, which could be generated in Tajikistan by using available residual biomass from pruning apricot orchards.

Table 5. Yearly amount of wastes and total energy yield obtained after pruning of apricot orchards in Tajikistan.

Waste	Amount of Waste per Hectare (t)	Total Amount of Waste (t Year^{-1})	Total Energy Yield of Apricot Wooden Wastes (TJ)
Residual wood obtained after pruning of apricot orchard	2.73	168,214.41	3244.86

Taking into consideration the average amount of waste per tree (17.5 kg), the yearly yield of apricot waste biomass in Tajikistan is nearly 170,000 t and the total energy yield was found to be around 3245 TJ (taking into account NCV dry basis). For comparison, according to Stavjarská [19], the maximum theoretical energy potential per ha (amount of residual biomass per ha multiplied by GCV dry basis) of cotton residues in Tajikistan was found to be 93.59 GJ ha^{-1}. In the case of apricot waste it would be less (55.90 GJ ha^{-1}) due to a lower amount of waste generated. However, the overall quality of apricot-based biofuels is higher.

Additionally, according to Cichy et al. [28], due to the fact that the fuel properties of orchard residues are not noticeably different from the typical values for solid biofuels made of woody forest biomass, biomass from orchards can be a suitable substitute for raw forest materials, the availability of which is becoming more and more limited in many counties.

4. Conclusions

Even though Tajikistan today has access to some of its own energy resources, such as coal (but often of a poor quality) or hydropower, there is still a big problem to supply people in remote regions of the country with accessible and cheap energy. On the other hand, the country has many regions with well-developed agriculture that not only plays an essential role in the economy and is the main source of income for the population in rural areas, but it is also the origin of waste accumulated yearly in large quantities. Thus, one appropriate solution to the energy and environmental issues seems to be the application of abundant agricultural wastes for energy purposes, for example, for the production of pellets and briquettes from apricot wood pruning.

Nevertheless, apricot orchards in Tajikistan are only on the fourth place by the cultivated area after wheat, cotton and vineyards. The estimated data of potential energy yield indicate the perspective of the tested biomass being suitable for practical utilization. Moreover, conducted laboratory tests on residual apricot biomass and produced biofuels (pellets and briquettes) have proved high physical, chemical and mechanical properties, as well as a good overall quality in comparison with solid biofuels made of other agricultural biomass available in the country. The above-mentioned facts confirm that apricot wood waste is one of the most convenient types of biomass for solid biofuels in Tajikistan. Beyond the benefits of densified fuels versus loose biomass, such as higher energy density, easier manipulation, transportation and storage, improved combustion, etc., the establishment of solid biofuel production will have a positive impact not only on the energy stability and safety but also on the creation of new working places for rural communities. As there is no industrial large-capacity pellet or briquette manufacturer in the country yet, a development of local small-scale production is recommended, especially in the northern part of Tajikistan.

Author Contributions: Conceptualization, T.I. and V.K.; Data curation, S.A. (Sayfullo Akhmedov) and T.I.; Formal analysis, S.A. (Sayfullo Akhmedov) and S.A. (Surayyo Abdulloeva); Funding acquisition, T.I.; Investigation, S.A. (Sayfullo Akhmedov), S.A. (Surayyo Abdulloeva) and A.M.; Methodology, T.I. and A.M.; Project administration, T.I.; Resources, S.A. (Sayfullo Akhmedov) and V.K.; Supervision, T.I. and V.K.; Writing—original draft, S.A. (Sayfullo Akhmedov), T.I. and A.M.; Writing—review & editing, S.A. (Sayfullo Akhmedov), T.I., S.A. (Surayyo Abdulloeva), A.M. and V.K.

Funding: The research was supported by the Internal Grant Agency of the Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague—grant number 20185011 and 20195010.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Bank. Agriculture, Forestry, and Fishing, Value Added (% of GDP). Available online: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=TJ (accessed on 28 January 2019).
2. TAJSTAT. *Socio-Economic Situation of the Republic of Tajikistan*; TAJSTAT: Dushanbe, Tajikistan, 2017; pp. 1–144.
3. Ministry of Agriculture Republic of Tajikistan. Gardening. Available online: http://moa.tj/bo-parvar/ (accessed on 19 January 2019).
4. Roussos, P.A.; Sefferou, V.; Denaxa, N.-K.; Tsantili, E.; Stathis, V. Apricot (*Prunus armeniaca* L.) Fruit Quality Attributes and Phytochemicals under Different Crop Load. *Sci. Hortic.* **2011**, *129*, 472–478. [CrossRef]
5. FAO. Apricot Production. Available online: http://www.fao.org/faostat/en/#data/QC/ (accessed on 18 December 2018).
6. Open Asia Online. Soghd—Apricot Paradise. 2016. Available online: https://news.tj/ru/node/227525 (accessed on 19 June 2019).
7. Kamolov, N.; Akhmedov, T.A.; Nazirov, H.N. *Apricot Growing Technology (Study Case Tajikistan)*; Institute of Horticulture and Vegetable Growing of Tajik Academy of Agricultural Sciences: Dushanbe, Tajikistan, 2010; pp. 1–28.
8. Demirtas, N.; Bolat, I.; Ercisli, S.; Ikinci, A.; Olmez, H.A.; Sahin, M.; Altindag, M.; Celik, B. The Effects of Different Pruning Treatments on the Growth, Fruit Quality and Yield of 'Hacihaliloglu'apricot. *Acta Sci. Pol.* **2010**, *9*, 183–192.
9. Walser, R.H.; Wright, W.A.; Hamson, A.R. *Pruning the Orchard*; Utah State University: Logan, UT, USA, 1994; pp. 1–21.
10. Laldjebaev, M.; Morreale, S.J.; Sovacool, B.K.; Kassam, K.A.S. Rethinking Energy Security and Services in Practice: National Vulnerability and Three Energy Pathways in Tajikistan. *Energy Policy* **2018**, *114*, 39–50. [CrossRef]
11. International Energy Agency. IEA World Energy Balances 2018. Statistics. Tajikistan—Total Primary Energy Supply (TPES) by Source. Available online: https://www.iea.org/statistics/?country=TAJIKISTAN&year=2016&category=Energysupply&indicator=TPESbySource&mode=chart&dataTable=BALANCES.Allrightsreserved (accessed on 5 June 2019).
12. Besant-Jones, J.E.; Fields, D.; Kochnakyan, A.; Mukhamedova, T.; Stuggins, G. *Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives*; A World Bank study; World Bank: Washington DC, USA, 2012; pp. 1–77.
13. Doukas, H.; Marinakis, V.; Karakosta, C.; Psarras, J. Promoting Renewables in the Energy Sector of Tajikistan. *Renew. Energy* **2012**, *39*, 411–418. [CrossRef]
14. Karimov, K.S.; Akhmedov, K.M.; Abid, M.; Petrov, G.N. Effective Management of Combined Renewable Energy Resources in Tajikistan. *Sci. Total Environ.* **2013**, *461–462*, 835–838. [CrossRef] [PubMed]
15. Laldjebaev, M. Energy Poverty in Rural Areas of Tajikistan. In Proceedings of the BEHAVE 2018 5th European Conference on Behaviour and Energy Efficiency, Zürich, Switzerland, 5–7 September 2018; pp. 5–7.
16. Galaktion, V.S.; Sirojiddin, R.C.; Alexey, G.V. Analysis and Evaluation of Potential of Renewable Energy Resources of Republic of Tajikistan. In Proceedings of the International Ural Conference on Green Energy (UralCon), Chelyabinsk, Russia, 4–6 October 2018; IEEE: Chelyanbinsk, Russia, 2018; pp. 26–33.
17. FAO. *Forage Harvesting and Farm Animals Feeding in Conditions of Pamir*; FAO: Horog, Tajikistan, 2013; pp. 1–17.
18. Akhmedov, S.; Ivanova, T.; Krepl, V.; Muntean, A. Research on Solid Biofuels from Cotton Waste Biomass—Alternative for Tajikistan's Energy Sector Development. *Agron. Res.* **2017**, *15*, 1846–1855. [CrossRef]
19. Stavjarská, M. Use of Cotton Plant Waste Biomass for Solid Biofuel Production. Master's Thesis, Czech University of Life Sciences Prague, Prague, Czech Republic, 2016.
20. Pizzi, A.; Pedretti, E.F.; Duca, D.; Rossini, G.; Mengarelli, C.; Ilari, A.; Mancini, M.; Toscano, G. Emissions of Heating Appliances Fuelled with Agropellet Produced from Vine Pruning Residues and Environmental Aspects. *Renew. Energy* **2018**, *121*, 513–520. [CrossRef]

21. Zanetti, M.; Brandelet, B.; Marini, D.; Sgarbossa, A.; Giorio, C.; Badocco, D.; Tapparo, A.; Grigolato, S.; Rogaume, C.; Rogaume, Y.; et al. Vineyard Pruning Residues Pellets for Use in Domestic Appliances: A Quality Assessment according to the EN ISO 17225. *J. Agric. Eng.* **2017**, *48*, 99–108. [CrossRef]
22. Royo, J.; Canalis, P.; Quintana, D.; Diaz-Ramirez, M.; Sin, A.; Rezeau, A. Experimental Study on the Ash Behaviour in Combustion of Pelletized Residual Agricultural Biomass. *Fuel* **2019**, *239*, 991–1000. [CrossRef]
23. Manzone, M.; Paravidino, E.; Bonifacino, G.; Balsari, P. Biomass Availability and Quality Produced by Vineyard Management during a Period of 15 Years. *Renew. Energy* **2016**, *99*, 465–471. [CrossRef]
24. Fernandez-Puratich, H.; Hernandez, D.; Tenreiro, C. Analysis of Energetic Performance of Vine Biomass Residues as an Alternative Fuel for Chilean Wine Industry. *Renew. Energy* **2015**, *83*, 1260–1267. [CrossRef]
25. Mendivil, M.A.; Munoz, P.; Morales, M.P.; Juarez, M.C.; Garcia-Escudero, E. Chemical Characterization of Pruned Vine Shoots from La Rioja (Spain) for Obtaining Solid Bio-fuels. *J. Renew. Sustain. Energy* **2013**, *5*, 033113. [CrossRef]
26. Muzikant, M.; Havrland, B.; Hutla, P.; Věchetová, S. Properties of Heat Briquettes Produced from Vine Cane Waste–Case Study Republic of Moldova. *Agric. Trop. Subtrop.* **2010**, *43*, 277–284.
27. Vacek, T. Energy Use of Vineyard Waste Biomass—Potential for the Republic of Moldova. Master's Thesis, Czech University of Life Sciences Prague, Prague, Czech Republic, 2015.
28. Cichy, W.; Witczak, M.; Walkowiak, M. Fuel Properties of Woody Biomass from Pruning Operations in Fruit Orchards. *BioResources* **2017**, *12*, 6458–6470. [CrossRef]
29. BSI EN 14780. *Solid Biofuels—Sample Preparation*; British Standards Institution: Bonn, Germany, 2011; pp. 1–24.
30. BS EN ISO 18134-3. *Solid Biofuel—Determination in Moisture Content—Oven Dry Method: Part 3: Moisture in General Analysis Sample*; British Standards Institution: Bonn, Germany, 2015; pp. 1–14.
31. BS EN ISO 18122. *Solid Biofuels—Determination of Ash Content*; British Standards Institution: Bonn, Germany, 2015; pp. 1–18.
32. BS EN 14918. *Solid Biofuels—Determination of Calorific Value*; British Standards Institution: Bonn, Germany, 2009; pp. 1–64.
33. BS EN ISO 16948. *Solid Biofuels—Determination of Total Content of Carbon, Hydrogen and Nitrogen*; British Standards Institution: Bonn, Germany, 2015; pp. 1–18.
34. BS EN ISO 17831-1. *Solid Biofuels—Determination of Mechanical Durability of Pellets and Briquettes–Part 1: Pellets*; British Standards Institution: Bonn, Germany, 2015; pp. 1–18.
35. BS EN ISO 17831-2. *Solid Biofuels—Determination of Mechanical Durability of Pellets and Briquettes–Part 2: Briquettes*; British Standards Institution: Bonn, Germany, 2015; pp. 1–18.
36. Ivanova, T.; Kolarikova, M.; Havrland, B.; Passian, L. Mechanical Durability of Briquettes Made of Energy Crops and Wood Residues. In Proceedings of the Engineering for Rural Development, Jelgava, Latvia, 29–30 May 2014; Volume 13, pp. 131–136.
37. BSI EN ISO 17225-2. *Solid Biofuels—Fuel Specifications and Classes Part 2: Graded wood pellets*; BS EN ISO; British Standards Institution: Bonn, Germany, 2014; pp. 1–18.
38. BSI EN ISO 17225-3. *Solid Biofuels—Fuel Specifications and Classes Part 3: Graded wood briquettes*; British Standards Institution: Bonn, Germany, 2014; pp. 1–16.
39. Ivanova, T.; Mendoza Hernández, A.H.; Bradna, J.; Cusimamani, E.F.; Montoya, J.C.G.; Espinel, D.A.A. Assessment of Guava (*Psidium guajava* L.) Wood Biomass for Briquettes' Production. *Forests* **2018**, *9*, 613. [CrossRef]
40. Brožek, M. The Effect of Moisture of the Raw Material on the Properties Briquettes for Energy Use. *Acta Univ. Agric. Silvic. Mendel. Brun.* **2016**, *64*, 1453–1458. [CrossRef]
41. Vyas, D.; Sayyad, F.; Khardiwar, M.; Kumar, S. Physicochemical Properties of Briquettes from Different Feed Stock. *Curr. World Environ.* **2015**, *10*, 263–269. [CrossRef]
42. Kamperidou, V.; Lykidis, C.; Barmpoutis, P. Assessment of the Thermal Characteristics of Pellets Made of Agricultural Crop Residues Mixed with Wood. *BioResources* **2017**, *12*, 9263–9272. [CrossRef]
43. Lunguleasa, A.; Spirchez, C. An Aggregated Property of Wheat Straw Briquettes. *Wood Res.* **2015**, *60*, 845–856.
44. Tang, J.P.; Lama, H.L.; Azizb, M.K.A.; Morad, N.A. Enhanced biomass characteristics index in palm biomass calorific value estimation. *Appl. Therm. Eng.* **2016**, *105*, 941–949. [CrossRef]
45. Bradna, J.; Malatk, J.; Hajek, D. The Properties of Wheat Straw Combustion and Use of Fly Ash as a Soil Amendment. *Agron. Res.* **2016**, *14*, 1257–1265.

46. Cosereanu, C.; Lica, D.; Lunguleasa, A. Investigation on the Quality of Briquettes Made from Rarely Used Wood Species, Agro-Wastes and Forest Biomass. *Pro Ligno* **2015**, *11*, 32–39.
47. Spinelli, R.; Nati, C.; Pari, L.; Mescalchin, E.; Magagnotti, N. Production and Quality of Biomass Fuels from Mechanized Collection and Processing of Vineyard Pruning Residues. *Appl. Energy* **2012**, *89*, 374–379. [CrossRef]
48. Erisman, J.W.; van Grinsven, H.; Leip, A.; Mosier, A.; Bleeker, A. Nitrogen and Biofuels; an Overview of the Current State of Knowledge. *Nutr. Cycl. Agroecosyst.* **2010**, *86*, 211–223. [CrossRef]
49. Zabava, B.-S.; Voicu, G.; Dinca, M.-N.; Ungureanu, N.; Ferdes, M. Durability of Pellets Obtained from Energy Plants: Review. In Proceedings of the Engineering for Rural Development, Jelgava, Latvia, 23–25 May 2018; Volume 17, pp. 1838–1843. [CrossRef]
50. Alakangas, E. *New European Pellets Standards*; Eubionet III: Jyväskylä, Finland, 2011; pp. 1–17.
51. Guo, L.; Tabil, L.G.; Wang, D.; Wang, G. Influence of Moisture Content and Hammer Mill Screen Size on the Physical Quality of Barley, Oat, Canola and Wheat Straw Briquettes. *Biomass Bioenergy* **2016**, *94*, 201–208. [CrossRef]
52. Brožek, M.; Nováková, A.; Kolářová, M. Quality Evaluation of Briquettes Made from Wood Waste. *Res. Agric. Eng.* **2012**, *58*, 30–35. [CrossRef]
53. Muntean, A.; Ivanova, T.; Hutla, P.; Havrland, B. Influence of Raw Material Properties on the Quality of Solid Biofuel and Energy Consumption in Briquetting Process. *Agron. Res.* **2017**, *15*, 1708–1715. [CrossRef]
54. Brunerová, A.; Pecen, J.; Brožek, M.; Ivanova, T. Mechanical Durability of Briquettes from Digestate in Different Storage Conditions. *Agron. Res.* **2016**, *14*, 327–336.
55. Brožek, M. Study of Briquette Properties at their Long-time Storage. *J. For. Sci.* **2013**, *59*, 101–106. [CrossRef]
56. Brožek, M. Influence of storage on Briquettes Mechanical Properties. *Sci. Agric. Bohem.* **2014**, *45*, 175–179. [CrossRef]
57. Kaliyan, N.; Morey, R.V. Factors Affecting Strength and Durability of Densified Biomass Products. *Biomass Bioenergy* **2009**, *33*, 337–359. [CrossRef]